QUANTIFIED EEG SPECTRAL ANALYSIS OF SLEEP AND TRANSCENDENTAL MEDITATION

JEAN-PAUL BANQUET, M.D. 1, and MAURICE SAILHAN, M.D. 2

1Stanley Cobb Laboratories for Psychiatric Research, Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts
2Institut La Rochefoucauld, Rue de la Rochefoucauld, Paris, France

Presented at the Second European Congress on Sleep Research, Rome, Italy, 10 April 1974.

Long-term participants in the Transcendental Meditation program showed awareness during different periods of sleep, including phases of deep sleep and paradoxical sleep.—EDITORS

Computerized spectral analysis and qualitative reports determined distinctions among the EEG records during Transcendental Meditation, the different sleep stages, and waking in meditators and controls. Speculations were formulated concerning the possibility that the changes in consciousness induced during the process of Transcendental Meditation may carry over into waking, dreaming, and sleep states.

INTRODUCTION

Some of the electrical patterns induced by the Transcendental Meditation (TM) technique are similar to the transitional phases and first stages of sleep (2). A uniquely descriptive approach of the EEG differentiates them, but it does not seem sufficient to fully describe Transcendental Meditation. Different techniques of quantification have been used recently to improve the discrimination between different types of EEG (5, 6). In this article the previous methodology of spectral analysis by Fast Fourier Transform (FFT) is implemented by the computation of new parameters and coefficients.

METHODS

The choice of control and experimental subjects (practicing Transcendental Meditation), the techniques of recording (7 monopolar electrodes of the 10–20 system and a technical channel), and the methods of analysis (computerized spectral analysis by FFT) were the same as those previously described (2).

Further data analysis included total and partial power spectra (for each frequency band); Pearson's correlation coefficients between the variations of the different spectral powers (first derivative of the spectral curves); and an interfrequency ratio, providing coefficients of (a) wakefulness: $\alpha/\Delta$; (b) activation: $\beta/\alpha$; and (c) depth of sleep: $\Delta/(\alpha + \Theta)$.

QUALITATIVE RESULTS

These results are derived from the joint interpretation of EEG trace and compact spectral arrays (CSA) (5).

CONTROL GROUP—The analysis of compact spectral arrays has distinguished more clearly than previous techniques the different phases of the sleep-wakefulness continuum, on the basis of a sharper definition of the frequency changes. As a consequence, different types of transitions from wakefulness to sleep have been specified (3). Also, the compact spectral array of paradoxical sleep examined in this study looked different from stages I and II (mixed slow frequency) and was characterized by continuous, desynchronized slow frequencies of very low amplitude, some short alpha bursts, and a significant amount of fast frequencies. Because of these fast frequencies, similarities between paradoxical sleep and the CSA of mental activation in the waking state are important to note.

SLEEP DURING MEDITATION—In addition to other EEG patterns, different types of sleep periods during Transcendental Meditation were observed. Subjects recently instructed in the TM technique showed phases of ordinary drowsiness occurring mostly at the beginning of the meditation period. Subjects practicing TM somewhat longer showed shortened transitions from alpha to large-amplitude delta periods. In the extreme case, large delta bursts occurred on a background of alpha activity without any significant transition.
Long-term meditators showed waxing and waning slow waves (1 Hz or less) simultaneously with alpha spindle activity (fig. 1a). These periods correspond to a mental state of deep rest quite similar to sleep, but with preserved awareness.

NIGHT SLEEP IN MEDITATORS—The study of sleep in long-term meditators, because of its special characteristics, poses fundamental questions about the physiology of sleep and consciousness. The total duration of sleep in long-term meditators is shorter than average. In the extreme case, 3–4 hours a night are sufficient. Two advanced subjects exhibited the simultaneous occurrence of slow activity and rhythmic beta activity at 20 Hz during light sleep (2). They also showed delta waves and alpha spindles during deep sleep. One subject could consistently signal (with a pushbutton) the occurrence of K complexes or delta trains of stage III sleep (fig. 1b). Both events correspond to the subjective experience of a deepening of sleep. Dream phases became shorter or less frequent. The content was mostly wish dreams of the type encountered during childhood. In accord with this observation is the recent finding that meditators need a shorter recovery period from sleep deprivation than controls, with a smaller increase of the compensatory REM sleep phases (7).

A certain level of awareness can be observed in normal subjects during hypnagogic phases or morning dreams. In long-term meditators awareness apparently can extend to the entire period of sleep, including phases of deep sleep.

QUANTITATIVE RESULTS

The main trend of this quantification was towards a comparison of the different frequencies and channels by means of power spectra.

SLEEP-WAKEFULNESS CONTINUUM—In our research on meditators and controls, the total power was at a relatively high level during (a) alpha-dominant activity with regular plateau; (b) delta activity of deep sleep with bell-shaped curve of maximal amplitude at the deepest phase of sleep and important fluctuations; and (c) some fast-frequency phases of mental activation (fig. 2). This total power was at a low level during mixed, desynchronized frequencies of light sleep and paradoxical sleep.

The voltage of alpha and beta frequencies can reach high levels during meditation (2). A statistical study has shown that the alpha and theta power generated in the postmeditation period is larger than in a group of controls (8).

FIG. 1a. COMBINATION OF SLOW WAVES AND ALPHA SPINDLES. Two normal alpha spindles were followed by slow waves of progressively increasing amplitude. Simultaneously, the alpha spindling continued on the convexity of the slow wave.

