ELECTROENCEPHALOGRAPHIC FINDINGS DURING MANTRA MEDITATION (TRANSCENDENTAL MEDITATION). A CONTROLLED, QUANTITATIVE STUDY OF EXPERIENCED MEDITATORS

BENT STIGSBY, JENNIFER C. RODENBERG and HANNE B. MOTH

Department of Clinical Neurophysiology, Gentofte Hospital, University of Copenhagen, DK 2900 Hellerup (Denmark)

(Accepted for publication: November 19, 1980)

Based on analysis of EEG, heart rate, galvanic skin resistance and oxygen consumption, Wallace (1970) and Wallace et al. (1971) postulated that transcendental meditation (TM) induces a wakeful hypometabolic state different from an ordinary relaxed drowsy state. The main EEG changes seen during TM were increased regularity and amplitude of the alpha activity. Supporting Wallace's proposal, Banquet (1973) concluded, on the basis of spectral analysis of the EEG, that the meditative state was a unique state of consciousness, separate from wakefulness, drowsiness or sleep.

This assumed hypometabolic state is, however, not restricted to TM, as subjects who had learned a relaxing method were also able to decrease their oxygen consumption significantly more by relaxing than by just sitting with the eyes closed (Beary et al. 1974). Further, Fenwick et al. (1977) concluded that both the metabolic changes and the EEG phenomena during TM could be explained by accepted physiological mechanisms, as the hypometabolic state was not more than that produced by muscle relaxation and the EEG changes were not different from those observed in the state of sleep onset.

Hebert and Lehmann (1977) observed theta bursts with frontal dominance exclusively in subjects practising TM and nearly twice as often during meditation as compared to ordinary wakefulness.

Pagano et al. (1976) reported that a considerable part of the meditation time was spent in various sleep stages. Also Wachsmuth (Thesis 1978) noticed sleep episodes during TM. The EEG pattern during these episodes could not be differentiated from that seen during sleep onset (Wachsmuth et al. 1980). On the contrary, Tebècis (1975) did not find any change of EEG activity during TM.

With these ambiguous EEG findings during TM in mind, the present study was undertaken to analyse quantitatively, and controlled, the effect of TM on the EEG. We have compared the EEG recorded during TM with that during various stages of consciousness: wakefulness, drowsiness, sleep onset and sleep. All the meditators had year-long experience and they were used while not meditating as their own controls. Furthermore, we have compared the EEGs from the TM group with those of an age-matched control group not practising TM.

Material and methods

Fourteen healthy subjects (5 females and 9 males, 22–60 years of age, median age 27 years), who had practised TM twice daily for at least 2 years, with the longest TM experience of 8 years, volunteered for the examination. The TM technique introduced by Maharishi Mahesh Yogi is a method to reduce mental activity by means of a simple silent repetition of a sound free of any meaning: a
mantra (Bloomfield et al. 1975). All subjects had their meditation technique checked within 2 months before the examination. None had any neurological disease, nor had any experienced significant head injuries. One subject was rejected from the study because his EEG was contaminated with extracerebral activity, mainly muscle and movement potentials, to such a degree that it made computer EEG analysis impossible. Thirteen healthy volunteers (8 females and 5 males, 21–63 years of age, median age 28 years) who were not practising TM or other types of meditation, zen, yoga, etc., served as controls. Except for two females on oral contraceptives in the control group, none of the participants was treated medically, or had a daily alcohol consumption. No alcohol was taken for at least 24 h before the study.

The EEG was recorded bipolarly with platinum iridium needle electrodes (DISA) placed according to the international 10-20 system during TM and during closed-eyed wakefulness (stage W), drowsiness (stage W-I), sleep onset (stage I) and, in 8 of the 13 subjects, also during sleep (stage II–III). The sleep stages were visually classified according to the EEG pattern (Rechtschaffen and Kales 1968). This visual classification was later confirmed by computer analysis, as the quantitated EEGs during wakefulness, drowsiness, sleep onset and sleep differed significantly one from another. The terms 'wakefulness', 'drowsiness', 'sleep onset' and 'sleep' are used solely for a level of consciousness determined by the EEG. The subjects were divided at random into two groups, A and B. In group A the examination began with meditation followed by sleep, in group B vice versa.

