mind of the meditator

Contemplative practices that extend back thousands of years show a multitude of benefits for both body and mind

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WHEN THE SOCIETY FOR NEUROSCIENCE ASKED TENGCHI OYATSO, THE 14TH DALAI LAMA (the leader of Tibetan Buddhism), to address its annual meeting in Washington, D.C., in 2005, a few hundred members among the nearly 36,000 or so attending the meeting petitioned to have the invitation rescinded. A religious leader, they felt, had no place at a scientific meeting. But this particular leader turned out to have a provocative and ultimately productive question to pose to the gathering: "What relation," he asked, "could there be between Buddhism, an ancient Indian philosophical and spiritual tradition, and modern science?"

The Dalai Lama, putting action before rhetoric, had already started trying to find answers to his own question. Back in the 1980s, he had sparked a dialogue about science and Buddhism, which led to the creation of the Mind & Life Institute, dedicated to studying contemplative science. In 2000 he brought new focus to this endeavor: he launched the subdiscipline of "contemplative neuroscience" by inviting scientists to study the brain activity of expert Buddhist meditators—defined as having more than 10,000 hours of practice.

For nearly 15 years more than 100 monastics and lay practitioners of Buddhism and a large number of beginning meditators have participated in scientific experiments at the University of Wisconsin–Madison and at least 18 other universities. The article you are reading, in fact, is the product of a collaboration between two neuroscientists and a Buddhist monk who originally trained as a cell biologist.

A comparison of the brain scans of meditators with tens of thousands of hours of practice with those of neophytes and non-meditators has started to explain why this set of techniques for training the mind holds great potential for supplying cognitive and emotional benefits. The goal of meditation, in fact, overlaps with many of the objectives of clinical psychology, psychiatry, preventive medicine, and education. As suggested by the growing compendium of research, meditation may be effective in treating depression and chronic pain and in cultivating a sense of overall well-being.

The discovery of meditation's benefits coincides with recent neuroscientific findings showing that the adult brain can still be deeply transformed through experience. These studies show that when we learn how to juggle or play a musical instrument, the brain undergoes changes through a process called neuroplasticity. A brain region that controls the movement of a violinist's fingers becomes progressively larger with mastery of the instrument. A similar process appears to happen when we meditate. Nothing changes in the surrounding environment, but the meditator regulates mental states to achieve a form of inner en-

**IN BRIEF**

Meditation is an ancient pursuit that, in some form, is practiced nearly everywhere in the world. Its practices, derived from various branches of Buddhism, have made their way into the modern world as a means of promoting calmness and general well-being.

Three common forms of meditation—focused attention, mindfulness, and compassion—are represented everywhere, from temples to schools and hospitals around the world.

Physiological changes in the brain—enlarged volumes of brain tissue—occur through meditation. Meditators also experience beneficial psychological effects; they react better to stimuli and are less prone to various forms of stress.
Varieties of Contemplative Experience

Advances in neuroimaging and other technologies have enabled scientists to gain insight into what happens in the brain during three major forms of meditative practice: focused attention, mindfulness, and compassion and loving kindness. The diagram below offers a glimpse into the cycle of events that occurs in the practice of focused attention meditation—and the corresponding activation of specific brain areas.

**Focused Attention**
This practice typically directs the meditator's attention to a sensory input, such as the rhythm of breathing. Even for the expert, the mind will wander, and the object of focus must be recentered. A brain-imaging study at Emory University has given insights into how the brain becomes involved in attention shifts.

**Mindfulness**
Also called open-monitoring meditation, mindfulness entails observing thoughts and sensations (including bodily sensations and thoughts) without being carried away by them. Expert meditators have reduced activity in anxiety-related areas, such as the insula and amygdala.

**Compassion and Loving Kindness**
In this practice, the meditator sustains a feeling of benevolence directed toward other people, whether fictitious or real. Two regions that fire up when putting oneself in the place of another—the ventromedial prefrontal cortex, for instance—show increased activity.

**Distraction Awareness**
This involves monitoring, which includes the anterior insula and the anterior cingulate cortex, underlying the meditator's awareness of the environment. One element that the mind has moved, the volunteer pushes a button to let researchers know what happened.

**Sustained Focus**
The dorsal lateral prefrontal cortex, which regulates when the meditator diverts attention from the breath for long periods.

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enrichment, an experience that affects brain functioning and its physical structure. The evidence amassed from this research has begun to show that meditation can rewire brain circuits to produce salutary effects not just on the mind and the brain but on the entire body.

WHAT IS MEDITATION?

