

Increased Theta and Alpha EEG Activity During Nondirective Meditation

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Abstract

Objectives: In recent years, there has been significant uptake of meditation and related relaxation techniques, as a means of alleviating stress and maintaining good health. Despite its popularity, little is known about the neural mechanisms by which meditation works, and there is a need for more rigorous investigations of the underlying neurobiology. Several electroencephalogram (EEG) studies have reported changes in spectral band frequencies during meditation inspired by techniques that focus on concentration, and in comparison much less has been reported on mindfulness and nondirective techniques that are proving to be just as popular.

Design: The present study examined EEG changes during nondirective meditation. The investigational paradigm involved 20 minutes of acem meditation, where the subjects were asked to close their eyes and adopt their normal meditation technique, as well as a separate 20-minute quiet rest condition where the subjects were asked to close their eyes and sit quietly in a state of rest. Both conditions were completed in the same experimental session with a 15-minute break in between.

Results: Significantly increased theta power was found for the meditation condition when averaged across all brain regions. On closer examination, it was found that theta was significantly greater in the frontal and temporal–central regions as compared to the posterior region. There was also a significant increase in alpha power in the meditation condition compared to the rest condition, when averaged across all brain regions, and it was found that alpha was significantly greater in the posterior region as compared to the frontal region.

Conclusions: These findings from this study suggest that nondirective meditation techniques alter theta and alpha EEG patterns significantly more than regular relaxation, in a manner that is perhaps similar to methods based on mindfulness or concentration.

Introduction

IN FAR EASTERN CULTURES, meditation has long been used for the maintenance of “well-being,” and its gradual disassociation from religious practice has allowed it to be subjected to scientific inquiry. Of late, meditation has been widely adopted in the West and is increasingly being used worldwide for the alleviation of stress and for the treatment of common psychiatric disorders, such as depression and anxiety.¹ The seemingly powerful effects of meditation are intriguing, and the potential health benefits have aroused particular interest, as individuals search for alternatives to

modern-day medicines.² Since the 1970s, a majority of studies have focused on concentrative meditation techniques and transcendental meditation. Over the past decade, however, there has been a shift toward various types of mindfulness meditation³ and nondirective meditation, as these techniques have increasingly been embraced by psychologists and psychiatrists. This is evidenced by their integration with psychotherapeutic techniques for the treatment of medical and psychologic problems.⁴

Although recent studies have demonstrated the effectiveness of such interventions, understanding of how meditation exerts its biological effects remains rudimentary. Its neural

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basis has been investigated using electroencephalography (EEG), and these studies have provided some insight into the neurophysiology of meditation, including long-term changes in cortical activity.^{5,6} An emerging body of literature suggests that meditation activates regions of the brain involved in the monitoring and regulation of emotion, attention, and autonomic body functions⁷ (Davenger et al., in review). Several studies have reported increased EEG theta and alpha activity^{8,9} along with increased bilateral alpha coherence in experienced meditators.^{10,11}

In the present study, we sought to identify electrical brain activity changes associated with acem meditation using EEG. Subjects were contrasted using a within-subject comparison across meditation, and resting states. Acem meditation is defined as a nondirective meditation technique, as it does not require volitional direction of attention toward a specific subjectively experienced state of mind. It is practiced with a "free mental attitude" similar to mindfulness meditation, which allows any thought, memory, emotion, or sensation to emerge and pass through the awareness of the practitioner, without any volitional attempt to control the current content. The meditation vehicle, a multisyllable sound with no semantic, emotional, or symbolic meaning, is repeated mentally in a gentle, effortless way to facilitate relaxation.¹² Previous studies have demonstrated significant relaxation effects during acem meditation, such as lowering of heart rate and increased blood concentrations of melatonin,¹³ as well as long-term changes, such as enhanced competitive performance of elite marksmen and less lactate increase during a standardized physical challenge of long-distance runners.¹⁴ In keeping with these behavioral and physiologic changes, we hypothesized that there would be discernable changes in theta and alpha brain activity during meditation, beyond those occurring in a resting state of regular relaxation.

