Does Meditation Enhance Cognition and Brain Plasticity?

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Meditation practices have various health benefits including the possibility of preserving cognition and preventing dementia. While the mechanisms remain investigational, studies show that meditation may affect multiple pathways that could play a role in brain aging and mental fitness. For example, meditation may reduce stress-induced cortisol secretion and this could have neuroprotective effects potentially via elevating levels of brain derived neurotrophic factor (BDNF). Meditation may also potentially have beneficial effects on lipid profiles and lower oxidative stress, both of which could in turn reduce the risk for cerebrovascular disease and age-related neurodegeneration. Further, meditation may potentially strengthen neuronal circuits and enhance cognitive reserve capacity. These are the theoretical bases for how meditation might enhance longevity and optimal health. Evidence to support a neuroprotective effect comes from cognitive, electroencephalogram (EEG), and structural neuroimaging studies. In one cross-sectional study, meditation practitioners were found to have a lower age-related decline in thickness of specific cortical regions. However, the enthusiasm must be balanced by the inconsistency and preliminary nature of existing studies as well as the fact that meditation comprises a heterogeneous group of practices. Key future challenges include the isolation of a potential common element in the different meditation modalities, replication of existing findings in larger randomized trials, determining the correct "dose," studying whether findings from expert practitioners are generalizable to a wider population, and better control of the confounding genetic, dietary and lifestyle influences.

Key words: **meditation; dementia; cognition; stress; cortisol**

Introduction

Meditation practices have been examined for their health promotion benefits and looked upon as an approach to increasing longevity.[1] Some scientific attention has focused on the effects of meditation on cardiovascular and other physiological parameters.[2–4] Even more intriguing is the supporting evidence that medication may have effects on lipid profiles and oxidative stress.[5,6] The exact mechanisms remain an area of active investigation.[7] With respect to brain aging and age-associated memory loss and the most common dementia afflicting the elderly, Alzheimer's disease, there is potential for meditation practices to be utilized in the prevention and perhaps treatment of memory loss.[8] This involves the potential role of meditation on the neuroendocrine system mediating neuropeptide production and consequent benefits on neuronal plasticity (Fig. 1).[9,10] The differences in meditation practice techniques, their unique origins, and various study scientific methodologies across multiple disciplines abound. The challenge is the systematic

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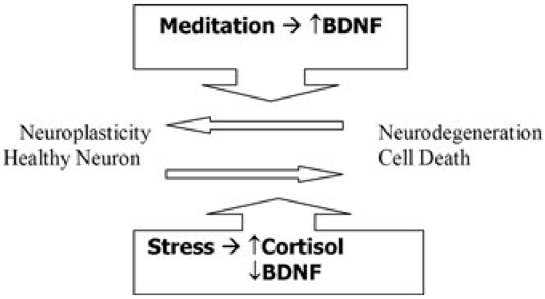

FIGURE 1. Hypothetical role of meditation on neuronal plasticity. BDNF, brain derived neurotrophic factor.

testing of different meditation practices and the consistent demonstration of individual beneficial components of meditation practices. While most meditation traditions are rooted in Eastern influences many more widely disseminated practices have been developed in Western societies. In this review, we focus specifically on the potential benefits meditation practices may have on cognitive and neurophysiological outcomes. We provide a survey of selected emerging studies that reflect active research of meditation practices.

Methods

We searched Medline from 1996 to 2006 for peer reviewed articles. Of these, we focused primarily on studies where meditation was the intervention, control groups were used, and outcomes involved cognitive or neurophysiological testing or brain imaging measures. But readers must be aware that the field contains numerous studies where other outcomes have been used (e.g., hormones) as well as numerous studies measuring peripheral measures of relevance to the brain. For these studies readers are referred to other reviews.[11–13]

Results

Of the numerous meditation practices, transcendental meditation (TM) has been more systematically studied compared to other meditation techniques (Table 1). The practice involves chanting of an individualized mantra (assigned by a certified TM teacher) with eyes closed for 20 minutes twice daily. TM and its effects on cognitive function have been reviewed elsewhere and we highlight some of the findings. Of 107 articles, Canter and Ernst[14] rigorously selected 10 randomized controlled trials most of which were conducted from in the 1970s to 1980s. The subjects were usually recruited from student volunteers who were interested in TM. Except for one study, which involved the elderly with mean age of 81 years,[15] the other studies were conducted in adolescents and those with average age in the mid-20s to early 30s. Since the intervention (TM) is delivered from certified centers, it is likely fairly standardized across the studies. The duration of TM practice ranged from 40 days to 6 months. The control arms were variable across the studies, however. These included no treatment, eyes-closed resting, sitting quietly, napping, music appreciation and relaxation response, and mindfulness training. The results show some benefits though they are not consistent across the board.