Meditation has roots in the contemplative practices of nearly every major religion. The prevalence of meditation in the media has given the word various meanings. We will refer to meditation as the cultivation of basic human qualities, such as a more stable and clear mind, emotional balance, a sense of caring, mindfulness, even more love and compassion—qualities that remain latent as long as one does not make an effort to develop them. It is also a process of familiarization with a more serene and flexible way of being.

In principle, meditation is relatively simple and can be done anywhere. No equipment or workout attire is needed. The meditator begins by assuming a comfortable physical posture, neither too tense nor too lax, and by wishing for self-transformation and a desire for others’ well-being and for the alleviation of suffering. Later the practitioner must stabilize the mind, which is too often disorderly and occupied by a stream of inner chatter. Mastering the mind requires freeing it from automatic mental conditioning and inner confusion.

We will examine here what happens in the brain during three common types of meditation developed through Buddhist and now practiced in similar programs in hospitals and schools throughout the world. The first one, focused-attention meditation, aims to tame and center the mind in the present moment while developing the capacity to remain vigilant to distractions. The second one, mindfulness or open-monitoring meditation, tries to cultivate a less emotionally reactive awareness to emotions, thoughts, and sensations occurring in the present moment to prevent them from spiraling out of control and creating mental distress. In mindfulness, the meditator remains attentive, moment by moment, to any experience without focusing on anything specific. Finally, another type of practice is known in Buddhist tradition as compassion and loving-kindness and fosters an altruistic perspective toward others.

UNDER THE SCANNER

Neuroscientists have new means to probe what happens inside the brain during the various types of meditation. Wendy Hasenkamp, then at Emory University, and her colleagues used brain imaging to identify the neural networks activated by focused-attention meditation. In the scanner, the participants trained their attention on the sensation produced by breathing. Typically during this form of meditations, the mind wanders from an object, and the meditator must recognize this and then restore attention to the gradual rhythm of the inhaling and exhaling. In this study, the meditator had to signal mind wandering by pressing a button. Researchers identified four phases of a cognitive cycle: an episode of mind wandering, a moment of becoming aware of the distraction, a phase of mind-correcting attention and a resumption of focused attention.

Each of the four phases involves particular brain networks. The first part of the cycle, when a distraction occurs, increases activity in the wide-ranging default-mode network (DMN). This network includes areas of the medial prefrontal cortex, the posterior cingulate cortex, the precuneus, the inferior parietal lobe and the lateral temporal cortex. The DMN is known to become activated during mind wandering and to play a general role in building and updating internal models of the world based on long-term memories about the self or others.

The second phase, becoming aware of a distraction, occurs in other brain areas such as the anterior insula and the anterior cingulate cortex, regions of what is called the salience network. This network regulates subjectively perceived feelings, which might, for instance, lead to being distracted during a task. The salience network is thought to play a key role in detecting novel events and in switching activity during meditation among assemblies of neurons that make up the brain’s large-scale networks. It may shift attention away from the default-mode network, for instance.

The third phase engages additional areas—among them the dorsolateral prefrontal cortex and the anterior cingulate cortex—that “take back” our attention by detaching it from any distracting stimulus. Finally, in the fourth and last phase, the dorsolateral prefrontal cortex continues to maintain a high level of activity as the attention remains directed toward an object such as the breath.

In our laboratory in Wisconsin, we further observed different patterns of activity depending on a practitioner’s level of experience. Veterans meditators with more than 20,000 hours of practice showed more activity in these attention-related brain regions compared with novices. Pecanudally, the most experienced meditators demonstrated less activation than the ones without as much experience. Advanced meditators appear to acquire a level of skill that enables them to achieve a focused state of mind with less effort. These effects resemble the skill of expert musicians and athletes capable of mesmerizing themselves in the “flow” of their performance with a minimal sense of effortful control.

To study the impact of focused-attention meditation, we also studied its volunteers before and after a three-month retreat with intensive meditation exercises for at least eight hours a day. They received headphones that broadcast sounds at a given frequency, occasionally mixed with slightly higher-pitched sounds. They had to focus on the sound displayed in one ear for 10 minutes and react to periodically interspersed higher-pitched tones. After the retreat, we found that the meditators, compared with a nonmeditating control group, showed less trial-to-trial variation in their reaction times on this highly repetitive task, which lent itself easily to distractions. The results suggested that the meditators had enhanced capacity to remain vigilant. The brain's electrical responses to high-pitched tones remained more stable at the second session only for the meditators.