During meditation and closed-eyed wakefulness the subjects sat comfortably in a chair with subdued light in the room. During drowsiness and sleep the subjects lay supine. The EEG was recorded for 5 min before TM, during 20 min of TM and until 5 min after, as well as during a period of up to 1 h when the subjects were trying to fall asleep or slept (8 subjects).

After the EEG recording the subjects completed a questionnaire regarding their subjective experiences of the meditation and the examination situation.

Fifty to 100 sec of EEG without artifacts were selected for analysis 5, 10 and 15 min after TM had started, and during wakefulness, drowsiness, sleep onset and sleep. The following derivations of the EEG were used: F3-C3, T3-T5, P3-O1, F4-C4 and P4-O2. Eye movement potentials were detected by surface electrodes placed peri-orbitally. The EEG was recorded on a 16-channel EEG machine, bandpass 0.5–70 Hz, connected to an analog tape recorder. The EEG was recorded on tape for later automatic period-amplitude analysis. Output from the period-amplitude analysis was the percentage activity time (% AT) and mean voltage (MV) in 21 frequency bands covering the frequency range from 0.5 to 28.6 Hz. In addition, the mean frequency of the percentage activity time distribution (MF) and the mean voltage of the analysis epoch (MVA) were calculated (Stigsby et al. 1973).

The Wilcoxon Matched-Pairs Signed-Ranks test and the Mann-Whitney U test (Siegel 1956; Wilcoxon and Wilcox 1964) were used for the statistical evaluation.

**Results**

**EEG differences between TM and states of wakefulness, drowsiness and sleep**

The EEGs during TM were not different from those recorded during wakefulness and drowsiness, but clearly different from those recorded during sleep onset and sleep (Table I, Fig. 1a–c). The EEG frequency spectra of wakefulness, drowsiness, sleep onset and sleep differed significantly one from another, but constituted a continuum of EEG changes with decreasing alpha and increasing theta and delta activity as the subjects tended to fall asleep (Table I). The frequency spectra during TM were in the same continuum between the stages of wakefulness and drowsiness (Fig. 1a–c).
TABLE I
The EEG mean frequency (MF) and the mean voltage (MVA) (mean ± S.E.M.) measured fronto-centrally, temporally and parieto-occipitally during wakefulness, drowsiness, sleep onset and sleep. Significant differences between TM and the sleep stages are indicated by the level of statistical probability (* P < 0.05; ** P < 0.01, Wilcoxon Matched-Pairs Signed-Ranks test).

<table>
<thead>
<tr>
<th>EEG region</th>
<th>EEG parameter</th>
<th>TM (X ± S.E.M.)</th>
<th>Wakefulness (X ± S.E.M.)</th>
<th>Drowsiness (X ± S.E.M.)</th>
<th>Sleep onset (X ± S.E.M.)</th>
<th>Sleep (X ± S.E.M.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MF (c/sec)</td>
<td>9.7 ± 0.33</td>
<td>10.3 ± 0.25 *</td>
<td>9.9 ± 0.35</td>
<td>9.5 ± 0.41</td>
<td>8.9 ± 0.38 *</td>
</tr>
<tr>
<td></td>
<td>MVA (µV)</td>
<td>13 ± 1.0</td>
<td>12 ± 0.9</td>
<td>12 ± 0.7</td>
<td>12 ± 0.9</td>
<td>12 ± 0.6</td>
</tr>
<tr>
<td>Temporal</td>
<td>MF (c/sec)</td>
<td>9.9 ± 0.44</td>
<td>9.8 ± 0.18</td>
<td>9.4 ± 0.29</td>
<td>8.9 ± 0.38 *</td>
<td>7.8 ± 0.24 *</td>
</tr>
<tr>
<td></td>
<td>MVA (µV)</td>
<td>20 ± 1.9</td>
<td>18 ± 1.9</td>
<td>17 ± 1.4 *</td>
<td>14 ± 1.3 **</td>
<td>12 ± 1.0 *</td>
</tr>
<tr>
<td>Parieto-occip.</td>
<td>MF (c/sec)</td>
<td>10.2 ± 0.24</td>
<td>10.0 ± 0.19</td>
<td>9.6 ± 0.26 *</td>
<td>8.9 ± 0.35 **</td>
<td>7.9 ± 0.31 **</td>
</tr>
<tr>
<td></td>
<td>MVA (µV)</td>
<td>19 ± 1.7</td>
<td>20 ± 2.6</td>
<td>18 ± 1.9</td>
<td>14 ± 1.4 *</td>
<td>13 ± 0.8 *</td>
</tr>
</tbody>
</table>