Among the 10 studies reviewed (with sample size ranging from 6 to 60, duration from 6 weeks to 6 months, and age from 10 to 81 years) 4 studies reported positive effects on cognitive functions, 4 were negative, and 2 demonstrated mixed results. The positive effects of TM includes higher clustering in recalled items and better performance in intervening arithmetic tasks, increased speed on the Embedded Figures Test and more accuracy in the Road and Frame Test,[16] improved reaction time and coordination (by 20%) and improved intelligence test (by 4%) in athletes, and higher creative thinking-drawing production (by 10%).[17] Of particular interest is a parallel, randomized control trial comparing TM ($n = 20$), relaxation ($n = 21$), and no treatment ($n = 11$) in elderly volunteers with mean age of 81.[18] TM performed better than the other two treatments on the Over-learned Verbal Task and better than control on the Associate Learning subtest of the Dementia Screen Test (DST). However, there was no significant

TABLE 1. Recent controlled studies of meditation and cognitive or neurophysiological outcomes

Study	Meditation practice	Sample size/ Instrument	Result	Comments
Canter and Ernst (2003)[14]	TM	10 randomized controlled trials	4 positive studies showing improvement in various cognitive outcomes.	Concern for expectation bias.
Lutz and colleagues (2004)[19]	Objectless meditation	8 Buddhist practitioners versus 10 student volunteers/EEG	High-amplitude gamma oscillations in EEGs of long-time practitioners at baseline and during meditation.	Practiced Tibetan Nyingmapa and Kagyupa traditions for 10,000 to 50,000 hours.
Davidson and colleagues (2003)[20]	8-week mindfulness meditation training program	25 in meditation group versus 16 wait-list control group/EEG	Increase in left-sided anterior activation on EEG.	Magnitude of increased left-side activation correlated with magnitude of antibody titer rise to influenza vaccine.
Aftanas and Golosheykin (2005)[24]	Sahaja Yoga meditation	25 Sahaja Yoga meditators versus 25 age-matched controls/EEG	Larger power values in theta-1, theta -2, and alpha-1 frequency bands were observed in practitioners during both non-emotional arousal and experimentally induced negative emotions.	Meditators have better capabilities to moderate intensity of emotional arousal.
Lazar and colleagues (2005)[25]	Insight meditation (mindfulness)	20 advanced Western practitioners versus 15 controls matched by age, education/MRI	Increased cortical thickness of the prefrontal cortex and right anterior insula.	Regional cortical thickness was more impressive between older subjects.
Solberg and colleagues (2004)[26]	Meditation organization developed in Norway	27 male meditators versus 29 age matched controls/Melatonin/ Serotonin	Melatonin level was reduced in advance meditators 1 and 3 hours after meditation. Serotonin level was reduced in both groups after meditation.	This study suggests that advance meditators have higher melatonin levels. Serotonin may be a marker of general rest.
Walton and colleagues (2004)[27]	TM	16 TM long-term (mean 23 years) woman practioners 23 age, gender matched controls/Cortisol level	Urinary cortisol was 3 times higher in controls than in TM women.	75 grams of glucose administered as metabolic stressor.

EEG, electroencephalogram; MRI, magnetic resonance imaging; TM, transcendental meditation.

difference in several other measures including total DST score, Word fluency subtest of DST, Stroop color word interference test, and Object Uses Test. The review cited concern for expectation bias because the 4 positive studies recruited subjects who were interested in TM and were recruited from TM lectures. In contrast, the other 6 studies recruited subjects who did not necessarily show any interest in TM. To partially remedy this relative weakness in study design, in 3 of the 4 positive studies, the raters of the instrument were blinded to the treatments received by the subjects. Therefore measures were taken, although imperfect, to attempt to reduce potential bias. We encourage readers to look for more updated studies on TM since publication of the systematic review by Canter and Ernst given the dearth of more rigorous recent studies.

