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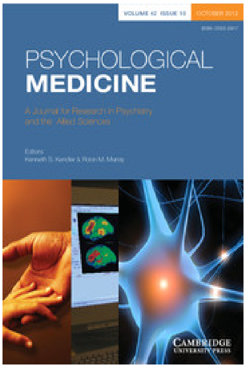

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Meditation and the EEG

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SYNOPSIS Previous research on meditation and the EEG is described, and findings relating to EEG patterns during meditation are discussed. Comparisons of meditation with other altered states are reviewed and it is concluded that, on the basis of existing EEG evidence, there is some reason for differentiating between meditation and drowsing. Research on alpha-blocking and habituation of the blocking response during meditation is reviewed, and the effects of meditation on EEG patterns outside of meditation are described. In conclusion, the need for more precisely formulated research is pointed out.

INTRODUCTION

Over the last 10 years a great deal of research effort has been directed towards examining the effects of the practice of meditation techniques. The research has examined changes taking place both during and outside of meditation practice on psychophysiological and psychological parameters. These results have suggested that decreases in arousal occur during meditation and that decreases in anxiety and neuroticism are associated with learning and regularly practising a meditation technique. Whether these results are due simply to placebo effects has not been precisely determined and there is still disagreement over the relative magnitude of the decreases in arousal which are seen during meditation. The greatest research effort in the area, however, has been in examining the EEG changes associated with meditation practice.

The earliest research interest in meditation centred on the psychophysiological changes which occur during its practice (Das & Gastaut, 1955; Bagchi & Wenger, 1957; Kasamatsu *et al.* 1957), and these experiments examined the EEG changes in some detail. Das & Gastaut (1955) reported that their 7 subjects (all Indian meditation experts) exhibited an increase in alpha frequency and a decrease in alpha amplitude coupled with the appearance of generalized fast activity during the ecstatic or 'samadhi' state. Bagchi & Wenger (1975) took recordings from 14 Indian Yogis who practised different techniques and took their equipment to both caves and universities in order to contact expert practitioners of meditation. They found only the normal alpha patterning between 8·5 and 11·5 cps and no evidence of the high amplitude fast waves reported by Das & Gastaut. It is interesting to note that the subjects of Das & Gastaut's work reported entering the 'samadhi' (or ecstasy) state in meditation while those of Bagchi & Wenger did not, and this distinction of states of meditation appears to be of importance in analysing EEG findings. The techniques which the subjects in these 2 experiments practised, however, were diverse, and the experimenters carried out different measurements on different subjects.

The first well controlled EEG study of meditation was conducted by Fenwick in 1960. Fenwick's subjects were Westerners who had been taught a technique of mantra meditation (almost identical to Transcendental Meditation or 'TM'). The subjects were asked to meditate for 30 minutes and to drowse for 30 minutes (randomized order of presentation). The records of 3 subjects were analysed and the author reported an increase in amplitude of alpha at the beginning of meditation, accompanied later in meditation by bursts of theta. Occasionally bursts of fast activity accompanied the theta.

In another careful study, Kasamatsu & Hirai (1966) selected 48 priests and disciples from the Soto and Rinzai sects in Japan, whose meditation

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experience ranged from 1 to more than 20 years. The EEG during Zazen (i.e. Zen meditation which involves the individual in sitting and maintaining 'simply a quiet awareness, without comment, of whatever happens to be here and now' (Watts, 1962)) was characterized by the initial appearance of 11–12 cps alpha, followed by an increase in alpha amplitude and a decrease in alpha frequency in the central and frontal regions. Occasionally, rhythmical theta trains of 6–7 cps appeared. The authors found a direct relationship between the length of time their subjects had practised meditation and the nature of the EEG changes during meditation. Those with over 20 years' experience always exhibited the rhythmical theta trains. Twenty-four of the disciples were evaluated by the Zen master on the basis of 'mental state', which was classified as low, middle or high. The correlation of EEG changes with 'mental states' was surprisingly high, even higher in fact than the correlation with years of meditation experience. Another interesting point to emerge from this study is that Zen masters and disciples are capable of displaying EEG patterning normally associated with closed eyes in their Zazen (eyes open and focused) meditation.