Fig 1. a–c: the mean activity distributions (% AT) and the mean voltage distributions (MV) in EEGs from the fronto-central (a), temporal (b) and parieto-occipital (c) regions recorded during TM (solid curves), wakefulness, drowsiness, sleep onset and sleep (stippled curves). Significant differences between TM and the 4 stages of consciousness are indicated by asterisks at the corresponding frequency bands (* P < 0.05; ** P < 0.01, *** P < 0.001; Wilcoxon Matched-Pairs Signed-Ranks test).
EEG FINDINGS DURING TM

EEG changes during TM
A slight, but significant slowing of the EEG mean frequency was seen in the left fronto-temporal region during the 20 min of TM, tested after 5, 10 and 15 min of meditation, whereas the mean frequency of the other regions remained stable (Table II). There was no change in the EEG voltage. Fig. 2 shows the individual changes in the EEG mean frequency.

Regional EEG differences during TM
There were no differences between the quantity of EEG activity in the two cerebral hemispheres during TM. The frequency ratio between the fronto-central and the parieto-occipital regions was maintained during TM and did not change as the meditation progressed.

EEG differences between meditators and controls
The EEG mean frequencies of the TM group during wakefulness were about 1 c/sec lower (Mann-Whitney U = 16-43, 0.001 < P < 0.05) than those of the control group, but still within the alpha range. Also the mean voltages were slightly lower (Mann-Whitney U = 45, P < 0.05). Fig. 3 shows that the lower EEG mean frequency in the TM group was due partly to more theta activity and partly to a slightly slower alpha frequency in this group, especially in the temporal region.

We found no correlation between the EEG

Fig. 1b. For legend see Fig. 1a.
TABLE II

Fronto-central, temporal and parieto-occipital EEG mean frequencies (mean ± S.E.M.) measured 5, 10 and 15 min (TM5, TM10 and TM15) after meditation start. Significant differences are indicated by the statistical probability level (Wilcoxon Matched-Pairs Signed-Ranks test)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F3-C3</td>
<td>10.3 ± 0.40</td>
<td>n.s.</td>
<td>10.3 ± 0.47</td>
<td>n.s.</td>
<td>9.9 ± 0.39</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>F4-C4</td>
<td>9.8 ± 0.49</td>
<td>n.s.</td>
<td>9.6 ± 0.41</td>
<td>n.s.</td>
<td>9.5 ± 0.33</td>
<td>n.s.</td>
</tr>
<tr>
<td>T3-T5</td>
<td>10.5 ± 0.49</td>
<td>P &lt; 0.05</td>
<td>10.1 ± 0.39</td>
<td>n.s.</td>
<td>9.9 ± 0.44</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>P3-O1</td>
<td>10.2 ± 0.27</td>
<td>n.s.</td>
<td>10.0 ± 0.34</td>
<td>n.s.</td>
<td>10.4 ± 0.42</td>
<td>n.s.</td>
</tr>
<tr>
<td>P4-O2</td>
<td>10.3 ± 0.27</td>
<td>n.s.</td>
<td>10.0 ± 0.27</td>
<td>n.s.</td>
<td>10.0 ± 0.24</td>
<td>n.s.</td>
</tr>
<tr>
<td>Total</td>
<td>10.2 ± 0.12</td>
<td>P &lt; 0.05</td>
<td>10.0 ± 0.11</td>
<td>n.s.</td>
<td>9.9 ± 0.14</td>
<td>n.s.</td>
</tr>
</tbody>
</table>
EEG FINDINGS DURING TM

Fig. 2. The mean frequencies (average of all 5 regions) measured 5, 10 and 15 min after TM start. The solid lines represent the 8 subjects with a successful meditation, the stippled and dotted lines the 5 subjects with an unsuccessful. The dotted lines represent the 2 subjects who felt drowsy during meditation.

frequency and the number of years the meditators had practised TM (\( r = 0.09, P > 0.1 \)).