Materials and Methods

Participants

Thirteen (13) male and 5 female participants aged 28–63 years (mean 52) were recruited randomly from a broad Norwegian acem meditation community. All were gainfully employed, and had incorporated meditation practice in their daily routine around career and employment commitments. All subjects were experienced acem meditators (range of meditation experience 9–14 years) and meditated 30 minutes twice daily. All subjects had attended at least one 3-week-long meditation retreat in the past 5 years. No subject had any significant current or previous medical or surgical illness, neurologic disease, or history of drug or alcohol abuse.

Subjects acted as their own controls in the experiment. The investigational paradigm involved 20 minutes of acem meditation as well as a separate 20-minute quiet rest condition. Both conditions were completed in the same experimental session with a 15-minute break in between. All subjects were seated in a comfortable chair in a sound-attenuated room at ambient temperature. The participants were only provided with instructions for the two separate conditions and no additional information was offered to the participants as to the nature of the rest condition. For the meditation condition, the subjects were asked to close their eyes and adopt their normal meditation technique. For the quiet rest condition, the subjects were asked to close their eyes and sit quietly in a

state of rest, without performing any meditation technique. The allocation of the order in which the two conditions (meditation or rest) were performed was randomly assigned (and subsequently counterbalanced) such that an equal number of subjects ($n = 9$) began with the meditation condition as those that began with the rest condition.

EEG was recorded during the meditation and relaxation periods via 20 scalp electrode sites (Fp1, Fp2, F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, P8, O1, Oz, O2) according to the international 10–20 electrode system using a Neuroscan Quik-Cap (Compumedics, Charlotte, NC). Linked mastoids served as reference. Horizontal eye movement potentials were recorded using two electrodes placed 1 cm lateral to the outer canthi of the each eye. Vertical eye movement potentials were recorded using two electrodes placed on the center of the supraorbital and infraorbital regions of the left eye. All electrode impedances were maintained at less than 5 k Ω . All potentials were amplified 200 times and acquired on a Neuroscan DC (Compumedics) system at a sampling rate of 500 Hz. Ten (10) minutes of eyes-closed EEG was recorded during each condition.

Spectral analysis

Prior to formal analysis, the data set was screened for normality and outliers. The mean regional data (frontal, temporal–central, posterior) for all four frequency bands (delta, theta, alpha, and beta) was normally distributed for rest and meditation conditions. Upon examination, these data were skewed due to a single outlier (participant number 1), hence the data for the relevant electrode sites (C3, Cz, Pz, P4, P8, P7, P3) were replaced with the respective mean score in order to transform the data and control for the outlier.

Within-group analysis (meditation/rest) was undertaken using multivariate regional analyses where the 20 electrode sites were broken down into frontal (Fp1, F7, F3, Fz, F4, F8, Fp2), temporal–central (T7, C3, Cz, C4, T8), and posterior (P7, P3, Pz, P4, P8, O1, Oz, O2) regions. Additionally, the EEG power was grouped into the following frequency bands: delta (0.5–3 Hz), theta (3.1–7.9 Hz), alpha (8–12 Hz), and beta (12.1–24 Hz). With the use of SPSS (version 12) (SPSS Inc., Chicago, IL), each frequency band was submitted to a within-subjects design analysis of variance (ANOVA) over the factors of condition (meditation/rest) and region (frontal/temporal–central/posterior). Within-subjects multivariate analyses of variance were conducted for each region in order to compare regional differences according to experimental condition.

Results

Main effects and interactions

Repeated-measures ANOVAs revealed significant main effects for experimental condition ($F_{(1,17)} = 4.99, p = 0.04$) and region ($F_{(2,34)} = 5.48, p = 0.01$) for theta power. Hence, there was a significant increase in theta power in the meditation condition compared to the rest condition, when averaged across all three brain regions (Table 1 and Fig. 1). Furthermore, there was a significant difference in theta power across the three brain regions when averaged across the experimental condition, with significantly greater theta power in the frontal ($F_{(1,17)} = 5.83, p = 0.03$) and temporal–central

TABLE 1. MEAN POWER VALUES (STANDARD DEVIATION IN PARENTHESES) AVERAGED ACROSS ALL THREE BRAIN REGIONS FOR THE MEDITATION AND REST CONDITIONS

	Delta (μV^2)	Theta (μV^2)	Alpha (μV^2)	Beta (μV^2)
Meditation	2.96 (0.77)	5.59 (2.07)	13.14 (6.14)	0.98 (0.26)
Rest	2.81 (0.81)	4.53 (1.58)	9.93 (4.34)	0.96 (0.27)

($F_{(1,17)}=13.86, p=0.003$) regions when compared to the posterior region (Table 2 and Fig. 2). There were no significant interaction effects ($F_{(2,34)}=1.27, p=0.30$).

