NEUROPHYSIOLOGICAL ORDER IN THE REM SLEEP OF PARTICIPANTS OF THE TRANSCENDENTAL MEDITATION AND TM-SIDHI PROGRAM

JAN M.R. MEIRSMAN[i]
Lelystad, Holland

Previous research into the sleep patterns of new-born human beings of different gestational ages has revealed that, in the course of ontogenesis, the randomly occurring, isolated, low frequency Rapid Eye Movements (REMs) of the undifferentiated sleep of the premature are gradually ordered in groups of REMs or high frequency REMs, characteristic of mature REM sleep (Petre-Quadens, 1967; 1969; 1978; 1980; Petre-Quadens & De Lee, 1974; Petre-Quadens, De Lee & Remy, 1971). This observation has led to the hypothesis that there exist two functionally different types of REMs in REM sleep: the high frequency (HF) REMs with an interval of less than one second, reflecting the "maturity" or "order" of brain functioning; and the low frequency (LF) REMs with an interval of more than one second, reflecting "random noise" in the brain.

Subsequent research has supported this hypothesis. Two types of REMs, with an interval $I < 1$ sec and $I \geq 2$ sec, were found to be statistically independent of each other (De Lee & Goffe, 1973). Moreover, the HF-REMs ($I < 1$ sec) were associated with cerebral maturation (age, intelligence, learning ability) and endocrinological maturation (age, second half of ovulatory cycle, second half of pregnancy), while the LF-REMs ($I \geq 2$ sec) were not (De Lee & Goffe, 1973; Petre-Quadens, 1969; 1978).

The HF-REMs of REM sleep were also found to parallel the "spindles" of quiet sleep to a certain extent, as they were associated with cerebral and endocrinological maturation (Feinberg, Braun & Shulman, 1969; Feinberg, Koresko & Heller, 1967), and were reflecting the cerebral ordering or integration of information (Andersen & Andersson, 1968; Petre-Quadens, 1978).

Because the amount of HF-REMs during REM sleep was also related to the amount of information given to the subject, Petre-Quadens proposed to consider these HF-REMs in relation to the LF- REMs in a HF/LF ratio, in order to obtain a measure for the cerebral capacity to structure "order" from the "noisy stream" of information (Petre-Quadens, 1980). "Information" could be internal (e.g. hormonal and metabolic substances) as well as external (e.g. a new computer language to learn) (Chevalier, 1982).

The research findings of Petre-Quadens and co-workers are in accordance with this suggestion. Among normal adults of the same age group, the HF-REMs/LF-REMs ratio remained relatively stable, irrespective of the total amount of REMs, which reflected the degree of stimulation of the brain (Petre-Quadens, 1980; Quadens & Green, 1984; Quadens, Green, Stott & Dequae, 1984). The ratio decreased when one was not able to respond adequately to physical or mental demands (distress): by a decrease in HF-REMs in case of disease (Petre-Quadens, 1980), and by an increase in LF-REMs in case of retirement (Hoffmann, Vanderbeken & De Cock, 1977; Petre-Quadens, 1980). The ratio increased slowly with endocrinological maturation in the woman during the luteal phase of the ovulatory cycle (which was correlated by Wuttke, Arnold, Becker, Creutzfeldt, Langenstein, and Tirsch (1975)), with increased mental performance, and in the growth from prepuberty to menopause (Hoffmann & Petre-Quadens, 1979).

To test this ratio of HF-REMs to LF-REMs further for its validity as an index of the order-creating function of the brain, and to clarify the mechanisms of this function during REM sleep, this pilot study examined the REM sleep of experienced practitioners of Transcendental Meditation (TM) and the TM-Sidhi techniques.

The Transcendental Meditation (TM) technique settles and refines the activity of the mind through repetition of a particular sound pattern (a "mantra"), thereby increasing its conscious capacity and alertness. Eventually, training in this practice allows the mind to gain a completely settled and unrestricted wakefulness. The TM-Sidhi techniques train the mind to act voluntarily from the quiet and lively level gained by the TM technique. A description of the specific mental activities and their results, the "Sidhis", is also given in the yoga system of Indian philosophy (e.g. Aranya, 1963; Prasada, 1978).

These mental techniques -- which one can learn in short, standardized courses developed by Maharishi Mahesh Yogi (International Association for the Advancement of the Science of Creative Intelligence, 1984; Maharishi Mahesh Yogi, 1967) -- have already been examined in a variety of research studies. They increase the occurrence and amplitude of alpha and theta waves and, by spreading them over the entire scalp, enhance the EEG synchrony of the anterior and posterior region and of the left and right hemisphere of the brain (Banquet, 1973; Hebert & Lehmann, 1977; Wallace, 1970; Wallace, Benson & Wilson, 1971). They also increase EEG coherence -- that is, the constancy of phase relationship between two EEG signals -- especially in the alpha and theta frequencies and in the frontal areas of the brain (Badawi, Wallace, Orme-Johnson, Rouzere, 1984; Dillbeck & Bronson, 1981; Farrow & Hebert, 1982; Levine, 1976; Orme-Johnson & Haynes, 1981). Moreover, they improve the processing of auditory information by changing the brainstem and cognitive components of the auditory evoked potentials (Kobal, Wandhofer & Plattig, 1975; McEvoy, Frumkin & Harkins, 1980; Wandhofer, Kobal & Plattig, 1976).