STREAM OF CONSCIOUSNESS

The second tier of well-established meditation also involves another form of attention. Mindfulness, or open-monitoring meditation, requires the meditator to take note of every sight or sound and track internal bodily sensations and inner self-talk. The person stays aware of what is happening without becoming overly preoccupied with any single perception or thought, returning to this detached focus each time the mind strays. As awareness of what is happening in one's surroundings grows,
normal daily irritants—an angry colleague at work, a worried child at home—become less disruptive, and a sense of psychological well-being develops.

With Helen Blair, then in our group at Wisconsin, we sought to learn about the influence of this form of training on mental functioning by measuring the participants’ capacity to detect rapidly presented visual stimuli—a means to measure mindfulness meditation, which is also sometimes called nonreactive awareness. To perform this experiment, we used a task in which the participants had to detect two numbers presented on a screen rapidly, and a succession of letters. If the second number appears about 300 milliseconds after the first one, subjects often do not see the second, a phenomenon known as attentional blink.

If the second number appears after a delay of 600 milliseconds, it can be detected without difficulty. The attentional blink reflects the limits of the brain’s ability to process two stimuli presented to the observer at close intervals. When too much of the brain’s attention is directed to processing the first number, the second number cannot always be detected, although the observer usually can see it on some of the trials. We hypothesized that mindfulness training could increase the propensity to “get stuck” or absorbed by seeing the first number. Mindfulness practice cultivates a nonreactive form of sensory awareness, which should result in a reduced attentional blink. As we predicted, after three months of an intensive retreat, the meditators perceived both numbers more frequently than the controls did. This improved perception was also reflected in lessened activity of a particular brain wave in response to the first number. Novices after repeated exposures to it. Other tests in our lab have shown that meditation training increases one’s ability to better control and buffer baseline physiological responses—inflammation or levels of stress hormones—to a socially stressful task such as giving a public speech or doing mental arithmetic in front of a supervisor.

Several studies have documented the benefits of mindfulness on symptoms of anxiety and depression and its ability to improve sleep patterns. By deliberately monitoring and observing their thoughts and emotions when they feel sad or worried, depressed patients can use meditation to manage negative thoughts and feelings as they arise spontaneously and a relearn meditation. Clinical psychologists John Read and his colleagues at the University of Cambridge, and Zindel Segal of the University of Toronto showed in 2000 that for patients who had previously suffered at least three episodes of depression, six months of mindfulness practice, along with cognitive therapy, reduced the risk of relapse by nearly 40 percent in the year following the onset of a severe depression. More recently, Segal demonstrated that the intervention is superior to a placebo and has a protective effect against relapse comparable to standard maintenance antidepressant therapy.

**COMPASSION AND LOVING KINDNESS**

The third form of meditation under study cultivates attitudes and feelings of loving kindness and compassion toward other people, whether they are close relatives, strangers or enemies. This practice entails being aware of someone else’s needs and then experiencing a strong, compassionate desire to help that person.
A MEDITATION BENEFIT

Grow More Brain

Researchers from several universities explored whether meditation might bring about structural changes in brain tissue. Using magnetic resonance imaging, they found that 20 experienced practitioners of one type of Buddhist meditation had a greater volume of brain tissue in the prefrontal cortex (Brodmann areas 9 and 10) than the nonmeditation control group (graph). These regions play a role in processing attention, sensory information and internal bodily sensations. Future long-term studies will help confirm this finding.

more recently, Tobias Singer and Olga Klimenko, both at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany, in collaboration with one of us (Rinpoche), sought to distinguish differences between the effects of empathy and compassion on meditators. They noted that compassion and altruistic love were associated with positive emotions, and they found that emotional exhaustion or burnout was, in fact, a kind of empathy “fatigue.”

According to the Buddhist contemplative tradition from which this practice is derived, compassion, far from leading to distress and discouragement, reinforces an inner balance and source of strength, becoming an instrument of self-healing, which in turn helps others. A study conducted in 2014 by Robert Acosta and Klimenko examined the effects of meditation on brain activity and found that meditation participants showed increased activity in the prefrontal cortex, which is associated with emotional regulation and emotional empathy. The study also found that meditation participants showed increased activity in the anterior cingulate cortex, which is associated with the regulation of negative emotions.

The meditation begins by focusing on an unconditioned feeling of benevolence and love for others, accompanied by silent repetition of a phrase conveying intent, such as: “May all beings find happiness and be free from suffering.” In 2009, Fredrickson and her colleagues found that volunteers who practiced this form of meditation had a greater increase in positive emotions and a decrease in negative emotions. These changes were associated with increased activity in the prefrontal cortex and decreased activity in the amygdala, which is associated with the regulation of negative emotions.