In 1970, when Wallace published the results of a study of the physiological effects of meditation on 15 subjects, his work received considerable publicity. Among other psychophysiological changes recorded during TM, he found that in the EEG alpha amplitude increased and in 4 subjects the alpha frequency slowed. In '2 or 3' subjects the rhythmical theta trains reported by earlier workers were recorded. In a further study (Wallace *et al.* 1971), these findings were replicated more generally – the theta trains occurring in the records of 5 subjects. Banquet (1972, 1973), in detailed examinations of the EEG changes in TM, observed a slowing of alpha frequency, an increase in alpha amplitude and the occurrence of the rhythmic theta trains. During 'transcendence' (the deep stage of TM, presumably the same as the samadhi or ecstasy stage), which was signalled by the subject pressing a push button, patterns of generalized fast activity with a dominant beta rhythm around 20 cps were apparent. This latter finding replicated those of Das & Gastaut (1955) and Fenwick (1960), and suggests that this fast activity is characteristic of the 'deep' stages of meditation. Banquet found that the beta rhythm stayed at an almost constant frequency during the transcendence stage. Fenwick has replicated his and other researchers' findings of increased alpha amplitude, decreased alpha frequency and the occurrence of theta activity (Fenwick *et al.* 1977). A summary of these findings reveals the following generally agreed EEG changes during meditation:

(1) On beginning meditation alpha amplitude increases and in some cases alpha frequency slows by 1–3 cps.

(2) Later in meditation trains of theta rhythms occur, often intermixed with alpha, especially when the subject is experienced at meditation.

(3) During deep meditation, 'samadhi' or 'transcendence', bursts of high frequency beta, 20–30 or 40 cps can occur.

(4) At the end of meditation alpha sometimes persists even with eyes open.

In a more sophisticated examination of EEG changes, Levine and colleagues (Levine, 1976; Levine *et al.* 1977) investigated the tendency towards EEG coherence during meditation (previously reported by Banquet, 1973), by determining coherence bilaterally and homolaterally between central and frontal derivations of the EEG in a group of experienced meditators. They found evidence of long range spatial ordering during meditation which was not apparent in an eyes-closed relaxation period. This coherence was particularly strong in the alpha and theta bands. The authors mention the possibility that their findings were due to arousal effects associated with the experimenter signalling the subjects to begin and end meditation. They dismiss this possibility as unlikely, despite Fenwick *et al.*'s (1977) finding that such arousal effects do occur and can contribute in large part to apparent decreases in arousal seen during meditation. This does not entirely account for the increase in alpha coherence observed during meditation, however, since in simple relaxation these patterns of change are not observed. In another study of EEG coherence during meditation (Haynes *et al.* 1977), consistency and spectral broadening of alpha was found to be significantly correlated with clarity of 'transcendental' experiences, creativity and rapid neuromuscular recovery (H-reflex recovery). The authors somewhat imaginatively concluded that their results were consistent with the idea that 'coherent ordering of brain functioning during the Transcendental

Meditation technique provides a basis for creative ability and holistic growth'.

Indeed, whether these EEG changes are characteristic of a unique 'wakeful hypometabolic physiologic state' (Wallace *et al.* 1971) has been questioned by other researchers. In particular, the similarity with self-hypnosis and light sleep has been examined.

MEDITATION AND OTHER ALTERED STATES

In most studies of meditation, the meditation state is compared with rest, napping or simply sitting with eyes closed. Tebecis (1975), however, compared the EEG during TM with the EEG during self-hypnosis and found few compelling mean differences. TM subjects were compared with a passive control group and the data from both of these groups were contrasted with data from a group trained in self-hypnosis. (These latter data were taken from the results of a previous experiment and it is not clear in the experimental report how far the experimental conditions were changed.) The self-hypnosis group had a significantly higher theta density than the TM group, who in turn displayed significantly more theta both in and out of meditation than did the control group. It is difficult to extrapolate much from this study, since only a 2 min sample, 100 s into meditation, and a 100 s sample prior to the end of meditation were taken. Nevertheless, this experiment represents an attempt to compare meditation with another technique which 'alters' consciousness, and a well-controlled exhaustive comparison of self-hypnosis and meditation would give more valuable information about the similarities and the differences between these two techniques.