With respect to neurophysiological outcomes, Lutz and colleagues studied electroencephalogram (EEG) findings in Buddhist practitioners ($n = 8$, mean age 49 ± 15 years) compared to controls ($n = 10$, mean age 21 ± 1.5 years).[19] The practitioners had extensive meditation experience with training in Tibetan Nyingmapa and Kagyupa traditions for 10,000 to 50,000 hours over 15 to 40 years. The meditative practice aim was to generate a state of "unconditional loving-kindness and compassion" without a need to concentrate on particular objects, memories, or images. Controls underwent meditation training 1 week prior to the study and were asked to practice daily for 1 hour. During the meditation periods, both groups were asked to generate a nonreferential state. At baseline, gamma-band activity is initially higher in the advanced practitioners over the medial frontoparietal electrodes. During the objectless meditation period, advanced practitioners also showed even higher gamma oscillation and phase-synchrony, especially over the lateral frontoparietal region compared to controls.

The investigators concluded that synchronized gamma oscillation occurs with high temporal precision indicating that neural synchronization develops over time. Additionally, the baseline EEG differences between the two groups may reflect the cumulative effects of meditation on long-term neuronal assemblies. After controlling for age, hours of practice significantly predicated relative gamma activity during the initial baseline period. The authors acknowledged that baseline demographics may still play a role given the control subjects differ from practitioners in culture of origin, first language, diet, and other factors.

Davidson and colleagues randomized subjects ($n = 25$) to an 8-week training program in mindfulness-based meditation versus a wait-list control group ($n = 16$) and found a significant increase in left-sided anterior activation on EEG (previously found to be associated with positive affect).[20] The investigators recruited employees from a biotechnology corporation in Madison, Wisconsin. The average age was 36 (range 23 to 56) years in both groups. The intervention group practiced 45 minutes a day, met weekly for up to 3 hours, and completed a silent 7-hour retreat at week 6. More interestingly antibody titers to influenza vaccine were greater in the meditation group compared to control. Further, the magnitude of increase in left-sided activation predicated the magnitude of antibody titer rise. The authors concluded that meditation may change brain and immune function. This study did generate quite a bit of interest in the media and controversy from investigators in the field about the interpretation of the results, the definition of "positive states," and specificity of the intervention.[21,22] The authors maintained that mindfulness, "defined as moment-to-moment nonjudgmental awareness," is the defining feature of this meditation practice, they agreed that changes in the brain, especially the observed immunological benefits, require further research.[23]

In another study primarily looking at EEG results, Aftanas and Golosheykin examined Sahaja Yoga meditation practitioners in Russia with 5–10 years of experience and specific focus on "intentional self-regulation of attention."[24] The key experience is "thoughtless awareness" or "mental silence" where the meditator is alert and aware but is free of any unnecessary mental activity, accompanied by the sense of relaxation and positive mood. The meditators ($n = 25$) were compared to age-match controls ($n = 25$) with age ranges of 20–40 years. At baseline (eyes-closed), meditators showed larger power values in theta-1, theta-2, and alpha-1 frequency bands by EEG. The subjects were shown emotionally neutral and negative movie clips. Despite desynchronization in both groups, the aversive movie clip synchronized gamma power over anterior cortical sites in the control group but not in the meditators. The authors reported that this demonstrated significantly higher emotional workload in the control because gamma activity is associated with increased information processing. Citing previous EEG findings on emotional arousal, the authors suggested that meditators have better capabilities to moderate intensity of negative emotions and thereby lower autonomic arousal. The study highlights the use of stress induction methods and the protective role of meditation practices. Replication and extension studies that could link these EEG findings to neurocognitive function would further advance the field.