Visual evaluation of the EEGs

All EEGs were evaluated as normal by visual inspection. During TM there were no theta bursts which met the criteria of Hebert and Lehmann (1977), i.e., a frequency between 4 and 7.5 c/sec, a minimum amplitude of 100 \( \mu \)V and a minimum duration of 1 sec. Short trains of theta activity were, however, seen in a few of the subjects, but the amplitude of the theta activity was within the range of the background activity, and the duration never reached 1 sec.

Subjective experience of the meditation

Two out of 13 meditators stated that they had felt drowsy in periods during meditation. Eight meditators considered their meditation 'normal' or even better than normal, and the remaining 5, including the two who felt drowsy, thought their meditation was not as successful as usual. One felt tense because of

Fig. 3. The mean activity distributions (% AT) and the voltage distributions (MV) in EEGs from the fronto-central, temporal and parieto-occipital regions of the TM group (solid curves) and the control group (stippled curves). The mean frequency of the TM group (\( \checkmark \)) and of the control group (\( \times \)) are indicated. Significant differences between the TM and the control group are indicated at the corresponding frequency bands as well as at the mean frequencies on the abscissa (* \( P < 0.05 \); ** \( P < 0.01 \), *** \( P < 0.001 \), Mann-Whitney U test).
the needle electrodes, but fell asleep during the control session.

There were no consistent EEG patterns associated with a meditation considered as successful or unsuccessful. The EEGs of the two meditators who felt drowsy during meditation did not differ from the rest (Fig. 2).

Discussion

The term ‘transcendental meditation’ (TM) was applied in this context to a short period (20 min) of meditation by the use of a meaningless mantra, with the aim of describing the concomitant EEG changes. It has nothing to do with the term ‘transcendental meditation’ used by the ‘International Association for the Advancement of the Science of Creative Intelligence’ and its affiliated organizations, to which this study has no adherence.

Quantitative analysis of the EEG during TM and during wakefulness, drowsiness, and sleep showed that experienced meditators are at a quantitative level of consciousness between wakefulness and drowsiness during meditation. During the 20 min of meditation there was an extraordinary stability of the EEG mean frequency in all meditators. This implies that these meditators were able, regardless of the examination situation, to put themselves into a state which electroencephalographically is characterized as a state between wakefulness and drowsiness. Further, they were able to maintain this state virtually unchanged during the 20 min of meditation, a phenomenon quite different from their normal pattern of relaxation. Most meditators thus fell asleep within 20 min of relaxation and all had considerable fluctuations in their state of consciousness during the control session. Although it should be remembered that meditation was performed in the sitting position and the control session in the supine, the difference is, however, striking.

Our findings are at variance with those of Tebécis (1975) who found no differences in EEG frequency between TM periods and non-TM periods. Tebécis’ material comprised a rather heterogeneous and inexperienced group, which might explain why a group analysis did not show any consistent changes. A comparative study between inexperienced and experienced meditators would be desirable.

In contrast to our findings, Wallace (1970), Banquet (1973) and Morse et al. (1977) reported that alpha activity during meditation was more regular and had a larger amplitude, indicating that the EEG during meditation is clearly different from the EEG during non-TM periods and not at all similar to the EEG during light drowsiness. In addition, Banquet reported development of a sustained beta activity of increased amplitude in 4 out of 12 subjects, which he ascribed to the state of transcendence. We have no explanation for these discrepancies. It should, however, be mentioned that 4 out of the 15 subjects in Wallace’s material showed a different EEG pattern during TM. This pattern resembled the findings in the present study as well as findings described during zen meditation by Kasamatsu and Hirai (1966). The beta activity seen by Banquet and also mentioned by Morse et al. could be a quite unspecific phenomenon, as increased beta activity, especially if prominent frontally, is normally seen in some people during drowsiness and sleep onset (Kooi et al. 1978).

Pagano et al. (1976) found that an appreciable part of meditation sessions was spent in sleep, as evaluated by the EEG, which in some cases was later admitted to by the meditators. No sleep episodes were registered during TM in this study. It is unlikely that the examination situation could be the reason for this, since all subjects reached the sleep onset stage during the control session. An examination during one TM session only does not, however, exclude the possibility that sleep may occur during TM in general.