Drowsiness or light sleep has been proposed as a useful comparison condition for meditation, and a number of studies have attempted to make this comparison (Fenwick, 1960; Otis, 1974; Banquet & Sailhan, 1974; Younger *et al.* 1975; Pagano *et al.* 1976). In Fenwick's (1960) comparison of meditation and drowsiness, 3 EEG researchers rated the records of 12 subjects by attempting to identify which represented drowsiness and which represented meditation. The most experienced rater achieved the best score – 10 out of 12 records being correctly identified. The least experienced rater correctly identified 8 out of the 12 records. Overall, the success rate was 27 correctly identified records and 9 incorrectly identified records. That these raters could achieve this success rate argues that there are clear differences between the EEG records of meditation and drowsiness. The raters identified one of these differences as the relative stability of the alpha rhythm during meditation. In a subsequent experiment (Fenwick *et al.* 1977), a consultant clinical neurophysiologist, when asked to allocate the EEG records of 24 subjects, correctly identified 13 meditation records and incorrectly identified 11 control records as meditation. This result would have been expected by chance.

Banquet & Sailhan (1974) found significant differences in the amount of wakefulness (measured by the EEG) between the beginning of meditation and light sleep in a control group, and between the end of meditation and the end of a period of rest in a control group. Thus, the meditators appeared to remain wakeful during meditation, while the controls drifted towards sleep during a comparable period of rest.

When the EEG records from meditation are scored by sleep researchers, a high percentage of Sleep Stage One is noted. Otis (1974) recorded the EEG of 23 meditators and 21 controls (who received no training) prior to the experimental group learning meditation and again 3 months afterwards. In the post-treatment testing session, the TM group displayed significantly more Sleep Stage One activity during meditation than they had done in a pre-meditation rest period and significantly more than the controls. There were no baseline differences between the groups prior to the experimental group learning meditation.

Younger *et al.* (1975) scored 31 meditation EEG records for sleep and found that 22·8 %

Table 1. *Content of EEG records during napping and meditation*

	Waking and Sleep Stage One (%)	Sleep Stages Two, Three and Four (%)	Waking (%)
Meditation	59·5	40·5	40·0
Napping	29·4	70·6	17·5

Derived from the data of Pagano *et al.* (1976).
Percentages represent time spent in different stages.

of the content of the records was Sleep Stage One, 17 % was Sleep Stage Two and 59·63 % was Wakefulness. Pagano *et al.* (1976) had similar results when they compared the EEGs of meditation and 'napping' in 5 experienced transcendental meditators. They found appreciable amounts of Sleep Stages Two, Three and Four during meditation, and questioned whether the reported benefits of meditation were due to the technique itself, since they might possibly be the results simply of sleep. Examination of their data (Table 1) reveals significant differences between meditation and napping, however, and these results tend to confirm the findings of Fenwick (1960) which suggested that the drowsiness state can be differentiated from the meditation state on the basis of EEG patterning. Fenwick *et al.* (1977) report that myoclonic jerks observed during meditation are different from those seen in normal drowsing, the former being repetitive, large, well-organized bodily movements, usually confined to a limb or the trunk, whereas in drowsing the jerks are usually single, stereotyped and simple. A further difference between meditation and the control conditions in Fenwick's second study (Fenwick *et al.* 1977) is that 4 subjects displayed a significant increase in abnormal paroxysmal theta bursts during meditation. Similarly, Hebert & Lehmann (1977) found that 21 out of 78 advanced practitioners of meditation demonstrated intermittent prominent bursts of frontally dominant theta activity. Subjects' reports suggested that these theta bursts were not related to sleep. During relaxation and sleep onset, 54 non-meditating controls showed no similar theta bursts. Hebert & Lehmann suggested that these theta bursts might be evidence of a state adjustment mechanism that comes into play during prolonged low-arousal states. They hypothesized that this mechanism might prevent the drift into sleep by widespread, brief, rhythmic neural activation.