To further explore the mechanisms of empathy and compassion, Slomski and Singer divided about 60 volunteers into two groups. One group meditated on love and compassion, while the other group meditated on the emptiness of self. Both groups were then asked to watch videos of people experiencing distress, and their emotional responses were measured. The group that meditated on love and compassion showed a greater decrease in negative emotions, while the group that meditated on the emptiness of self showed a greater increase in positive emotions.

The researchers concluded that meditation can bring about structural changes in the brain, leading to an increase in the prefrontal cortex, which is associated with emotional regulation and emotional empathy. This increase in the prefrontal cortex is associated with increased activity in the anterior cingulate cortex, which is associated with the regulation of negative emotions. The researchers also noted that meditation can bring about changes in the amygdala, which is associated with the regulation of negative emotions.
to demonstrate that a week of training in compassion increased prosocial behavior in a virtual game specially developed to measure the capacity to help others.

A DOOR TO CONSCIOUSNESS
Researchers focus on the nature of the mind, providing a way to study consciousness and subjective mental states from the first-person perspective of the meditator. In collaboration with expert Buddhist meditators at Stillpoint, we have studied the brain's electrical activity using magnetoencephalography (MEG) during compassion meditation in which the meditators described the well-being and well-being of others during meditation, and then we measured the neural correlates of compassion.

We found that long-term meditation practitioners were able to maintain a particular EEG pattern. Specifically, it is called high-amplitude gamma-band oscillations and phase synchrony at between 70 and 90 hertz. The coordination of brain oscillations may play a potentially crucial role in the brain's processing of information through the use of high-amplitude gamma-band oscillations and phase synchrony in the brain circuitry.

High-amplitude oscillations persisted throughout the meditation session, with a clear peak around 70 hertz, as well as in the number and strength of connections among brain regions. A preliminary study by Susan W. Westmoreland and her colleagues showed that long-term meditation practitioners maintain a pattern of gamma-band oscillations, as compared with a control group, the volume of the brain's default mode network, gray matter, and functional connectivity, specifically, regions called Brodmann areas 10 and 11, which are frequently activated during various forms of meditation. These distinctions were most pronounced in older participants in the study, suggesting that meditation might influence the brain's default mode network at younger ages.

In a follow-up study, Lazar and her colleagues also showed that mindfulness training decreased the volume of the amygdala, a region involved in fear processing, for those participants who showed the most noticeable decreases in stress over the course of training. Eileen Luders of the University of California, Los Angeles, and her colleagues further observed differences in meditation in the brain called areas that connect different brain regions, suggesting enhanced brain connectivity. This observation may suggest the hypothesis that meditation actually causes structural alterations in the brain.

An important limitation of this research relates to the lack of long-term longitudinal studies that follow a group over the course of many years and to the absence of comparisons between meditators and people of similar backgrounds and ages who do not meditate.

Some evidence even exists that meditation—and its ability to enhance overall well-being—may diminish inflammation and other biological stressors that occur at the molecular level. A collaborative study between our group and one led by Fred Kandel of the Institute for Biomedical Research at the University of California, Los Angeles, showed that one day of intensive mindfulness practice in experienced meditators turned down the activity of inflammation-related genes and enhanced the functioning of enzymes involved with turning genes on and off. A study by V. S. Ramachandran, also at the University of California, Los Angeles, showed that meditation practice increased the activity of genes involved with regulating the longevity of the cell. The mechanism is likely an enzyme called telomerase that lengthens DNA segments at the ends of chromosomes. The telomeres, called telomeres, ensure that the cell's genetic material is copied exactly during cell division. They shorten every time a cell divides, and when their length decreases below a critical threshold, the cell stops dividing and gradually enters a state of senescence.

A PATH TO WELL-BEING
About 15 years of research have shown more than 1,000 that meditation produces significant changes in both the function and structure of the brains of experienced practitioners. These studies are now starting to demonstrate that contemplative practices may have a substantial impact on biological processes critical for physical health.

More studies using well-defined, randomized controlled trials are needed to isolate mediation-related effects from other psychological factors that can influence the outcome of a study. Other variables that may affect study results are the level of motivation of a practitioner and the role played by both the teachers and students in a meditation session. The norm is to understand the possible negative side effects of meditation, the desirable length of a given practice session and the way to tailor it to a person's specific needs.

Even with the requisite caution, research on meditation provides new insights into methods of mental training that have the potential to enhance human health and well-being. Equally important, the ability to cultivate compassion and other positive human qualities may lay the foundation for an ethical framework unsuited to any philosophy or religion, which could have a profoundly beneficial effect on all aspects of human society.