Principles and Neurobiological Correlates of Concentrative, Diffuse, and Insight Meditation

Craig Mehrmann, BS, and Rakesh Karmacharya, MD, PhD

Keywords: Buddhism, central executive network, default mode network, diffuse attention, focused attention, insight, intrinsic connectivity network, meditation, mindfulness, salience network

The term *meditation* encompasses a broad variety of mental-training practices that vary between cultures and traditions, ranging from techniques designed to promote physical health, relaxation, and improved concentration, to exercises performed with farther-reaching goals, such as developing a heightened sense of well-being, cultivating altruistic behaviors, and, for some, attaining enlightenment.[1] Meditation can be conceptualized as complex emotional and attentional regulatory practices in which mental and somatic events are affected by specific mental-training practices.[2] Meditation is typically associated with a concurrent state of heightened vigilant awareness and reduced metabolic activity[3]—which lead to improved physical health,[4] psychological balance, and emotional stability.[5] Not all meditation practices focus on the training of specific cognitive skills, and in those that do, the methodologies and outcomes often vary. It is therefore essential to be explicit about the type of meditation practice under investigation.

Different types of meditation can be classified based on how the practitioner's attentional processes are regulated and directed.[6] In this article we focus on the two most common styles of meditation derived from Buddhist traditions: (1) concentrative, or focused-attention, meditation, and (2) diffuse, or open-monitoring, meditation. Concentrative meditation involves maintaining and continually refocusing attention on a chosen object, such as a body sensation, single point in space, color, object, sound, or affective state such as compassion. Open-monitoring meditation involves developing a present-centered and unattached/neutral mode of observation toward all sensational phenomena, including thoughts.

From the Center for Human Genetic Research, Massachusetts General Hospital, Boston, MA (Mr. Mehrmann and Dr. Karmacharya); Harvard Medical School and Chemical Biology Program, Broad Institute of Harvard and MIT (Dr. Karmacharya); Schizophrenia and Bipolar Disorder Program, McLean Hospital, Belmont, MA (Dr. Karmacharya).

Supported, in part, by National Institutes of Health Mentored Clinical Scientist Research Career Development Award no. K08MH086846 (RK).

Correspondence: Rakesh Karmacharya, MD, PhD, Massachusetts General Hospital, Center for Human Genetic Research, 185 Cambridge St., Boston, MA 02114. Email: karmacharya@mcb.harvard.edu

DOI: 10.1097/HRP.0b013e31828e8ef4

Concentrative and diffuse meditation practices are often combined, whether in a single session or over the course of the practitioner's training, and are intentionally designed to train specific cognitive processes.[6] In many instances, the attentional stance cultivated through meditation not only is characterized by the style of meditation (i.e., concentrative or diffuse) but also includes the awareness of certain philosophical principles (or metaphysical characteristics) that support practitioners' ability to impartially perceive their reality. In other words, the attentional stance often integrates the continuous awareness of certain metaphysical characteristics that act as a medium through which practitioners may objectively observe their sensory experience. Such characteristics often include the perpetual transience of all phenomena, the illusion of a separate and permanent self or ego, and the understanding that one will never ultimately be satisfied by sense objects—hence the term *insight meditation*, which refers to a form of diffuse meditation that is practiced with the continual awareness or experience of these philosophical principles, and with an emphasis on experiencing impermanence or change (i.e., the continual arising and passing of phenomena from moment to moment).

Western scientific interest in meditation has grown tremendously in recent years, reflecting the increased application of meditation-based modalities in clinical settings. However, the scientific study of meditation has, in large part, been conducted with minimal reference to its religious and spiritual origins.[7] Buddhist traditions offer widely applied, extensive, precisely descriptive, and highly detailed theories about concentrative and diffuse forms of meditation, which have remained intrinsically unchanged for over 2500 years and are presented in a systematic manner befitting a scientific approach.[6] Mindfulness-based therapeutic programs are all derivatives of traditional Buddhist meditation. The theory and practice of concentrative, diffuse, and insight meditation are at the core of these programs, making these meditation practices the basis for most applications in clinical and psychiatric settings.[1,8,9] Mindfulness-based therapeutic programs have become a popular form of therapeutic intervention: they are efficacious; their principles are universal; they are cost-effective; and they are highly adaptable for diverse populations with different cognitive abilities.[7,10] Moreover, these programs have made training in concentrative and diffuse meditation more accessible by offering what one may consider a nonreligious alternative for individuals who may be unwilling to adopt Buddhist terminology.[7]

A third style of meditation, known as transcendental meditation (TM), has been extensively researched and encompasses the remaining forms of meditation practice. TM practice is centered on the repetition of a mantra, and emphasizes the development of a witnessing, thought-free "transcendental awareness" or "pure consciousness" that is described by practitioners to be "the original source of thought."[11] This state is explicitly said to be cultivated in the absence of any concentration or effort and is characterized by the experiences of "unboundedness" and "loss of time, space, and body sense," thus placing TM in a meditation category of its own.[1,11] TM is not easily comparable and is relatively unrelated to mindfulness-based meditation techniques and therefore will not be discussed here.

The theory and practice of meditation are not grounded in mysticism or in religious dogma, rites, rituals, or ceremonies, and may rather be accurately described as composing a detailed and precisely descriptive scientific technique. Meditation is universal in nature; meditation methodologies are equally applicable to individuals of any religious, cultural, or spiritual background; and the practice of meditation does not require any form of conversion or identification with a religious tradition. Many Westerners, however, are unfamiliar with the cultural context in which the terminology of Buddhist meditation has developed. This lack of knowledge has, in some cases, resulted in misinterpretations of meditation practices as well as in unwarranted religious or dogmatic stigma being attached to them. To help bridge this cultural boundary, we present an introduction to the principles and clinical applications of concentrative and diffuse forms of meditation. We also review relevant scientific studies to date on concentrative and diffuse meditation, and discuss the clinical implications of these findings. Following a discussion of the philosophical basis and neurological underpinnings of these practices and how they apply to modern psychiatry, we suggest further directions for scientific research.

CONCENTRATIVE AND DIFFUSE MEDITATION

Concentrative meditation is often practiced in preparation for practicing diffuse meditation and, as noted earlier, entails voluntarily focusing attention on a chosen object in a sustained fashion, such as breath sensations or a visual object, visualized image, sound, or affective state (e.g., compassion).[6] To sustain this focus, practitioners must constantly monitor and regulate their quality of attention, thereby naturally developing three regulatory skills: (1) to monitor and remain vigilant to distractions, thereby enabling practitioners to recognize when and to what degree their attention has wandered from the object of focus, (2) to release distractions from the attentional field without further involvement, and (3) to restore attention promptly to the chosen object of focus.[1,6]

Concentrative meditation develops the three regulative skills to the point that advanced practitioners have an especially acute ability to notice when the mind has wandered, resulting in an automatic and instantaneous restoration of attention on the chosen object of focus.[6] Eventually, attention rests more readily and stably on the chosen object. As concentration continues to develop, the regulative skills are invoked less and less frequently, and soon the ability to sustain focus becomes "effortless," a state commonly known as *access concentration*.[1,12] The achievement of access concentration is often considered the appropriate time to begin practicing diffuse meditation; however, this relatively high degree of concentration is not absolutely necessary for the beginning stages of diffuse meditation.

Diffuse meditation is done with the aim of becoming more objectively aware of sensate experience through the development of one's ability to be psychologically present and equanimous with all forms of sensory phenomena. This state involves the nonreactive monitoring of the ongoing stream of experience from moment to moment, without focusing on any explicit object for a prolonged period of time.[13] Practitioners aim to familiarize themselves with reality at the pure sensate level, without interpretation of, or identification with, sensational phenomena. In the context of meditation, *sensate* refers to anything that can be mentally observed, including thoughts.

The prelude to diffuse meditation typically involves concentrative meditation to calm and focus the mind, reduce distractions, and enhance one's equanimity toward sensational phenomena. For example, the practitioner may use concentrative meditation focusing on breath sensations at the area of the philtrum (the indentation below the nostrils and above the upper lip). Continually monitoring breath sensations in the chosen area develops equanimity (or nonreactivity) toward body sensations and enables the practitioner to disengage from, quiet, and eventually stop the internal dialogue of the mind. From here, the practitioner may shift to diffuse meditation even if access concentration has not yet been established, so long as the awareness of breath sensations is maintained with relative continuity. The practitioner would then work at continually disengaging from body-mind sensations as quickly as possible until a continual stream of awareness, or access concentration, has been established. Otherwise, as previously described, practitioners would practice concentrative meditation on breath sensations until access concentration has been established, and then redirect their focus from breath sensations to begin practicing diffuse meditation. Usually, practitioners direct their attention to the most subtle (or least perceptible) features of experience possible.