Several authors have suggested on the basis of studies of the EEG that meditation is simply light sleep by another name. Fenwick *et al.* (1977) point out that 'several subjects whose EEG records showed them to be drowsy or frankly asleep during the control periods did not recognise this experience but insisted they had been wide awake' and that 'it is predictable from the level of alertness seen in meditation that the subject's self-report systems will not be functioning effectively'. The implication of these statements is that the EEG is a more reliable indicator of states of consciousness than is self-report but, as Fenwick goes on to point out, this may not necessarily hold – 'Because the EEG phenomena are suggestive of a hypnagogic state it is not possible to be sure that the mental state of stage onset sleep is present.' Indeed it is questionable whether it is logical to score meditation records for sleep stages and to call certain stages of meditation 'sleep' on the basis of EEG recordings where there are consistent EEG differences between meditation and 'napping' and when meditators consistently differentiate meditation subjectively from drowsiness or sleep.

Thus, a number of researchers have shown EEG patterning similar to sleep stages during meditation, and subjective reports of meditators (West, 1980) imply the experience of some phenomena often associated with the hypnagogic state. On the basis of existing research on the EEG and on other psychophysiological measures taken during meditation (Woolfolk, 1975; West, 1979*a*), it appears likely that meditation is, psychophysiologically, a finely held hypnagogic state.

Williams & West (1975) compared 9 practising meditators and 10 control subjects on their EEG responses to photic stimulation. One finding from this study was that meditators shifted less along the arousal continuum than the control subjects who tended to drift into sleep, suggesting that meditation practice may produce an ability to hold the hypnagogic state. It is of interest also that regular meditators, deprived of sleep, show significantly less compensatory paradoxical sleep than non-meditators after a period of sleep deprivation, and that their return to pre-deprivation levels of paradoxical sleep is significantly faster than that of control subjects (Miskiman, 1977). Woolfolk *et al.* (1976) have also reported that meditation is an effective treatment for chronic insomnia.

ALPHA-BLOCKING AND HABITUATION OF THE BLOCKING RESPONSE IN MEDITATION

Das & Gastaut (1955) report no effect on the EEG pattern as a result of external stimuli during the ecstasy stage of meditation. Similarly, Bagchi & Wenger (1957) found that 'low intensity noise' i.e. shuffling of feet, produced no alpha-blocking in one subject. Kasamatsu *et al.* (1957) found that the alpha waves of their meditating subjects 'were hardly depressed by the sound of hand claps and bells'.

In a more systematic study of alpha-blocking and habituation, Kasamatsu & Hirai (1966) presented a click stimulus every 15 s to a group of Zen masters in Zazen meditation and found no evidence of habituation. A control group exhibited the classical habituation curve to the same stimulus during a period when they sat quietly with eyes open. The Zen masters are reported to have displayed 'theta blocking' to the click stimulus. When the stimulus was presented during a train of theta, the theta was blocked, not being replaced by alpha – the usual arousal reaction in drowsiness – but returning within a few seconds. Banquet (1973) has also reported this phenomenon in TM subjects.

Wallace (1970) and Wallace *et al.* (1971) reported no habituation of the blocking response in meditating subjects. Banquet (1973), however, reports that with TM subjects there was 'usually no blocking', though click stimulation of theta did produce a blocking effect as reported above. In deep meditation, Banquet found that there was no change in the electrical pattern as a result of stimulation. Anand *et al.* (1961) also report that during 'samadhi' there was no blocking.

These conflicting results must derive at least partially from the fact that different experimenters have used subjects with vastly different experience of meditation and who employ different techniques of meditation. It seems possible from an examination of the literature that there is no habituation of the blocking response in experienced meditators and that there is a stage of 'deep' meditation (with a variety of names such as samadhi or transcendence) where the alpha-blocking response does not occur. Unfortunately, too few systematic studies of alpha-blocking and its habituation which have used meditators as subjects have been conducted.