Repeated-measures ANOVAs revealed a significant main effect for experimental condition ($F_{(1,17)}=7.19, p=0.02$) and a significant trend for region ($F_{(2,16)}=3.67, p=0.06$, Pillai's Trace) for alpha power. Hence, there was a significant increase in alpha power in the meditation condition compared to the rest condition, when averaged across all three brain regions (Fig. 1). Furthermore, there was a significant difference in alpha power across the three brain regions when averaged across the experimental condition, with significantly greater alpha power in the posterior ($F_{(1,17)}=5.44, p=0.04$) region when compared to the frontal region. There were no significant interaction effects ($F_{(2,16)}=2.14, p=0.16$, Pillai's Trace) (Fig. 2).

There were no significant main effects for experimental condition or interaction effects for delta ($F_{(1,17)}=0.99, p=0.34; F_{(2,34)}=2.67, p=0.09$). However, there were significant main effects for brain region for delta ($F_{(2,16)}=15.52, p=0.00$; Pillai's Trace), reflecting a significant difference in delta power across the three brain regions when averaged across the two conditions (Fig. 2). *Post-hoc* analyses revealed significantly lower delta power in the posterior regions compared to both the frontal ($F_{(1,17)}=20.92, p=0.001$) and temporal-central ($F_{(1,17)}=33.16, p=0.00$) regions.

There were no significant main or interaction effects for beta power ($F_{(1,17)}=0.57, p=0.46; F_{(2,16)}=2.8, p=0.10$, Pillai's Trace; $F_{(2,34)}=0.46, p=0.64$).

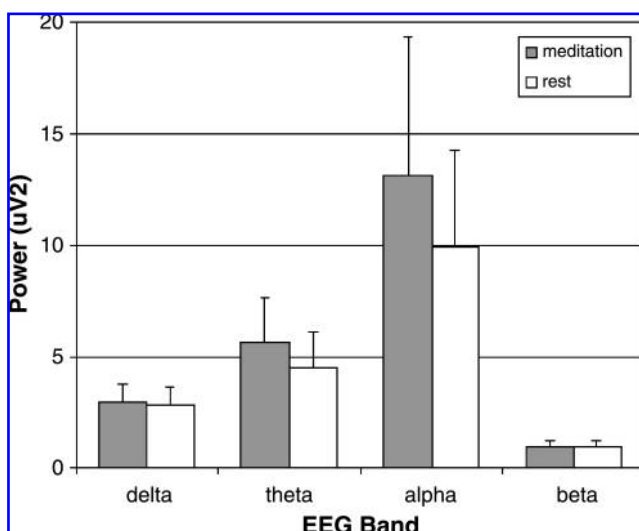


FIG. 1. Graphical representation of the effect of condition on the spectral power across the four electroencephalogram (EEG) bands. The EEG power from all three brain regions was averaged.

TABLE 2. MEAN POWER VALUES (STANDARD DEVIATION IN PARENTHESES) AVERAGED ACROSS BOTH CONDITIONS AND THE THREE BRAIN REGIONS

	Delta (μV^2)	Theta (μV^2)	Alpha (μV^2)	Beta (μV^2)
Frontal	3.44 (0.46)	5.60 (1.68)	8.93 (2.48)	0.79 (0.14)
Temporal-central	2.96 (0.81)	5.51 (2.36)	11.03 (4.56)	0.96 (0.23)
Posterior	2.35 (0.68)	4.30 (1.50)	14.14 (6.44)	1.13 (0.29)

Regional analysis

Within-subjects ANOVAs were conducted to determine whether there were differences in the frequency bands across the two experimental conditions in each specific region, rather than averaged across all three regions. Given that we are interested in group effects rather than specific differences between electrode sites within the regions, only main effects for condition (meditation versus rest) are reported.