FIG. 1b. STAGE II AND III SLEEP RECORD. The technical channel S shows a signal of the meditator, following a K complex and a high-amplitude delta period. The decision to send a signal was accompanied by a lighter sleep. The signal itself was concurrent with beta spindles different from the previous sleep spindles. In A and B, vertical calibration = 50 μV; horizontal = 1 sec.
PARTIAL POWER—The results are displayed in table 1 and fig. 3. As measured by coefficients of sleep \( \frac{\Delta}{\alpha + \Theta} \) and wakefulness \( \frac{\alpha}{\Delta} \), the "sleep" observed during Transcendental Meditation was markedly different from the night sleep of controls. The depth of sleep during "sleep" phases in meditation (fig. 3, top left) was much less than during sleep for the controls. At the same time, the extent of wakefulness during sleep (fig. 3, bottom left) was much greater for the meditators than the non-meditators. The meditators at the beginning of meditation showed about the same coefficient of wakefulness as the controls during rest. At the end of meditation, however, this coefficient was higher than for controls at rest.

Significant differences were found between rest and light sleep in the control group \( (p < .001) \), between the beginning of meditation and light sleep in the controls \( (p < .01) \), and between the end of meditation and rest for the controls \( (p < .01, t\text{-test}) \).

In conclusion, let us compare the sleep-wakefulness continuum in terms of both EEG patterns and degree of vigilance in control subjects and in meditators.

Usually waking state is related to rhythmic alpha activity, with different degrees of vigilance supporting free-flowing mental activity. Attention and mental activation result in desynchronized fast frequencies. In both cases (waking and mental activation) awareness is "object awareness," whatever the nature of this object—internal or external.

Deep sleep is characterized by synchronized delta frequency with loss of awareness and mental activity. Paradoxical sleep results in a dominance of fast frequencies on a background of slow activity with distorted consciousness and intense mental activity.

Thus, each state is characterized by a dominant frequency that can be almost exclusive of the others, e.g., the delta of deep sleep or the fast activity of mental activation. The opposition between these different frequencies is particularly important between alpha and delta, and to a lesser degree between beta and delta \( (4) \).

However, such a situation may not necessarily occur in long-term meditators. They usually report the experience

![Figure 2](image.png)

**Figure 2.** Power at various EEG frequencies. The bands in the lower portion of the figure represent the power in the delta, theta, alpha, and beta frequencies as the percentage of the total power. The X axis represents time; the Y axis represents the percentage of the total power. The upper part of the figure indicates the relative total power for each time period on a scale of zero to one. The X axis represents time; the Y axis represents the total power.

**A:** Shift from deep to light sleep in night sleep of a control subject.

**B:** A few seconds after A, beta dominance occurred during paradoxical sleep.

**C:** Theta phase early in meditation.

**D:** Important alpha dominance late in meditation.

### Table 1

**Spectral Power Quantification**

<table>
<thead>
<tr>
<th>Test Period</th>
<th>( \Delta )</th>
<th>( \Theta )</th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>( \frac{\Delta}{\alpha + \Theta} )</th>
<th>( \frac{\alpha}{\Delta} )</th>
<th>( \frac{\beta}{\alpha} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest (control)</td>
<td>50 ± 8</td>
<td>13 ± 3.5</td>
<td>19 ± 7</td>
<td>14 ± 5.5</td>
<td>1.6 ± 0.8</td>
<td>0.4 ± 0.2</td>
<td>0.8 ± 0.6</td>
</tr>
<tr>
<td>Deep sleep (control) (stages III–IV)</td>
<td>88.5 ± 1.5</td>
<td>2.2 ± 1</td>
<td>2.1 ± 1</td>
<td>6.4 ± 1</td>
<td>20 ± 2</td>
<td>0.02 ± 0.01</td>
<td>3 ± 1.7</td>
</tr>
<tr>
<td>&quot;Sleep&quot; during meditation (stages III–IV)</td>
<td>75 ± 7.3</td>
<td>11 ± 3</td>
<td>8 ± 4</td>
<td>6 ± 7</td>
<td>4.4 ± 2.1</td>
<td>0.12 ± 0.06</td>
<td>0.55 ± 0.5</td>
</tr>
<tr>
<td>Beginning of meditation</td>
<td>46.5 ± 7.8</td>
<td>21 ± 4.6</td>
<td>16 ± 4.6</td>
<td>12 ± 4.2</td>
<td>1.3 ± 0.2</td>
<td>0.36 ± 0.1</td>
<td>0.8 ± 0.5</td>
</tr>
<tr>
<td>End of meditation</td>
<td>29 ± 9.4</td>
<td>10 ± 3</td>
<td>44 ± 12</td>
<td>14 ± 3</td>
<td>0.56 ± 0.34</td>
<td>1.6 ± 0.95</td>
<td>0.34 ± 0.17</td>
</tr>
</tbody>
</table>

**Note:** The first four columns represent the mean percentage of total power for each frequency band in five control subjects over 650 sec periods and in four periods of Transcendental Meditation of the same duration. The last three columns are coefficients expressing the ratio between different frequencies. The electrode placements were O1 for rest and meditation studies and C3 for the night sleep records.
of awareness of “pure consciousness” occurring during TM without the support of any perception, thought, or feeling. This absence of mental activity should normally induce sleep, but the EEG correlates of such periods of deep meditation are a combination of rhythmical alpha and beta activities on a background of relatively large slow frequencies, delta included. During other phases of meditation short periods of high amplitude delta waves are associated with alpha spindles. The subjective report at these moments is one of deep rest with preservation of an intact awareness. The same pattern can be encountered during night sleep.

Thus, the phenomenon of awareness seems to become independent of any mental state. It rather functions as a background, support, or witness to these different states. These results, if confirmed, would indicate that the brain can simultaneously integrate and harmonize two different or even apparently opposite modes of functioning in a unique state of consciousness.

REFERENCES


7. Miskiman, D. E. 1972. The effect of the Transcendental Meditation program on compensatory paradoxical sleep. (Published in this volume.)