THE EEG BEFORE AND AFTER MEDITATION

Schwartz (1973) reports that meditators show more alpha with eyes open upon entering the laboratory than controls, yet after brief meditation this was reversed. Kras (1977) found that meditators displayed significantly more alpha than controls in eyes-open and eyes-closed conditions. Tebecis (1975) found that meditators exhibited a higher theta density out of meditation than controls, though he found no evidence of differences on the alpha range. A number of researchers have reported that alpha persists after meditation, even with eyes open (Das & Gastaut, 1955; Hirai *et al.* 1959; Hirai, 1960; Kasamatsu & Hirai, 1966; Wallace, 1970; Banquet, 1973). Westcott (1977) compared interhemispheric EEG symmetry in a group of meditators and 2 control groups. Between-group differences showed that the EEG was correlated more highly across hemispheres in the meditating group than in the control groups, over the alpha range. This was true before, during and after a period of meditation (during which the controls either relaxed or concentrated on a letter writing task). The meditators also displayed a lower right to left hemisphere power ratio than the other two groups, thus providing some support for Ornstein's (1972) suggestion that meditation practice may produce a greater integration of hemispheric functioning.

In a longitudinal study of a group of subjects who learned meditation, subsequent to an initial laboratory testing session (Vassiliadis, 1973), significant changes were seen in alpha and theta content in the occipital region as a function of length of practice. After 6–9 months of meditation, the meditators showed more alpha content than a control group, when sitting with eyes open. Following a 20 min period of meditation, the alpha content in the post-meditation, eyes-open period was significantly greater than pre-meditation levels. After 6–9 months of meditation, there was a significant gradual increase in theta wave power during meditation and the theta content was higher at the end than at the beginning of meditation. In another longitudinal study of the effects of meditation, Glueck & Stroebel (1975) taught a group of in-patients in a psychiatric hospital a technique of meditation. Over a 6-month experimental period the patients exhibited a significant increase in resting density of alpha outside of meditation and an increase in density of alpha during meditation. A control group exhibited no significant change.

In a study of EEG responses to photic stimulation in meditators (Williams & West, 1975), it was found that meditators exhibited the alpha induction response earlier than a control group, and the incidence of the alpha induction response was significantly higher among the meditators. One interpretation offered for this latter finding was that the regulation of attention during meditation may have led to an increased ability in the meditators to sustain attention. Recent research has shown that there are reliable increases in measures of attentional absorption in conjunction with a significant decrement in trait anxiety, as a function of length of time of practice of meditation (Davidson *et al.* 1976), though whether these increases in absorption are due to decreases in anxiety or attentional regulation directly produced by meditation has not yet been discovered.

CONCLUSIONS

Research into meditation suggests that meditation is associated with increases in subjective feelings of relaxation and decreases in measured anxiety (West, 1980; Hjelle, 1974; Fehr, 1977). Meditation has been used successfully as a therapy in cases of insomnia (Woolfolk *et al.* 1976), hypertension (Patel, 1977), and headache (Benson *et al.* 1974). How meditation achieves its effects and whether they are primarily due to placebo effects, experimenter effects and cognitive dissonance effects, is open to debate. Research on psychophysiological correlates of meditation has shown that decreases in arousal take place during meditation (Woolfolk, 1975), and possibly outside of meditation, as a result of regular practice (West, 1979*b*; Goleman & Schwartz, 1976), though there is some disagreement about the relative magnitude of these effects (Fenwick *et al.* 1977). The work on meditation and the EEG has produced results which suggest that meditation might be differentiated from other altered states and is therefore of some importance. Future research might answer some of the questions posed or rebuff suggestions made in this review, but there is obviously a need for better-controlled and more precisely formulated research, since meditation is increasingly being used as a form of therapy (Shafii, 1973; Carrington, 1977) and may represent a method of producing generalized relaxation and relief from anxiety and tension. Akers *et al.* (1977), in an investigation of personality correlates of EEG responses to meditation, have found that those individuals who indicated more concern with their physical or psychological well-being also exhibit a greater psychophysiological response (in terms of increased alpha) to meditation than those who indicated less concern. These findings are consistent with other research which has shown that those attracted to meditation are significantly more neurotic than the normal population (West, 1980). Thus, it may be possible to predict, on the basis of EEG responses to meditation, which individuals would be most likely to derive therapeutic benefit from continued meditation practice. The possible usefulness of the EEG as the most reliable psychophysiological measure of both the response to meditation, and the effectiveness of meditation in producing relaxation over time, is therefore apparent.

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