There was a significant increase in alpha power in the posterior ($F_{(1,17)}=5.19, p=0.04$), frontal ($F_{(1,17)}=6.86, p=0.02$), and temporal-central ($F_{(1,17)}=6.73, p=0.02$) regions and an increase in theta power in the posterior ($F_{(1,17)}=5.59, p=0.03$), frontal ($F_{(1,17)}=3.64, p=0.08$; trend only), and temporal-central ($F_{(1,17)}=5.36, p=0.04$) regions during the meditation condition compared to at rest. There was also a significant increase in delta power in the temporal-central region in the meditation condition compared to rest ($F_{(1,17)}=4.75, p=0.05$) (Figs. 3–5 and Table 3). There were no other significant differences between the meditation and control conditions.

Discussion

The novelty of the present study is that nondirective meditation increases theta and alpha waves significantly more than regular sitting relaxation. Theta activity was

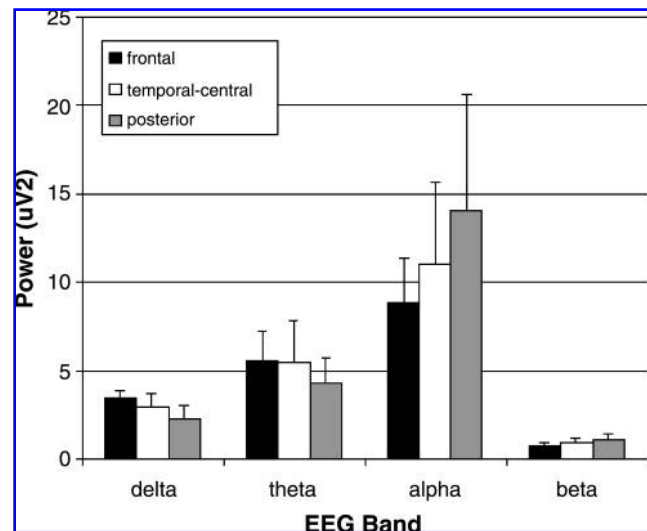


FIG. 2. Graphical representation of the effect of region on the spectral power across the four electroencephalogram (EEG) bands. The EEG power from both meditation and rest conditions was averaged.

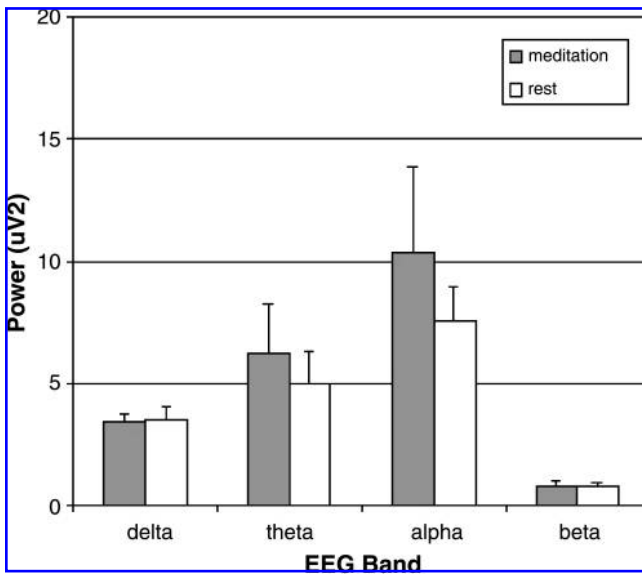


FIG. 3. Graphical representation of the effect of condition (meditation versus rest) averaged across the frontal electrode (Fp1, F7, F3, Fz, F4, F8, Fp2) sites. EEG, electroencephalogram.

greater in frontal and temporal-central areas, whereas alpha was more abundant posteriorly. These results concur with previous studies of other meditation types, reporting similar EEG patterns for either theta or alpha.

In general, several aspects of EEG recordings are associated with specific changes in brain function during meditation and other mental activities. It is a well-established technique, which measures cortical activity directly from the scalp of subjects. These electrical signals are described in terms of frequency bands, with the more reliable patterns being delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–30 Hz), and gamma (30–70 Hz). Delta activity is associated with pathological conditions such as tumors,¹⁵ and also occurs during sleep. In the context of meditation research, the presence of delta can indicate that the subject is asleep. Theta activity on the other hand is associated with alertness, attention, and the efficient processing of cognitive and perceptual tasks.¹⁵ Theta activity has also been associated with orienting, working memory, and affective processing,¹⁶ with frontal theta activity indicative of concentration. Hence, increases in theta activity may reflect increased cognitive processing and awareness. In contrast, alpha activity characterized by large rhythmic waves is associated with relaxation and the lack of active cognitive processes. When an individual is asked to engage in a cognitive task, alpha activity will cease. This is termed alpha desynchronization,¹⁵ and higher-band alpha wave desynchronization is indicative of increased cognitive processing and external attention, whereas synchronization reflects internal attention.¹⁷