Open-monitoring meditation enhances one's faculty of present-centered, nonjudgmental awareness of psychosomatic phenomena, thereby enhancing cognitive flexibility and reappraisal.[1] This state is accomplished through nonreactive, metacognitive monitoring of body-mind sensations—which gradually increases awareness of "automatic cognitive and emotional interpretations of sensory, perceptual, and endogenous stimuli."[1,13–15] With consistent practice, the practitioner becomes progressively more aware of subtle body-mind sensations, lending access to rich features of sensational experience, such as emotional tone, active cognitive schema, awareness of sensation all over the body (inside and out), degree of phenomenal intensity, and bodily vibrational frequency[6] (i.e., the literal, physical experience of the body and mind as "vibrations," or rapidly oscillating particular sensational phenomena whose strength [amplitude] and speed [frequency] fluctuate over time). One also develops the ability to experience the arising and passing of phenomena at a high velocity and at very subtle levels[6]—that is, the literal and distinct physical or mental experience of the arising and passing of particular phenomena up to 50 times per second. The subtlety of the practitioners' experience is in direct accordance with their concentrative capacity (the degree of effort exerted to observe the subtlest sensations possible while remaining continuously aware of, and equanimous toward, the internal sensate experience).

Practitioners continue to practice meditation's concentrative or diffuse techniques in everyday life, which enables them to maintain a wholesome lifestyle and contributes to their degree of readily accessible concentrative absorption during formal meditation. The degree of concentrative absorption refers to the depth or strength of concentration on a single-pointed focus and, during formal meditation, correlates directly with how well the continuity of awareness has been maintained since the previous meditation session. For example, practitioners may strive to maintain a continuous awareness of breath sensations or of an affective state such as compassion, or try to maintain a continuous superficial "body-scan" throughout the day. Advanced practitioners report a sense of physical lightness and increased mental and physical vitality as a result of maintaining a concentrated mind.[12] This perception may be explained in part by a possible correlation between increased concentration and decreased emotional reactivity, accounting for a more efficient use of energy both during meditation and in everyday life.[15,16]

Significant progress has been made recently in investigating the effects of consistent concentrative and diffuse meditation practice on systems for sensory processing and integration, revealing two temporally distinct neural modes of self-reference: (1) extended self-reference linking subjective experience across time (*narrative* focus, also known as the *default mode*) and (2) momentary self-reference centered on the present moment (*experiential* focus).[17] Narrative focus is characterized by relating to the world through a construction of narratives that constitute the *I* or *self*, distinguishing the individual self from the selves of others and objects, whereas experiential focus refers to the neuropsychological experience of the present moment, without ruminative, ego-centered interpretation of sense objects.[17]

In the context of meditation, it is useful to think of experiential focus as the experience of life through the "internal, present-centered, objective mental observer." To observe means to watch impartially as an outsider. The internal observer is that which enables us to experience a sensation without identifying with it, or figuratively "stand next to" a sensation and observe it objectively. Through meditation, one becomes aware of this observer and develops one's ability to make a continuous and objective observation of one's sensate reality. Therefore, practicing experiential focus may be described as practicing present-centered awareness by "continually disengaging attentional processes from self-referential elaboration toward sense objects."[17,18]

MINDFULNESS-BASED MEDITATION

Mindfulness-based therapeutic techniques have been extensively incorporated into the psychiatric setting as evidence-based therapeutic programs, such as mindfulness-based stress reduction (MBSR),[9] dialectical behavioral therapy,[19] acceptance and commitment therapy,[20] relapse-prevention therapy,[21] and mindfulness-based cognitive therapy,[22] and have been shown to be effective in treating depression,[23] anxiety,[24] drug and alcohol addiction,[7,25] and various personality disorders.[7,19,26,27] In the clinical setting, these programs are popular interventions for hypertension, stress, and cardiovascular illness, and in slowing and perhaps stopping or reversing neurodegeneration and cognitive decline.[7,27]

Mindfulness may be conceptualized as bringing one's complete attention to one's present experience through the nonjudgmental observation of the ongoing stream of all perceivable internal and external stimuli as they arise from moment to moment.[28] Thus, mindfulness is remembering to pay attention in a particular way: on purpose, in the present moment, and nonjudgmentally.[28] Dakwar and Levin[7] have compiled several psychological mechanisms through which mindfulness may aid in psychiatric symptom reduction and behavioral change. It has been shown that an accepting and nonjudgmental mental outlook toward distressing phenomena can reduce associated stress.[15] For example, patients with borderline personality disorder who have learned to observe distressing thoughts and feelings without dissociation show diminished fear response and cessation of avoidance behaviors previously triggered by those stimuli.[19] This effect may be attributed to a kind of habituation/desensitization therapy, where a repetitious, but intentionally objective, cognitive exposure toward the distressing stimulus gradually reduces its associated negative significance.[7]

Training in mindfulness may also assist in recognizing maladaptive coping skills and aid in implementing better ones.[7] A nonjudgmental attitude toward phenomena fosters cognitive flexibility and reappraisal, and therefore may lead to changes in thought patterns or attitudes about one's thoughts.[1,7] The unattached or neutral appraisal of one's thoughts and emotions may reduce automatic reactivity toward them, thereby enabling those who have learned mindfulness to shift from maladaptive thought patterns and behaviors to ones that are more adaptive.[29] Increased unattached awareness of behavioral, cognitive, and emotional stimuli may improve stress tolerance, the ability to recognize behavioral consequences, and the ability to set healthy motivations into action.[4,7,19,30] Mindfulness-based acceptance may also aid in reducing dissociative adaptations toward feelings or thoughts, as seen in borderline personality disoroder.[7] Developing one's faculty of unattached observation and acceptance of distressing thoughts or feelings may reduce the likelihood of maladaptive behavior patterns. For example, borderline patients who practice accepting their chronic feelings of emptiness may engage less frequently in self-destructive and self-injurious behaviors that were previously used to distract from those feelings.[7,19]

As with Buddhist meditation, participants undergoing mindfulness-based therapy sit in a calm, but vigilant, position and observe their object of attention (e.g., breath, body parts, thoughts) without judgment or rumination and as continuously as possible. However, a mindfulness-based approach to therapy does not necessarily require formal meditation in the strict sense.[7] The goal of mindfulness-based treatment is to promote mindfulness in the patients according to their own capacities. For instance, a patient with developmental disabilities, brain damage, severe depression or mania, anxiety, or psychosis may be unable to practice formal sitting meditation. Often, patients may refuse to practice because they do not clearly understand its purpose. Therefore, some strategies offer mindfulness-promoting cognitive exercises that may seem more engaging, less stressful, or more practical to some individuals. Such strategies include group discussions, lectures, worksheets, readings, or cognitive exercises such as guided imagery or metaphor to aid in the development of mindfulness-based insights.[7] For example, participants may be asked to visualize their thoughts as debris floating over a river, watching their thoughts come and go, giving them as much importance as they would a piece of passing driftwood.[31] Participants are also encouraged to develop an unattached relationship to phenomena through intellectual concepts such as the transient nature of sensations and thoughts, helping them to understand that even the most difficult or agitating thoughts and feelings are bound to change. This understanding fosters the ability to experience painful thoughts or feelings more presently and calmly, allowing space for contemplation, reevaluation, and the ability to allow them to pass on without further elaboration.[7] Patients are also encouraged to practice mindfulness at home and in everyday life, such as while walking, eating, or talking. If the patient is in a state of severe psychological turmoil, such as psychosis or suicidal depression, then providing a quiet, peaceful environment with positive human influence, healthy food, and necessary medications may be the first step in helping them to establish a balanced mind capable of developing the foundations of mindfulness practice. Nevertheless, these modified treatments consider the practice of meditation techniques to be central to their therapeutic efficacy.[7,9,10]

Mindfulness-based meditation works under the premise that all individuals—health care providers and patients alike—can benefit from objective self-observation. It has been shown that health care professionals who regularly practice mindfulness meditation, particularly those in the psychiatric setting, are better equipped to treat patients. For example, a recent study found that participation in an eight-week mindfulness-based stress reduction program was associated with improved mental health in graduate-level psychology students.[32] When compared to a control group, students in the MBSR program reported significant pre/post declines in perceived stress, negative affect, state and trait anxiety, and rumination, and a significant increase in positive affect and self-compassion. Compassion may be described as a nonpossessive state of loving that is motivated by a person's own sense of well-being with regard to his or her interactions and connectedness with others.[33] Developing self-compassion is particularly relevant to the fields of counseling and therapy. It has been purported that in order to have compassion toward one's client, which is an essential aspect of conducting effective therapy,[32–34] a therapist must first have compassion toward him- or herself. Research shows that counselors and therapists lacking in self-compassion are more critical and controlling toward themselves, and are also more critical and controlling toward their patients, resulting in poorer patient outcomes.[32,35]

NEUROBIOLOGICAL STUDIES OF MEDIATION

Many studies have shown that meditation and meditation-derived therapeutic approaches improve overall physical and mental health.[4,10,36] In this section, we present findings from imaging, electroencephalography (EEG), and physiological studies that relate to biological effects observed with meditation.