While neurophysiological measures have been more widely studied, meditation may confer enduring structural changes in the brain. Lazar and colleagues examined magnetization prepared rapid gradient echo (MPRAGE) structural brain MRI images of participants with extensive Insight meditation experience. Insight meditation involves nonjudgmental, mindful attention to internal and external sensory stimuli without the use of any mantra or chanting phrases. Western practitioners ($n = 20$) with extensive experience in meditation (9.1 ± 7.1 years) and who practice approximately 40 minutes of mindfulness per day were compared to controls ($n = 15$) matched based on age, gender, race, and education.[25] The overall brain cortical thickness did not differ significantly between the two groups. However, regional cortical thickness was greater in the right anterior insula and right middle and superior frontal sulci in the practitioners compared to controls. The length of meditation experience appears to be positively correlated to cortical plasticity. While the most experienced subjects were also among the oldest, controlling for age and right-hemisphere average thickness, the inferior occipitotemporal visual cortex correlated with years of meditation experience (partial $r(15) = 0.627$, $P = 0.007$). With respect to the aging process, cortical thinning occurs as one ages. In one focal region of the Brodman Area 9/10 (BA9/10), the average cortical thickness of 40 to 50-year-old meditators was similar to that of the 20 to 30-year-old meditators and controls. Therefore, meditation might help to attenuate the aging process by preserving cortical thickness. The authors suggested that meditation might offset age-related cortical thinning and perhaps modulates cortical plasticity. This is the first structural evidence of a dose-gradient effect of meditation experience on cortical thickness. Although duration of meditation practice is difficult to assign in a randomized controlled fashion, such findings warrant replication, preferable in prospective studies. Finally, it would be important to see if the cortical thickness differential translates into meaningful differences in cognitive function.

In addition to the above neuroanatomical and neurophysiological studies, research on cognition would not be complete without an examination of hormones and neurotransmitters. Solberg and colleagues[26] attempted to examine the neurochemical effects of meditation and found effects on melatonin but not serotonin. TM effects on metabolic stressor induced cortisol secretion has been examined in a study of 29 postmenopausal women, 16 of them were long-term TM practioners and 13 were controls who did not practice TM.[27] Cortisol response was greater in controls than TM practioners. In addition, the number of months of practicing TM was inversely correlated with vascular risk factors. These pilot data suggest two additional ways by which TM may enhance brain longevity: (1) reducing vascular risk factors and stroke risk and (2) reducing the harmful effects of stress-induced hypercortisolemia on hippocampal atrophy. In particular, these data raise the hypothesis that meditation may enhance levels of growth factors, such as brain derived neurotrophic factor (BDNF), which may contribute to longevity. Reduced levels of BDNF have been linked to depression and dementia. Prospective randomized controlled trials looking at effects of meditation on BDNF and hippocampal volume in aging people are warranted to test this hypothesis and confirm the pilot findings above.

Discussion

Much work remains in advancing the systematic investigation of meditation practices and cognitive and neurophysiological outcomes. First, it is difficult to find the "active ingredient(s)" or common element among the immense variety of meditation practices. Replication of the existing studies with larger well-defined cohorts by independent groups and multicenter studies would add supporting evidence. It would also be of interest to study meditation in comparison to existing pharmacologic drugs used in elderly populations (e.g., cognitive enhancers) to compare risks and benefits. However, in order to advance the field, it would be critical for the scientific community to expand current research efforts to isolate and examine individual component effects of different meditation practices.[28] Second, investigators from different disciplines have examined different outcomes. It would be important to demonstrate the consistency among the outcomes and whether meditation practices affect neurophysiological, anatomical, and chemical mediators in concert. Finally, adaptation of scientific methodologies (such as randomization, blind assessments, and use of placebo controls) remains challenging. For most meditation practices, neuropsychological outcomes (such as cognitive testing, dementia rating scales, and functional assessment) need to be incorporated into future studies. At the present, the links between meditation and cognition remain intriguing but the association should still be viewed as preliminary until confirmed by rigorous research. The control of genetic makeup and lifestyle factors such as diet habits would also be important to include in future clinical trials. For example, curcumin in the diet has also been demonstrated to have a protective role on brain health.[29,30] It is likely new technical advancements such as structural and functional neuroimaging and adaptation of rigorous scientific evidence-based criteria will serve to advance and validate the significance of traditional meditation practices.

Conflicts of Interest

GLX declares no conflicts of interest. PMD has consulted for several pharmaceutical and medical food companies and received research grants for clinical trials from both companies and government.

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