Initial stages of meditation research focused predominantly on alpha band effects. However, several investigators have proposed that increased theta rather than alpha activity is a specific state effect of meditative practice, and that increased theta correlates positively with the level of meditation experience.¹⁸ Several studies have shown that long-term meditators exhibit higher theta and alpha power.¹⁶ Murata

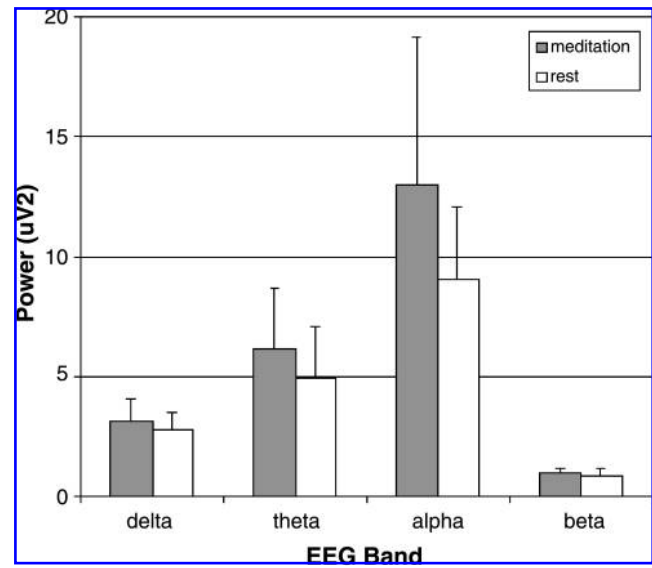


FIG. 4. Graphical representation of the effect of condition (meditation versus rest) averaged across the temporal-central electrode (T7, C3, Cz, C4, T8) sites. EEG, electroencephalogram.

et al.¹⁹ compared 20 monks (10 with extensive experience, 10 with moderate experience) to 10 controls prior to and during Zen meditation. They found that alpha appeared in all the groups, whereas theta activity only appeared in the experienced group, affecting the frontal region, proportionally to the level of experience, hence supporting the previous findings of Kasamatsu and Hirai.¹⁸ Increased theta activity was also observed in the frontal and posterior temporal region. In a single case-study, repeated-measure design involving three meditation scans and one control condition over 4 days, Faber et al.²⁰ demonstrated increased theta coherence and

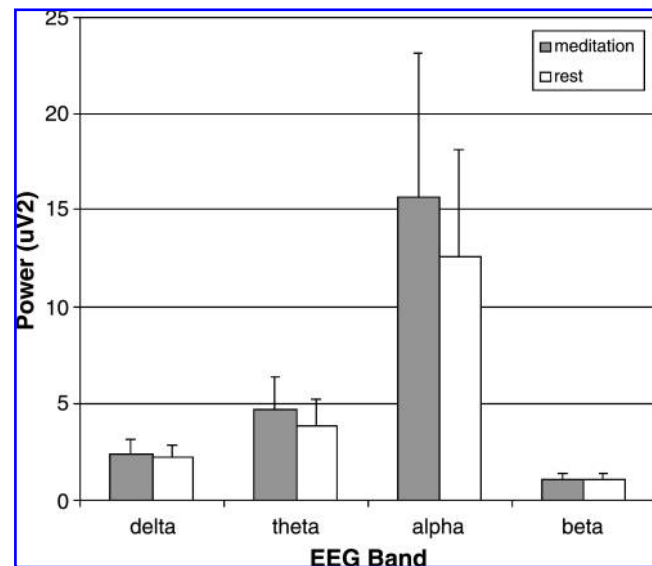


FIG. 5. Graphical representation of the effect of condition (meditation versus rest) averaged across the posterior electrode (P7, P3, Pz, P4, P8, O1, Oz, O2) sites. EEG, electroencephalogram.