Brain Imaging

Intrinsic connectivity networks are large-scale brain networks that may function either in an active (engaged) or passive (resting) state, suggesting that the human brain is organized into distinct functional networks.[37] Significant progress has been made in investigating the effect of consistent meditation practice on systems for sensory processing and integration, revealing two temporally distinct neural modes of self-reference: (1) momentary self-reference centered on the present moment (*experiential* focus), neurologically correlated with the *central executive network*, and (2) extended self-reference linking subjective experience across time (*narrative* focus), neurologically correlated with the *default mode network*.[17,37,38]

The default mode network comprises an integrated system for autobiographical, self-centered, and social cognitive functions characterized by ruminative, often subconscious, self-referential narrative thought linking subjective experience across time—which generates one's concept of self or identity.[39] The default mode network concept emerged from a body of evidence demonstrating a consistent pattern of deactivation across a distributed network of brain regions during focused mental tasks; these regions become activated in the absence of such focused mental tasks.[39] The brain regions include the posterior cingulate cortex (involving autobiographical memory and self-referential processes), the ventromedial prefrontal cortex (VMPFC) (involving social-cognitive processes related to self and others), the medial temporal lobe (involved in episodic memory), and the angular gyrus (involved in semantic processing).[37] Conversely, the central executive network is activated (and default mode network deactivated) during focused mental tasks and is anchored in the dorsolateral prefrontal cortex (DLPFC) and the posterior parietal cortex.[37] There is a third intrinsic connectivity network, known as the *salience network*, acting as a switch or "toggle" between the activation/deactivation of the central executive network and default mode network, depending on the degree of mental engagement. The salience network is anchored in the anterior insula (AI) and the anterior cingulate cortex (ACC).[37]

Abnormal default mode network activity has been implicated in a number of psychiatric diseases, including schizophrenia,[40] autism,[41,42] epilepsy,[43] depression[44] and anxiety disorders,[45–47] bipolar disorder,[44] attention-deficit/hyperactivity disorder (ADHD),[44] and Parkinson's and Alzheimer's diseases.[44] In many of these cases, particularly in schizophrenia,[40] ADHD,[44] bipolar disorder,[44] and depression/anxiety disorders,[45–47] an inability to "switch off" the hyperactive default mode network through focusing the mind appears to be a major contributor to the disease.[44] A recent study conducted by Whitfield-Gabrieli and colleagues[40] used fMRI to examine potential alterations in default mode network activity in subjects with schizophrenia. While pointing out that the default mode network is activated during internal, self-referential thought, the authors noted that the normal boundary between internal thought and external perceptions might be blurred by hyperactivity of the default network.[40] This suggestion is consistent with psychotic symptoms in schizophrenia whereby patients have an exaggerated sense of self-reference in the world, as evidenced by paranoia, and a blurring of internal thoughts and external perception, which may give rise to hallucinations.[40] In line with these observations, results indicate that the default mode network is hyperactive and hyperconnected in people with schizophrenia and that the strength of connectivity and the defect in appropriate deactivation of the default mode network are correlated with more prominent psychotic symptoms.[40] The study also found a significant increase in hyperactivity and hyperconnectivity of the default mode network in immediate family members of schizophrenic individuals as compared to individuals from families with no occurrence of schizophrenia.

Another recent fMRI study analyzed working-memory, task-induced modulation of default mode network activity in subjects with posttraumatic stress disorder (PTSD) compared to healthy controls.[47] The control group showed significantly stronger connectivity in areas implicated in the salience and executive networks, such as the right inferior frontal gyrus and the right inferior parietal lobule. However, the PTSD group showed stronger connectivity in areas implicated in the default mode network, such as stronger connectivity between the posterior cingulate cortex and the right superior frontal gyrus, and between the medial prefrontal cortex (MPFC) and the left parahippocampal gyrus. Subjects with PTSD showed a significantly impaired ability to switch from an idling state into a task-oriented state when compared to healthy controls, as implied by hyperconnectivity in the default mode network during the working-memory task in the PTSD group.[47] The different patterns of connectivity suggest significant group differences in the ability to disengage from the default mode network and to engage the central executive network during tasks that require focused attention.[47]

The psychological characteristics associated with default mode network activation are commonly known distractions in the meditation milieu, such as daydreaming, mind wandering, and projections into the past or future, which has led researchers to investigate the effects of meditation on default mode network activity.[52] An fMRI study compared differential brain-activation patterns during two distinct modes of perception: narrative focus correlated with default mode network activation, and experiential focus correlated with the central executive network activation, in both novice participants and participants who had attended an eight-week course in mindfulness meditation.[17] In novices, experiential focus yielded focal reductions in self-referential cortical midline regions associated with narrative focus. In trained participants, experiential focus resulted in more marked and pervasive reductions in the MPFC, including the rostral subregions of the dorsal MPFC and ventral MPFC, suggesting that present-centered experience may rely on suppression of MPFC representations supporting narrative focus. Trained participants also showed marked reductions in the MPFC and increased recruitment of a right lateralized network, comprising the right lateral PFC and viscerosomatic areas such as the insula, secondary somatosensory cortex, and inferior parietal lobule. Moreover, right insular functional connectivity analysis revealed a strong coupling between the right insula and the VMPFC in novices that was uncoupled in the mindfulness group, suggesting viscerosomatic signals are by default associated with activation in the VMPFC.[17] This decoupling in the trained mindfulness group was replaced by an increased coupling of the right insula with the DLPFC during formal meditation, which may reflect a neuronal reorganization that supports a continuous, present-centered attentional stance.[17]

In another fMRI study, brain activity patterns observed during concentrative and diffuse meditation were contrasted in an experiment between expert Buddhist monks and lay novices with an integrated concentrative/diffuse paradigm, where involvement of differential brain activations was analyzed between groups during concentrative and diffuse meditation with reference to rest.[38] No particular interest was given to identifying previously theorized large-scale brain networks, such as the aforementioned intrinsic connectivity network. Striking differences between activity patterns were found between the groups. Activity patterns during diffuse meditation resembled the ordinary brain-resting state in monks, but not in controls, suggesting that monks also maintain an open-monitoring attentional stance during nonformal meditation conditions (i.e., in everyday life).[38] There may be a meditation-related functional reorganization of brain activity patterns in the prefrontal cortex and insula in expert practitioners, reflected by a substantially increased reliance on the central executive network and decreased reliance on the default mode network during nonformal meditation conditions.[38] Neuronal populations in regions typically associated with self-referential processing during everyday life may have been reallocated to support areas that are involved in metacognition of phenomenal experience; that is, objective, present-centered awareness.[13] Several crucial aspects of Buddhist meditation practice are relevant here—all of which relate to transcending conceptions of a separate self or ego—such as the cultivation of mental states of unconditional love, compassion, and kindness, or remaining continually aware of impermanence, or the arising and passing of particular sensational phenomena from moment to moment.[8,33,38,48,49] Moreover, this finding is consistent with the goal of meditation, which is to disintegrate the experiential psychological distinction between meditation and normative functioning over time.[48,49]

The study also found that the ACC and DLPFC play antagonistic roles in the executive control of attention setting in monks during meditation.[38] A negative correlation between ACC activation and DLPFC deactivation during rest was found, possibly suggesting increased reliance upon the salience network when distraction is more likely, such as during resting state.[38] This may be a functional reflection of increased reliance on the ACC/salience network and decreased reliance on the DLPFC/central executive network during rest, and a decreased reliance on the ACC/salience network and increased reliance on the DLPFC/central executive network during concentrative meditation. Note that concentrative meditation is used to establish (or reestablish) concentration when concentration is weak. Predominant ACC activation during rest, as part of the salience network, may be a neurological reflection of continually disengaging from distractors caused by default mode network activation and reengaging with the object of focus during focused mental processing (i.e., toggling between the default mode network and central executive network). However, the DLPFC, as part of the central executive network, is predominantly activated during continual focused attention, which is confirmed by predominant DLPFC activation during formal concentrative meditation. It would be interesting to see if there is a gradual reduction in ACC/salience and default mode network activation with a concurrent, corresponding increase in DLPFC/central executive network activation during a concentrative meditation session in expert participants—and, if so, how this result correlates with the reported strength of concentration during the session. The findings also address the question of whether meditative states are associated with a transient deactivation[50,51] or activation[11,13] of executive brain areas. The findings clearly show that executive areas are activated during meditation.[38]