Several authors (Levine et al. 1977; Orme-Johnson 1977; Westcott 1977) have described an increased coherence between the cerebral hemispheres during TM. This could not be
EEG FINDINGS DURING TM

further examined in this study because of the type of EEG analysis used. However, we found no intra- or interhemispheric differences concerning the quantity of EEG activity and EEG voltage during the course of TM.

The EEG mean frequency of the meditating group before and after TM was slightly, but significantly, slower than that of the control group. This finding is in accordance with Tebècis (1975), who found increased theta density in a TM group as compared to a control group. This could either be a result of practising TM or a premeditational phenomenon. Tebècis suggested that the EEG changes that occurred during TM were gradual, occurring slowly during long-term practise. We were not able to support this suggestion as we found no correlation between EEG frequency and 2–8 years of practising TM.

The possible specificity of theta bursts which Hebert and Lehmann (1977) found in one-third of their experienced meditators, but not in a control group which also consisted of novice meditators, could not be supported by this study of experienced meditators, as we found no theta bursts which could fulfil the criteria set by Hebert and Lehmann.

It is difficult by scientific means to relate the short-term physiological changes seen during TM to the beneficial long-term psychological effects claimed by the meditators. However, when we compare the physiological state of TM with the stages of sleep, with their known importance for psychological wellbeing, we cannot exclude that 20 min of meditation twice a day is of some importance. Further research is certainly needed before the objective value of meditation can be settled.

Summary

The EEGs of 13 experienced practitioners of transcendental meditation (TM) were recorded for 5 min preceding TM, during 20 min of TM and until 5 min after, as well as during closed-eyed wakefulness, drowsiness, sleep onset and sleep. Thirteen healthy volunteers matched for age served as control subjects. Computer period-amplitude analysis of F3-C3, T3-T5, P3-O1, F4-C4 and P4-O2 epochs of 50–100 sec duration resulted in a frequency and amplitude spectrum (0.5–28.6 c/sec), and the mean frequency and the mean voltage of each EEG lead.

The EEG frequency spectra constituted a continuum with increasing theta and delta activity and decreasing alpha activity as the participants tended to fall asleep. The frequency spectrum during TM corresponded to a spectrum situated between that of wakefulness and drowsiness and remained virtually unchanged during the 20 min of meditation. The EEG mean frequency of the TM group was about 1 c/sec slower than that of the control group.

Intra- or interhemispheric differences between quantities of EEG activity remained stable during TM, nor did we observe any theta bursts.

There was no consistent EEG pattern associated with a successful or unsuccessful meditation, nor did the EEGs of two meditators who stated they had felt drowsy during TM show a different pattern.

Résumé

Résultats EEG obtenus durant la méditation mantra (méditation transcendantale). Etude quantitative, effectuée sous contrôle, chez des adeptes entraînés

Les EEG de 13 adeptes entraînés à la méditation transcendantale (MT) furent enregistrés pendant les 5 min précédant la MT, pendant 20 min de MT et les 5 min qui l'ont suivie, ainsi que durant la veille, yeux fermés, durant l'installation du sommeil et le sommeil. Treize volontaires en bonne santé, d'âges identiques, servirent de témoins. L'analyse sur calculateur des fréquences et amplitudes de F3-C3, T3-T5, P3-O1, F4-C4 et P4-O2 a permis d'établir des spectres d'amplitude et de
fréquence (0,5–28,6 c/sec), une fréquence moyenne et un voltage moyen pour chaque plot EEG.

Les spectres de fréquence EEG constituaient un continuum avec augmentation de l'activité delta et thêta et décroissance de l'activité alpha tandis que les sujets tendaient à s'endormir. Le spectre de fréquence durant la MT correspondait à un spectre intermédiaire entre celui de la veille et celui de l'assouplissement et restait pratiquement inchangé durant les 20 min de méditation. La fréquence moyenne EEG pour le groupe MT était d'environ 1 c/sec plus basse que celle du groupe témoin.

Les différences intra- ou interhémisphériques entre les quantités des activités EEG restèrent stables pendant la MT et nous n'avons pas non plus observé de bouffées thêta.

Il n'y avait pas de configurations EEG typiques associées à une méditation soit réussie soit manquée; pour 2 sujets qui firent état d'un assouplissement lors de la MT, les configurations ne furent pas non plus différentes.

The computer work was performed at the Department for Data Processing in Medicine, Gentofte Hospital.

References