TABLE 3. MEAN POWER VALUES (STANDARD DEVIATION IN PARENTHESES) FROM THE REGIONAL ANALYSIS COMPARING BETWEEN MEDITATION AND REST CONDITIONS

	<i>Delta</i> (μV^2)	<i>Theta</i> (μV^2)	<i>Alpha</i> (μV^2)	<i>Beta</i> (μV^2)
Frontal				
Meditation	3.41 (0.34)	6.24 (2.02)	10.32 (3.56)	0.8 (0.16)
Rest	3.48 (0.57)	4.98 (1.34)	7.54 (1.40)	0.8 (0.14)
Temporal–central				
Meditation	3.16 (0.89)	6.14 (2.55)	12.99 (6.15)	1 (0.2)
Rest	2.78 (0.75)	4.9 (2.18)	9.06 (2.98)	0.9 (0.25)
Posterior				
Meditation	2.45 (0.73)	4.7 (1.67)	15.7 (7.37)	1.13 (0.29)
Rest	2.24 (0.62)	3.9 (1.34)	12.6 (5.51)	1.13 (0.29)

decreased gamma coherence, except over temporal regions where gamma coherence increased.

Kubota et al.²¹ suggested that frontal theta reflects the involvement of attention and working memory systems in the prefrontal neural circuitry, including the anterior cingulate cortex, and that activity within these systems is integrated with peripheral autonomic functioning. To test this hypothesis, a study involving instruction of 25 novice participants in the *su-soku* Zen technique was conducted. A significant difference was found in frontal midline theta rhythm during meditation, compared with the resting control condition. Both sympathetic and parasympathetic indices increased during frontal theta activity, suggesting a close relationship between cardiac autonomic functioning and activity of the medial frontal neural circuitry.

A study by Takahashi et al.⁶ in 20 novice meditators also found increased theta and alpha activity in frontal areas and decreased sympathetic and increased parasympathetic activity during meditation. The authors pointed out that alpha and theta waves are independently involved in mental processing during meditation. They also suggested that successful meditation involves slower frontal alpha synchronization coupled with reduced sympathetic activity, and that mindfulness may activate theta activity in the frontal areas as well as increased parasympathetic activity.

Previous studies of the nondirective technique *acem* meditation documented a long-term reduction in blood pressure and mental symptoms in everyday life outside meditation.²² During practice, heart rate reduction compared to regular relaxation indicated lower sympathetic and/or higher parasympathetic nerve activity.²³ The present study demonstrated significant increases in theta- and alpha-wave activity in frontal and temporal–central areas, and in posterior regions, respectively. Higher theta activity probably reflects increased awareness and attention, as well as cognitive and affective processing during meditation,¹⁶ whereas the increase in alpha activity likely relates to relaxation.^{24,25} Predictably, meditation produced little change in delta (sleep or pathological processes) or beta activity (concentration and demanding tasks). Theta power, greater in frontal and temporal–central regions than in posterior regions, may be meditation specific and suggests neural processing in the frontal midline (anterior cingulate cortex), and limbic areas, all of which have been previously implicated in meditation. These areas are

known to have a prominent role in emotion processing. In contrast, alpha waves were more abundant in posterior regions, which is compatible with reduced cognitive processing in sensory-related areas.

The experimental design of this study was such that all the subjects acted as their own controls. This type of design affords several advantages (including exact age and gender matching for both conditions); however, it is associated with several limitations. First, the potential interactive effects of a combination of both practice and experience cannot be discounted, as all the subjects were experienced meditators. Second, although the meditation and rest conditions were randomly assigned across all of the subjects, a lack of blinding in this study may have contributed to a potential bias for the meditation condition. Future studies need to elucidate whether such an effect exists.

Conclusions

These novel EEG findings related to *acem* meditation suggest that nondirective meditation techniques alter theta and alpha EEG patterns significantly more than regular relaxation, in a manner that is perhaps similar to methods based on mindfulness or concentration. Future studies should try to delineate the functional meaning of the alpha and theta activity in meditation (e.g., follow meditation novices who comply with the technique over an extended period and look for potential gradual alterations in brain activity that correspond to the amount of meditation undertaken).

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Svend Davanger, Øyvind Ellingsen, and Are Holen are affiliated with *Acem* School of Meditation, an international nonprofit organization.

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