Another recent study examined meditation-induced cortical gyrification to shed light on anatomical correlates of meditation and meditation-related neuroplasticity throughout the lifespan.[52] *Gyrification* refers to the pattern and degree of cortical folding on the surface of the brain. Participants consisted of a large sample ($n = 100$) of long-term insight meditators and age- and sex-matched controls. The degree of cortical gyrification was established by calculating mean curvature with a 3-D version of a well-known gyrification magnetic resonance imaging index across thousands of cortices on individual cortical surface models. When applying more liberal significance thresholds ($p < 0.05$), gyrification was larger in meditators as well as in controls overall.[52] However, meditators showed larger gyrification in some of the areas where prior analyses revealed thicker gray matter cortices in meditators as compared to nonmeditators.[52,53] Regions included the anterior insula,[53] left anterior temporal gyrus,[54,55] left central sulcus and vicinity,[52,56] and right parietal operculum, which houses the secondary somatosensory cortex.[52,56] Stricter significance thresholds ($p < 0.01$) revealed five distinct regions where cortical gyrification was exclusively larger in meditators: the left precentral gyrus, left and right anterior insula, right fusiform gyrus, and left cuneus, showing a global maximum in the right AI.[52] As previously mentioned, the AI has been shown to play a crucial role in switching between the default mode network and central executive network.[37] The current study suggests a correlation between AI gyral complexity and the number of years spent practicing meditation.[52] Although the findings of this study should be interpreted with caution since it did not correct for multiple comparisons, previous studies have likewise shown structural differences between meditators and nonmeditators within the AI.[53–55,57] Moreover, functional analyses have shown activation of the insula during meditation,[52] supporting the notion that the salience network is acting to shift the mind from a state of wandering to a state of present-centered awareness during meditation.

The AI has also been described as a "hub" for autonomic, affective, and cognitive integration, as it has been shown to integrate a wide array of stimuli, including cognitive, socio-emotional, olfactory-gustatory, interoceptive sensation, and pain processing.[52,58–61] Meditators learn to master their faculties of introspective awareness, emotional control, and self-regulation, as well as techniques oriented toward enhancing wholesome and unconditional mental states.[52] Therefore, the AI may be a contributing neural correlate of a fundamental, all-inclusive awareness that acts to shift the mind from a state of self-referential perception of sensation (i.e., identification with sensation) to a state of all-inclusive, present-centered awareness with regard to any possible sensation. This category includes all body sensation, thoughts, beliefs, emotional states—everything that can be observed, which is literally everything but awareness itself. Therefore, the salience network may act as the bridge between the subconscious reactive experience of being identified with sensation, associated with default mode network activation, and an all-inclusive, "transcendent" state of objective, present-centered awareness of sensate experience, contributing to a sense of "oneness" or interconnectedness that is associated with central executive network activation.

Electroencephalography Studies

EEG coherence is characterized by the synchronous firing of neural networks at a particular frequency. It is theorized that the amplitude of a brain wave is positively correlated with the degree of precision with which cells oscillate and the size of the neural population through which the wave is occurring.[62,63] It has been found that increases in EEG coherence correlate with increased brain processing capacity in areas such as attention, working memory, learning, and conscious perception.[63–66] Synchronization of oscillatory neural discharges, particularly of the gamma-band frequency (25–70 Hz), appears to play a key role in developing the ability to integrate distributed neural processes into one overarching network with highly ordered cognitive and affective functions, suggesting that gamma synchrony may also play a crucial role in neuroplasticity.[63]

In an EEG study, long-term Buddhist meditators were found to possess the ability to induce high-amplitude gamma synchrony during meditation, where robust gamma-band oscillations and long-range phase synchrony were found during a nonreferential compassion meditation state.[63] The amplitude of activity in some of these practitioners was found to be the highest reported outside of pathological contexts.[63,67] This finding suggests that massive distributed neural assemblies were oscillating with high temporal precision during meditation.[63] In expert meditators, the transition from basal cognition to the meditation state typically took 5–15 seconds. Time to develop deep meditative states characterized by neural synchronization at high amplitude frequencies was found to be proportional to the size of the neural assembly being stimulated. The goal of meditation is to transform normative functioning into a consistent meditative state by disintegrating the distinction between meditation and normative functioning over time—which is reported to occur naturally with consistent practice.[8,48,49] In support of this claim, Lutz and colleagues[63] found differences in basal gamma activity between novice and expert meditators before meditation, with expert meditators showing more gamma activity during resting state. Further testing found that the duration of time spent meditating over the lifespan, and not age, predicted differences in gamma activity during baseline cognitive functioning.[63]

A recent neurophysiology study investigated the effects of attentional training on the global precedence effect (i.e., the faster detection of targets on a global, rather than on a local, level) in eight highly trained Buddhist monks and nuns and in eight age- and education-matched controls with no previous meditation experience.[68] Analysis of reaction times showed a significantly reduced global precedence effect in meditators but not in controls, implying that the meditators had a unique ability to willingly, quickly, and effectively disengage their attention from the dominant global level.[68] Analysis of event-related potentials revealed that, due to an enhanced processing of target-level information, the meditators had an acute ability to select the respective target level in which the target number was embedded.[68] Moreover, meditators selected target-level information earlier in the processing sequence than controls. These results suggest that with mental training, meditators are able to increase the speed and accuracy with which they allocate attentional resources, thereby increasing the depth and breadth of information processing while reducing response latency to stimuli.[68]

As described by the methodology involved in concentrative and diffuse meditation, these findings support the notion that concentrative and diffuse meditation practices result in an increased capacity to process sensory information by training the practitioner to not "get stuck" on specific stimuli, possibly contributing to the ability to notice fine details more quickly and accurately. To reiterate, concentrative meditators center their attention on a specific object of focus for extended periods of time, and when their attention is diverted from the object of focus, they learn to disengage quickly from the distractor and to reengage with the object of focus until access concentration is established. A similar process may be used to establish access concentration during diffuse meditation, though instead of maintaining attentional focus on a specific object, the meditator practices continually disengaging from sense objects throughout the body/mind as quickly as possible until a continual awareness of the ongoing stream of experience is established. The above results also support the traditional notion that meditation "concentrates" the mind—that is, makes the mind progressively more acutely aware of the details of momentary experience.

Physiological Studies

It has been known that regular meditation practice can reduce psychological stress and enhance perceived well-being.[8,9,48,49,69] Some attention has been given to the physiological correlates of meditation-derived health benefits as a means to understanding the mechanistic links between psychological functioning and physical health. An early physiology study compared the effect of Buddhist meditation on several physiological markers (serum cortisol, total protein levels, blood pressure, pulse rate, lung volume, and reaction time) between 52 male meditators and 30 age- and sex-matched nonmeditators.[4] Measurements of these markers were taken after three and six weeks of practice. At three weeks, results showed significant reductions in serum cortisol level, blood pressure, pulse rate, and reaction time in meditators compared to controls.[4] Vital lung capacity, tidal volume, and maximal voluntary ventilation were significantly lower following each meditation session than before, indicating a lower need for oxygen as a result of meditation.[4] In addition, the serum total protein level significantly increased by the six-week time point. Meditators also showed a 23% reduction in reaction time compared to measurements taken before practice, suggesting that a high degree of present-centered attentional acuity was developed during practice.[4] The control group showed a 7% reduction in reaction time at six weeks, most likely due to task repetition, indicating that meditation practice was not entirely responsible for the reduced reaction time in the experimental group. These results are consistent with the current conception of meditation as being associated with a concurrent state of heightened vigilant awareness and reduced metabolic activity that elicits improved physical health, psychological balance, and emotional stability.[3,6,15,49]

A recent study investigated whether meditation practice is associated with telomerase activity and whether this association is at least partly explained by changes in two major contributors to the experience of stress—"perceived control" and "neuroticism."[70] Telomeres are terminal DNA protein complexes consisting of repetitive nucleotide sequences that are located at the ends of chromosomes.[71] They are known to ensure genomic stability during cellular replication by protecting the ends of chromosomes from deterioration and from fusing with other chromosomes. However, telomeres shorten under conditions of oxidative stress, as well as with each cell-division cycle. Telomerase is a ribonucleoprotein that counteracts this process by adding DNA to the 3' end in the telomere regions.[71] As cells divide during the aging process, telomere length steadily decreases and hence is an indicator of the biological age of a cell.[70,72] Cell division can no longer occur below a critical telomere length, resulting in a state of senescence.[71,73] Therefore, telomere length acts as an effective "psychobiomarker" in predicting physical health and longevity by linking stress and disease.[70,74–76]

Recent longitudinal studies indicate that telomere length in peripheral blood mononuclear cells can increase over time, suggesting that there may be determinable mechanisms—and therefore possible interventions—that regulate the rate of telomere length alteration.[70,77–79] Greater perceived stress, negative affect, and stress-related cardiovascular risk are factors associated with lower telomerase activity that is responsible for protecting against telomere shortening.[70,80,81] Individuals who respond with suppressed vagal tone when presented with an acute stressor and who show correspondingly increased measures of negative affect and vulnerability to psychological stressors show reduced telomerase activity.[70,82,83] Therefore, telomerase activity may play a key role in mediating the relation between psychological stress and disease.[70] This controlled, longitudinal study by Jacobs and colleagues[70] investigated the effects of a three-month meditation retreat on telomerase activity and on two major contributors to the experience of stress—perceived control (associated with decreased stress) and neuroticism (associated with increased subjective stress). Perceived control is a marker of stress resilience and refers to a feeling of adequate control that has been associated with reduced psychological stress and more adaptive responses to stressful events.[70,84–89] For example, an internal locus of control refers to the extent to which individuals believe they can control their external circumstance and has been shown to mediate responses to stressful events by improving coping strategies[90,91] and reducing anxiety.[70,92] High trait negative affectivity, or neuroticism, refers to chronic feelings of tension, anxiety, lability, or insecurity, and typically amplifies the stress response to acute stressors, causing "greater stress vulnerability."[70,93–96]

The study by Jacobs and colleagues[70] also examined the causal relationship between meaning-finding and affect, with specific regard to how these factors are influenced by meditation. Longitudinal studies have shown that the ability to integrate stressful events into an encompassing sense of meaning or purpose leads to a change in affect.[70,97] In the context of meditation, Fredrickson and colleagues[98] showed that the amount of time per week spent in "loving-kindness," or compassion, meditation over a two-month period predicted a cumulative increase in positive affect, contributing to an increase in life satisfaction and reduced depressive symptoms as mediated by one's degree of perceived purpose in life and mindfulness. Jacobs and colleagues[70] found that telomerase activity was significantly greater in retreat participants than in controls at the end of the retreat ($p < 0.05$). Moreover, increases in perceived control, decreases in neuroticism, and increases in both mindfulness and perceived purpose in life were greater in the retreat group ($p < 0.01$).[70] The data suggest that increases in perceived control and decreases in negative affectivity, as influenced by meditation practice, contributed to an increase in telomerase activity. If so, consistent meditation could potentially result in increases in telomere length and immune cell longevity throughout the lifespan.[70] Hence, the practice of meditation seems to affect cellular processes that are influenced by stress and linked to disease.

Another recent study examined the effect of compassion meditation, a form of emotional diffuse meditation, on innate immune, neuroendocrine, and behavioral responses to psychological stress, and evaluated the degree to which engagement in meditation practice influenced stress reactivity.[99] Sixty-one healthy adults were randomized to either six weeks of training in compassion meditation (n = 33) or participation in a health discussion control group (n = 28). These were followed by exposure to a standardized laboratory stressor (Trier Social Stress Test (TSST)) that consists of public speaking followed by mental arithmetic. Physiologic and behavioral responses to the TSST were determined by repeated assessments of plasma concentrations of interleukin-6 (IL-6) and cortisol, and by total distress scores on the Profile of Mood States (POMS). Initially, no differences between groups were found on TSST response scores for IL-6, cortisol, or POMS scores. However, increased meditation practice as measured by mean number of practice sessions per week was strongly correlated with decreased TSST-induced IL-6 ($p = 0.008$) and POMS scores ($p = 0.014$). Because no differences based on group assignment were found (meditation versus controls), further analysis was done to compare individuals who spent more time meditating (above the median, high practice) to individuals who spent less time meditating (below the median, low practice) and controls (no practice). High-practice individuals (n = 17) exhibited significantly lower TSST-induced IL-6 and POMS scores compared to low-practice individuals and controls ($p = 0.005$). These data suggest that engagement in compassion meditation may progressively reduce stress-induced immune and behavioral responses relative to one's degree of experience with meditation.[99]

Yet another study examined the effects of mindfulness on HPA activity and sleep by comparing morning cortisol samples and also sleep duration and quality between long- and short-term meditators.[100] This study was conducted with the specific aim of clarifying existing contradictory conclusions from numerous previous studies on the effects of mindfulness on health by investigating the relationship between traditional Buddhist meditation, mindfulness-based stress reduction, HPA activity, and sleep among long-term practitioners of meditation (Buddhist monks and nuns, and mindfulness teachers) compared to those with no prior meditation experience (novices). Long-term meditators showed decreased morning cortisol levels that corresponded with length of practice over the lifespan ($p < 0.03$). Similarly, novices who took an eight-week introductory MBSR course showed reduced morning cortisol levels ($p = 0.04$) and substantially improved sleep ($p = 0.008$) and self-attribution of mindfulness ($p = 0.001$). However, cortisol levels did not change between the beginning and end of individual MBSR sessions. These results support the view that meditation and meditation-derived therapeutic techniques such as MBSR have beneficial effects on biomarkers of stress regulation, such as cortical secretion and quality of sleep, and also seem to improve one's ability to remain mindful. [35] These results provide support for MBSR as a nonpharmacological intervention alongside standard therapies, as well as in nonclinical settings to foster well-being. Moreover, the empirical physiological data summarized from this study support the validity of the self-attributed data previously discussed in this section. For example, increased perceived control, reduced negative affectivity, and increased life satisfaction scores would be expected in individuals with improved biomarkers of stress regulation.

DISCUSSION

Western medical traditions have progressed by way of hypothetical deduction, relying heavily upon pharmaceuticals and technology-based interventions to treat or suppress diseases caused by pathophysiologic processes. While these have had a substantial impact in improving human health globally, the effectiveness of Western medicine remains limited, especially when treating chronic diseases and mental illness in which stress and the environment play major roles.[101] The study and integration of Eastern healing techniques may bring about a complementary approach that will help develop a more comprehensive and holistic attitude toward patient care.

Meditation is an ancient Eastern technique that has recently been accepted as a form of clinical intervention in the West. The study and practice of Buddhist meditation, along with the increasing use of Buddhist-derived, mindfulness-based therapeutic modalities in the clinical setting, have piqued scientific interest. Here, we have introduced the basic concepts of concentrative, diffuse, and insight meditation, as well as some of the relevant clinical applications and scientific studies that suggest significant physiological and neurological correlates of these meditative practices. Neuroscientists have made strides in elucidating some of the basic biological mechanisms underlying the benefits of meditation. Our understanding, however, is rudimentary at this stage.

Compelling scientific evidence supports the role of meditation in promoting health in general[20,21,53,70] and in treating numerous clinical and psychiatric disorders.[20–30,36,44,47] Buddhist meditation induces what one may consider a low-entropy state of equanimous, vigilant awareness,[3] bringing the body to a "hypometabolic state of parasympathetic dominance" that serves to rejuvenate the organism's capacity for resilience and adaptability.[7] Long-term Buddhist meditation has been correlated with reduced stress response and lower cortisol levels overall,[4,36,70] possibly contributing to reduced chronic stress and a restored healthy response to acute stress,[4] longevity,[70] reduced stress-induced craving, and increased craving tolerance.[7] Developed meditators also have the ability to access "highly reinforced" (i.e., deep) meditative states,[5,6,16,38,48] which may contribute to cognitive resilience and adaptation in the face of even highly agitating stressors.[7] Buddhist meditation has been found to increase cerebral plasticity[1,6,36,38] and cerebral blood flow and thickening in brain regions associated with the mental exercises practiced by concentrative and diffuse meditation,[15–17,36,38,50–56] suggesting a role in potentially preserving and enhancing brain regions affected by meditation.[7] This notion is supported by increased proficiency in several cognitive skills associated with consistent concentrative and diffuse meditation, such as the highly developed ability to disengage from distractors during concentration and the ability to observe one's internal states in a non-evaluative way.[7–9,33,48,49]

Buddhist meditation has been found to increase EEG coherence through the synchronization of neural discharges, particularly in the gamma-band frequency (25–70 Hz).[1,5,6,11,37] It is theorized that a brain wave's amplitude is positively correlated with the degree of precision with which cells oscillate and with the size of the neural population through which the wave is occurring.[62,63] Increased EEG coherence is correlated with increased brain-processing capacity in areas such as attention, working memory, learning, and conscious perception.[63–66] Synchronization of oscillatory neural discharges, particularly of the gamma-band frequency, appears to play a key role in developing the ability to integrate distributed neural processes into one overarching network with highly ordered cognitive and affective functions, suggesting that gamma synchrony may also play a crucial role in meditation-induced neuroplasticity.[63,67]

Recent findings have shown that a gradual, meditation-induced, functional reorganization of brain activity patterns occurs between the default mode network, salience network, and central executive network; reliance upon the central executive network and salience network seems to increase, and reliance upon the default mode network seems to decrease.[37,38] Abnormal activity in this intrinsic connectivity network has been implicated in a number of psychiatric diseases (such as ADHD, bipolar disorder, borderline personality disorder, depression and anxiety disorders, and schizophrenia),[37,38,44] and an inability to "switch off" the hyperactive default mode network through focusing the mind appears to be a major contributor to the disease process,[44] suggesting that meditation may aid in reducing symptoms in these disorders. Future research should consider the state of the anterior insula in individuals with these disorders. The AI plays a critical role for the initiation of network switching by the salience network,[37] suggesting that AI integrity or connectivity may be compromised in individuals with these disorders.

In light of meditation's effect on this intrinsic connectivity network, meditation may be contraindicated in cases in which there are existing deficits in default mode network function. For example, autistic patients show reduced and abnormal default mode network activation overall, which may be neurologically related to difficulty in structuring social relationships, and they also show an increased reliance on the central executive network,[37,41,42] suggesting that meditation may act to solidify or exacerbate existing symptoms. Therefore, more research is needed to determine how meditation affects large-scale brain networks associated with psychopathology in order to ensure the safe and effective application of meditation in clinical and psychiatric settings.

The skills developed through meditation practice have significant implications for the treatment of various psychiatric disorders. The neural correlates of these skills may be partially explained by mechanisms involved in neuroplasticity over the lifespan. These findings also support the notion that concentrative and diffuse meditation practices aid in behavior modification, in attenuating stress-related illness, and in slowing, and perhaps stopping and rehabilitating, neurodegeneration and cognitive decline.[7] Future meditation research should aid in developing a clearer understanding of how large-scale brain network organization in the human brain produces cognition. Recent evidence suggests that cognitive function depends on a dynamic interaction of dissociable large-scale brain networks, such as recently discovered intrinsic connectivity networks.[1,37–39] Determining dissociable large-scale brain networks and their cognitive and behavioral correlates in healthy individuals would aid in studying psychiatric diseases by providing a reference point for comparison. Developed meditators may provide researchers with a more objective point of reference for healthy brain function than may be found in the general population.

Research in the field of neurometacognition has already made progress in understanding the neural correlates of cognition and complex behavior.[1,2,6,13,16,34–38] Continued research in this field may eventually give rise to a coherent theoretical framework for the neurobiology of consciousness. Meditation research can provide a framework for study that will aid in correlating electrophysiological recordings with simultaneously activated brain areas and their associated cognitive and behavioral analogues. Research has suggested that long-range phase synchrony may serve as a dynamic mechanism underlying functional interactions in large-scale brain networks.[37] Large-scale functional networks (such as the intrinsic connectivity network) and their cognitive and behavioral correlates may be able to be identified and differentiated through the comparison of concentrative and diffuse meditation conditions using respectively different fields of experiential awareness (e.g., concentrative meditation on breath sensations versus an external visual point, and diffuse meditation on body versus thought/emotion versus external sensory fields), while simultaneously recording brain-imaging activity patterns and concurrent electrophysiology. Participants with expert attentional control are able to direct their attention to differential fields of awareness at will and continuously, providing a well-defined and highly controlled activation of specific attentional fields and associated functional network activity, without the residual activation that may be produced in untrained populations by the lack attentional control and by "cortical noise."[16,37,38] Therefore, expert meditation practitioners may prove to be a valuable population for investigating a wide variety of phenomena that may aid in defining neural correlates of cognition and also the specific altered states of consciousness, including the neural correlates of attentional stance; mechanisms underlying dynamic engagement and disengagement of large-scale networks; how differential large-scale networks cooperate, compete, or coordinate their activity; how knowledge is neurologically constructed; how large-scale network imaging correlates with synchronized ocillatory neural activity; and the neural-physiological correlates of specific meditation-induced states of consciousness.[37] Buddhist practitioners and literature provide meditation instructions within a comprehensive theoretical framework of the states of consciousness that may be experienced through meditation, which may prove useful in guiding and expediting the process of meditation itself.[33,48,49,102–104] Moreover, this process may provide a strong and invaluable unification of two diametrically opposed methodologies used for the scientific investigation of consciousness—namely, the intellectual and deductive approach taken by Western scientists and the experiential and inductive approach taken by Eastern spiritual practitioners.

The complex cognitive methodology involved in meditation presents researchers with unique challenges when determining appropriate controls for the specific variables under investigation. Many experiments have failed to control for the type of meditation practice under investigation, making it difficult or impossible to compare results. As previously mentioned, meditation styles can differ significantly in their methodologies and intended results because each style is explicitly designed to train specific cognitive faculties. Moreover, the neurological correlates of specific practices differ significantly between populations, such as the differences one may find between monks, lay persons, adults, children, and individuals with psychopathology. Therefore, researchers must be specific about the style of meditation practice and the population under investigation, or else risk causing experimental confounds that produce results with limited or no potential for broader scientific comparison or application. Similarly, while mindfulness-based treatments in the clinical setting have been found to be effective, the majority of mindfulness-based treatments rely on other therapeutic modalities in cooperation with meditation, such as cognitive therapy, making it difficult to determine the efficacy of mindfulness practice itself during mindfulness-based treatment. In order to make results derived from mindfulness-based practitioners more comparable to other populations, it may be helpful to determine the effects of mindfulness practice itself through, for example, longitudinal studies on individuals who have maintained their practice after the therapy program has been completed. In a similar vein, longitudinal studies on Buddhist meditation are lacking overall and would be of great use in determining neural development and reorganization with meditation experience and in verifying behavioral and experiential modifications over time in relation to constant information (e.g., Buddhist texts). Longitudinal studies would also aid in separating out the specific neurological/behavioral factors affected by meditation itself from those found across individuals who are already likely to practice meditation.

Research on how meditation affects neurobiological pathways governing the stress response is lacking overall. Numerous studies have shown, however, that meditation has a normalizing effect on psychobiomarkers of stress regulation and that it produces overall improvements in self-attributed mood scores.[8,9,48,49,69] Moreover, the practice of meditation has been shown to positively affect cellular processes that are affected by stress and linked to disease, as is shown by increased telomerase activity with long-term meditation practice.[70]

The aspects of Buddhist theory that have been scientifically investigated thus far have served mainstream psychology and cognitive neuroscience well, making Buddhist theory a potential avenue for in-depth and critical scientific investigation. Such investigations may provide a useful and arguably necessary broadening of perspective with regard to defining and treating psychopathology. It has been suggested that the mechanisms underlying psychiatric symptom reduction occur at a level of "personality reorganization," because almost all of the commonly defined personality types—healthy, neurotic, borderline, psychotic, and so on—can be recognized in terms of personality development and organization over time.[105] Therefore, in the context of meditation in the clinical setting, it may be useful to think of mental illness in terms of a symptomatic continuum, from most to least pathological, with the aim of progressively reducing symptoms through shifting the mind and body toward a state of natural balance.[105]

The Western scientific study of meditation has, in large part, been conducted with minimal reference to its religious and spiritual origins, and only a brief overview of the most fundamental and commonly practiced forms of Buddhist meditation has been presented here. However, Buddhism has been successful in maintaining the practice and teaching of insight meditation for over 2500 years, and an extensive and detailed literature is devoted to theoretical aspects of the stages of meditative experience, or the "process of insight."[102–105] Investigation of these texts reveals a theoretical science with corresponding technical meditation instructions that guide the practitioner, in a stepwise manner, through a process of coming out of suffering (or attachment to ego) by gradually deepening his or her knowledge of experiential reality. In short, this process involves a gradual cumulative development of specific faculties of awareness that the individual uses to literally heal his or her own body. A detailed synopsis of this process and its implications is beyond the scope of this article. However, a wide body of literature is available for readers who are interested in further exploration.[102–105]

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

REFERENCES

1. Slagter H, Davidson R, Lutz A. Mental training as a tool in the neuroscientific study of brain and cognitive plasticity. Front Hum Neurosci 2011;5:1–12.
2. Raffone A, Srinivasan N. The exploration of meditation in the neuroscience of attention and consciousness. Cogn Process 2010;11:1–7.
3. Young JDE, Taylor E. Meditation as a voluntary hypometabolic state of biological estivation. News Physiol Sci 1998;13:149–53.
4. Sudsaung R, Chantanez V, Veluvan K. Effects of Buddhist meditation on serum cortisol and total protein levels, blood pressure, pulse rate, lung volume and reaction time. Physiol Behav 1990;50:543–8.
5. Lutz A, Brefczyski-Lewis J, Johnstone T, Davidson R. Regulation of the neural circuitry of emotion by compassion meditation: effects of meditative expertise. PLoS One 2008;3: e1897.
6. Lutz A, Dunne JD, Davidson RJ. Meditation and the neuroscience of consciousness: an introduction. In: Zelazo P, Moscovitch M, Thompson E, eds. Cambridge handbook of consciousness. New York: Cambridge University Press, 2007:81–109.
7. Dakwar E, Levin FR. The emerging role of meditation in addressing psychiatric illness, with a focus on substance use disorders. Harv Rev Psychiatry 2009;17:254–67.
8. Gunaratana H. Mindfulness in plain English. Somerville, MA: Wisdom, 2007.
9. Kabat-Zinn J. Mindfulness-based interventions in context: past, present, and future. Clin Psychol Sci Pract 2003;10: 144–53.
10. Ludwig DS, Kabat-Zinn J. Mindfulness in medicine. JAMA 2008;300:1350–2.
11. Cahn BR, Polich J. Meditation states and traits: EEG, ERP, and neuroimaging studies. Psychol Bull 2006;132:180–211.
12. Goleman D. The Buddha on meditation and states of consciousness. In: Shapiro DH Jr, Valsh RN, eds. Meditation, classic and contemporary perspectives. Piscataway, NJ: Aldine Transaction, 2008:345–7.
13. Lutz A, Slagter HA, Dunne JD, Davidson RJ. Attention regulation and monitoring in meditation. Trends Cogn Sci 2008;12:163–9.
14. Bishop SR, Lau M, Shapiro S, et al. Mindfulness: a proposed operational definition. Clin Psychol Sci Pract 2004;11: 230–41.
15. Chambers R, Gullone E, Allen NB. Mindful emotion regulation: an integrative review. Clin Psychol Rev 2009; 29:560–72.
16. Brefczynski-Lewis JA, Lutz A, Schaefer HS, Levinson DB, Davidson RJ. Neural correlates of attentional expertise in long-term meditation practitioners. Proc Natl Acad Sci U S A 2007;104:11483–8.
17. Farb NAS, Segal ZV, Mayberg H, et al. Attending to the present: meditation reveals distinct neural modes of self-reference. Soc Cogn Affect Neurosci 2007;2:313–22.
18. Watkins E, Teasdale JD. Rumination and overgeneralization memory in depression: effects of self-focus and analytic thinking. J Abnorm Psychol 2001;110:353–7.
19. Linehan MM. Skills training manual for treating borderline personality disorder. New York: Guilford, 1993.
20. Hayes SC. Acceptance and change: content and context in psychotherapy. Reno, NV: Context, 1994.
21. Marlatt GA, Witkiewitz K, Dillworth TM, et al. Vipassana meditation as a treatment for alcohol and drug use disorders. In: Hayes SC, Follette VM, Linehan MM, eds. Mindfulness and acceptance: expanding the cognitive-behavioral tradition. New York: Guilford, 2004:261–87.
22. Teasdale JD, Segal ZV, Williams JM, Ridgeway VA, Soulsby JM, Lau MA. Prevention of relapse/recurrence in major depression by mindfulness-based cognitive therapy. J Consult Clin Psychol 2000;68:615–23.
23. Wolf DB, Abell N. Examining the effects of meditation techniques on psychosocial functioning. Res Soc Work Pract 2003;13:27–42.
24. Shannahoff-Khalsa DS. Kundalini Yoga meditation techniques for the treatment of obsessive-compulsive and OC spectrum disorders. Brief Treat Crisis Interv 2003;3:369–82.
25. Marlatt GA, Marques JK. Meditation, self-control and alcohol use. In: Stuart RB, ed. Behavioral self-management: strategies, techniques and outcome. New York: Brunner/ Mazel, 1977:117–53.
26. Linehan MM, Comtois KA, Murray AM, et al. Two-year randomized controlled trial and follow-up of dialectical behavior therapy vs therapy by experts for suicidal behaviors and borderline personality disorder. Arch Gen Psychiatry 2006;62:1–10.
27. Fjorback LO, Walch H. Meditation based therapies—a systematic review and some clinical observations. Religions 2012;3:1–18.
28. Kabat-Zinn J. Wherever you go, there you are: mindfulness meditation in everyday life. New York: Hyperion, 1994.
29. Teasdale JD, Segal Z, Williams JM. How does cognitive therapy prevent depressive relapse and why should attentional control (mindfulness training) help? Behav Res Ther 1995;33:25–39.
30. Kisteller JL, Hallett CB. An exploratory study of meditation-based intervention for binge eating disorder. J Health Psychol 1999;4:357–63.
31. Kozak A. Wild chickens and petty tyrants: 108 metaphors for mindfulness. Somerville, MA: Wisdom, 2009.
32. Shapiro SL, Brown KW, Biegel GM. Teaching self-care to caregivers: effects of mindfulness-based stress reduction on the mental health of therapists in training. Train Educ Prof Psychol 2007;1:105–15.
33. Kornfield J. A path with heart: a guide through the perils and promises of spiritual life. New York: Bantam, 1993.
34. Gilbert P. Compassion: conceptualizations, research and use in psychotherapy. New York: Routledge, 2006.
35. Henry WP, Schacht TE, Strupp HH. Patient and therapist introject, interpersonal process, and differential psychotherapy outcome. J Consult Clin Psychol 1990;58:768–74.
36. Rubia K. The neurobiology of meditation and its clinical effectiveness in psychiatric disorders. Biol Psychol 2009;82:1–11.
37. Bressler SL, Menon V. Large-scale brain networks in cognition: emerging methods and principles. Trends Cogn Sci 2010;14:277–90.

38. Manna A, Raffone A, Perrucci MG, et al. Neural correlates of focused attention and cognitive monitoring in meditation. Brain Res Bull 2010;82:46–56.
39. Raichle ME, MacLeod AM, Snyder AZ, Powers WJ, Gusnard DA, Shulman GL. A default mode of brain function. Proc Natl Acad Sci U S A 2001;98:676–82.
40. Whitfield-Gabrieli S, Thermenos HW, Milanovic S, et al. Hyperactivity and hyperconnectivity of the default network in schizophrenia and in first-degree relatives of person with schizophrenia. Proc Natl Acad Sci U S A 2009;106:1279–84.
41. Murias M, Webb SJ, Greenson J, Dawson G. Resting state cortical connectivity reflected in EEG coherence in individuals with autism. Biol Psychiatry 2007;62:270–3.
42. Uddin LQ, Menon V. The anterior insula in autism: under-connected and under-examined. Neurosci Biobehav Rev 2009;33:1198–203.
43. Liao W, Zhang Z, Pan Z, et al. Default mode network abnormalities in medial temporal lobe epilepsy: a study combining fMRI and DRT. Hum Brain Mapp 2011;32:883–95.
44. Whitfield-Gabrieli S, Ford JM. Default mode network activity and connectivity in psychopathology. Annu Rev Clin Psychol 2012;8:49–76.
45. Stein MB, Simmons AN, Feinstein JS, Paulus MP. Increased amygdala and insula activation during emotion processing in anxiety-prone subjects. Am J Psychiatry 2007;164:318–27.
46. Feinstein JS, Stein MB, Paulus MP. Anterior insula reactivity during certain decisions is associated with neuroticism. Soc Cogn Affect Neurosci 2006;1:136–42.
47. Daniels JK, McFarlane AC, Bluhm RL, et al. Switching between executive and default mode networks in post traumatic stress disorder: alteration in functional connectivity. J Psychiatry Neurosci 2010;35:258–66.
48. Goenka SN. Mahasatipatthana sutta: the great discourse on establishing awareness. Seattle, WA: Vipassana Research Institute, 1996.
49. Hanh TN. The miracle of mindfulness. Boston, MA: Beacon, 1976.
50. Deitrich A. Functional neuroanatomy of altered states of consciousness: the transient hypofrontality hypothesis. Conscious Cogn 2003;12:231–56.
51. Lou HC, Norwak M, Kjaer TW. The mental self. Prog Brain Res 2005;150:197–204.
52. Luders E, Kurth F, Mayer EA, Toga AW, Narr KL, Gaser C. The unique brain anatomy of meditation practitioners: alterations in cortical gyrification. Front Hum Neurosci 2012;6:34.
53. Lazar SW, Kerr CE, Wasserman R, et al. Meditation experience is associated with increased cortical thickness. Neuroreport 2005;16:1983–7.
54. Hozel BK, Ott U, Gard T, et al. Investigation of mindfulness meditation practitioners with voxel-based morphometry. Soc Cogn Affect Neurosci 2008;3:55–61.
55. Luders E, Toga A, Lepore N, Gaser C. The underlying anatomical correlates of long-term meditation: larger hippocampal and frontal volumes of grey matter. Neuroimage 2009;45:673–8.
56. Grant JA, Courtemanche J, Duerden EG, Duncan GH, Rainville P. Cortical thickness and pain sensitivity in Zen meditators. Emotion 2010;10:43–53.
57. Baerensten KB, Stodklide-Jorgensen H, Sommerlund B, et al. An investigation of brain processes supporting meditation. Cogn Process 2010;11:57–84.
58. Critchley HD. Neural mechanisms of automatic, affective, and cognitive integration. J Comp Neurol 2005;495;154–66.
59. Kurth F, Zilles K, Fox PT, Laird AR, Eickhoff SB. A link between the systems: functional differentiation and integration within the human insula revealed by meta-analysis. Brain Struct Funct 2010;214:519–34.
60. Mutschler I, Wiekhorst B, Kowalevski S, et al. Functional organization of the human anterior cingulated cortex. Neurosci Lett 2009;457–60.
61. Damasio AR. The feeling of what happens: body an emotion in the making of consciousness. Orlando, FL: Harcourt, 1994.
62. Niedermeyer E, da Silva FL. Electroencephalography: basic principles, clinical applications, and related fields. New York: Lippincott Williams & Wilkins, 2004.
63. Lutz A, Greischar L, Rawlings N, Ricard M, Davidson J. Long term meditators self-induce high-amplitude gamma synchrony during mental practice. Proc Natl Acad Sci U S A 2004;101:16369–73.
64. Sheppard WD. Pretrial EEF coherence as a predictor of semantic processing effects in a lexical decision test. Dissertation Abstr Int 1998;49:B3610.
65. Sheppard WD, Boyer RW. Pretrial EEG coherence as a predictor of semantic priming effects. Brain Lang 1990;39:37–68.
66. Cardin JA, Carlen M, Meletis K, et al. Driving fast-spiking cells induces gamma rhythm and control sensory responses. Nature 2009:459:663–7.
67. Baldeweg T, Spence S, Hirsch SR, Gruzelier J. Gamma-band electroencephalographic oscillations in a patient with somatic hallucinations. Lancet 1998;352:620–1.
68. Leeuwen S, Singer W, Melloni L. Meditation increases the depth of information processing and improves the allocation of attention in space. Front Hum Neurosci 2012;6:133.
69. Lama D, Cutler HC. The art of happiness: a handbook for living. New York: Riverhead, 2009.
70. Jacobs TL, Epel ES, Lin J, et al. Intensive meditation training, immune cell telomerase activity, and psychological meditators. Psychoneuroendocrinology 2011;36:664–81.
71. Blackburn E. Structure and function of telomeres. Nature 1991;350:569–73.
72. Frenck RW, Blackburn EH. The rate of telomere sequence loss in human leukocytes varies with age. Proc Natl Acad Sci U S A 1998;95:5607–10.
73. Fossel M. Role of cell senescence in human aging. J Antiaging Med 2000;3:91–8.
74. Epel ES. Telomeres in a life-span perspective: a new “psychobiomarker”? Curr Dir Psychol Sci 2009;18:6–10.
75. Cawthon RK, Smith E, O’Brien E, Sivatchenko A, Kerber RA. Association between telomere length in blood and mortality in people aged 60 years of older. Lancet 2003; 361:393–5.
76. Njajou OT, Hsueh WC, Blackburn EH, et al. Association between telomere lengths, specific causes of death, and years of healthy life in health, aging, and body composition, a population-based cohort study. J Gerontol A Biol Sci Med Sci 2009;64:860–4.
77. Epel ES, Merkin SS, Cawthon R, et al. The rate of leukocyte telomere shortening predicts mortality from cardiovascular disease in elderly men. Aging 2008;1:81–8.
78. Nordfjall K, Svenson U, Norrback KF, Adolfsson R, Lenner P, Roos G. The individual blood cell telomere attrition rate is telomere length dependent. PLoS Genet 2009;5: e1000375.
79. Farzaneh-Far R, Lin J, Epel E, Lapham K, Blackburn E. Telomere length trajectory and its determinants in persons with coronary artery disease: longitudinal findings from the heart and soul study. PLoS One 2010;5:e8612.
80. Epel ES, Blackburn EH, Lin J, et al. Accelerated telomere shortening in response to life stress. Proc Natl Acad Sci U S A 2004;101:17312–5.

81. Epel ES, Lin J, Wilhelm FH, et al. Cell aging in relation to stress arousal and cardiovascular disease risk factors. Psychoneuroendocrinology 2006;31:277–87.
82. Porges SW. Cardiac vagal tone: a physiological index of stress. Neurosci Biobehav Rev 1995;19:225–33.
83. Carney RM, Blumenthal JA, Stein PK. Depression, heart rate variability, and acute myocardial infarction. Circulation 2001; 104:2024–8.
84. Seligman MEP. Learned helplessness. Annu Rev Med 1972;23: 407–12.
85. Averill JR. Personal control over aversive stimuli and its relationship to stress. Psychol Bull 1973;80:286–303.
86. Wallston KA, Wallston BS, Smith S, Dobbins CJ. Perceived control and health. Curr Psychol Res Rev 1987;6:5–25.
87. Vollmayr B, Henn FA. Learned helplessness in the rat: improvements in validity and reliability. Brain Res Brain Res Protoc 2001;8:1–7.
88. Mausbach BT, Patterson TL, von Kanel R, et al. Personal mastery attenuates the effect of caregiving stress on psychiatric morbidity. J Nerv Ment Dis 2006;194:132–4.
89. Mausbach BT, von Kanel R, Patterson TL, et al. The moderating effect of personal mastery on the relations between stress and plamninogen activator inhibitor-1 (PAI-1) antigen. Health Psychol 2008;27:S172–9.
90. Krause N, Stryker S. Stress and well-being: the buffering role of locus of control beliefs. Soc Sci Med 1984;18:783–90.
91. Litt MD. Cognitive mediators of stressful experience: self efficacy and perceived control. Cognit Ther Res 1988;12:241–60.
92. Chorpita BF, Barlow DH. 1998. The development of anxiety: the role of control in early development. Psychol Bull 1998;124:3–21.
93. Brody S, Veit R, Rau H. Neuroticism but not cardiovascular stress reactivity is associated with less longitudinal blood pressure increase. Pers Individ Dif 1996;20:375–80.
94. Schneider TR. The role of neuroticism on psychological and physiological stress responses. J Exp Soc Psychol 2004;40: 795–804.
95. Shurgot GR, Knight BG. Influence of neuroticism, ethnicity, familism, and social support on perceived burden in dementia caregivers: pilot test of the transactional stress and social support model. J Gerentol B Psychol Sci Soc Sci 2005;60B:331–4.
96. Suls J. Affect, stress and personality. In: Forgas JP, ed. Handbook of affect and social cognition. Mahwah, NJ: Erlbaum, 2001:392–409.
97. Kabat-Zinn J. An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: theoretical considerations and preliminary results. Gen Hosp Psychiatry 1982;4:33–47.
98. Fredrickson BL, Cohn MA, Coffey KA, Pek J, Finkel SM. Open hearts build lives: positive emotions, induced through loving-kindness meditation, build consequential personal resources. J Pers Soc Psychol 2008; 5:1045–62.
99. Pace TW, Negi LT, Adame DD, et al. Effect of compassion meditation on neuroendocrine, innate immune, and behavioral responses to psychosocial stress. Psychoneuroendocrinology 2009;34:87–98.
100. Brand S, Holsboer-Trachsler E, Naranjo JR, Schmidt S. Influence of mindfulness practice on cortisol and sleep in long-term and short-term meditators. Neuropsychobiology 2012;65:109–18.
101. National Institutes of Health. At http://www.nimh.nih.gov/statistics/index.shtml
102. Buddhaghosa B; Nyanamoli B, trans. The path of purification: Visuddhimagga. Kandy, Sri Lanka: Buddhist Publication Society, 1991.
103. Piyadhassi Bhikkhu. Vimuttidhamma: from chakra to dhammachakra. Thailand: Dhamma Publication Fund, 2011.
104. Ingram D. Mastering the core teachings of the Buddha: an unusually hardcore Dhamma book. London: Aeon, 2008.
105. Wilber K, Engler J, Brown DP. Transformations of consciousness: conventional and contemplative perspectives on development. Boston, MA: Shambala, 1986.