The TM and TM Sidhi techniques have also been found to induce physiological quiescence as a concomitant of the increase in the orderliness of brain functioning (for a research overview, see Wallace, 1987). For example, TM increases serotonergic activity, which has been described as a "rest and fulfillment" parasympathetic response (Bujatti & Riederer, 1976; Kochabhakdi & Chentanez, 1980). In sleep research on mongoloid patients, a lack of serotonine was found to be associated with a lack of REMs during REM sleep and with a low intelligence or learning ability (Castaldo, 1969; Feinberg, Braun & Shulman, 1969).

TM and TM-Sidhi techniques, when practised 20-40 minutes twice a day as a daily program, have been found in psychological tests to improve cognitive and affective functioning (Aron, Orme-Johnson & Brubaker, 1981; Dillbeck, Assimakis, Raimondi, Orme-Johnson & Rowe, 1986; Gelderloos, 1987; Warner, 1986). Improvements took place regardless of the age of the subjects, even on variables like "fluid intelligence" and "field independence", which normally do not improve after the age of 17 (see Dillbeck et al., 1986). TM practitioners also showed a shorter duration of sleep and REM sleep during the night (Banquet & Sailhan, 1974) and needed less compensatory REM sleep after an experimental 40 hours of sleep deprivation (Miskiman, 1977).

In view of these research findings, it seemed appropriate to us to further test the above described hypothesis -- that the brain during REM sleep carries out information-ordering processes which are reflected in the neurophysiological patterns of the REM sleep -- with subjects who are practising the TM and TM-Sidhi programs. This has been done with the following REM sleep parameters: the ratio of the HF-REMs ($I < 1$ sec) to the LF-REMs ($I \geq 2$ sec) (as a measure for the order-creating capacity of the brain); the density of the HF-REMs (as a measure for the intensity of the information-ordering process); the density of the LF-REMs (as a measure for the intensity of the cerebral "noise" which accompanies the information-ordering process to a certain extent); the REM density, or density of all REMs regardless of their frequency (as a measure for the intensity of the stimulation of the brain); the total number of HF-REMs (as a measure for the absolute amount of ordered information over the total REM sleep time); the total number of LF-REMs (as a measure for the absolute amount of cerebral "noise" over the total REM sleep time); the REM sleep time (as a measure for the total efficiency of REM sleep); and the REM sleep percentage (as a measure for the total efficiency of REM sleep, in relation to total sleep).

In addition, several of these temporal characteristics of REM sleep have been analyzed in their evolution with the progress of sleep during the night. Previous studies have found, as characteristics of a greater maturity, that: 1.) the cerebral order during the REM phases of sleep, expressed in the density of the HF-REMs, gradually increases in the course of sleep (Petre- Quadens, 1969; Petre-Quadens, De Lee & Remy, 1971); 2.) this increase of the density of the HF-REMs happens according to a pattern of alternately low and high values, from one REM phase to the other (Petre-Quadens, De Lee & Remy, 1971); 3.) the density of the HF-REM within one REM phase gradually increases, reaches a maximum in the middle of the phase, and subsequently again gradually decreases (Petre-Quadens, 1969).

Finally, in a qualitative observation, attention was also given to the shape of the REM signals, and to the quality of the EEG alpha activity and the sleep spindles before, during and after the REM phases, and immediately before and after sleep.

Methods

Subjects

Six experienced male TM-Sidhi practitioners, aged between 31 and 39, with different educational backgrounds, served as experimental subjects (Table 1). They had been practising TM for an average period of 139 months (range, 94-199 months), and the advanced TM-Sidhi program for an average period of 87 months (range, 76-96 months). All but the youngest were teachers of the TM technique. The author was one of the experimental subjects. The experimental group was part of a larger group of 230 male TM-Sidhi practitioners, predominantly Europeans, who resided at the TM academy in Vlodrop (Limburg, The Netherlands). There, they worked full-time and, in addition, practised an extensive TM-Sidhi program collectively. Four of the six experimental subjects reported clear experiences of the TM-Sidhis and of "witnessing"[ii] their night's sleep, and two reported less clear experiences (Table 1).

Table 1 Background Data for Experimental and Control Subjects

Subjects	Age, In Years	Technical Education, Years	Academic Education, Years	Number of TM-Sidhis Practised	Amount of Witnessing During Night
Experimental					
A	39	4	-	All	All night
B	36	-	8	All	All night
C	36	-	4	Some	-
D	35	2	-	All	All night
E	32	-	5	Some	End of night
F	31	-	4	All	Half of night
Control					
A	38	-	4	-	-
B	37	-	7	-	End of night
C	36	4	4	-	-
D	36	-	7	-	-
E	34	4	3	-	-
F	33	-	6.5	-	-

Six male subjects who did not practise any form of meditation, yoga, or similar technique for holistic development, served as control subjects. Their ages ranged between 33 and 38, and they all had had an academic education (Table 1). Because the control subjects sometimes pulled off the electrodes or lay on them, it was necessary to measure nine individuals in this group in order to obtain six intact night recordings. The control subjects were family members, friends, or acquaintances of TM-Sidhi practitioners, and were living in or near Maastricht (Limburg, The Netherlands). One of the six control subjects (subject B, see Table 1) reported signs of the initial stage of witnessing his night's sleep.

All subjects were in good health. On the day preceding the measurement, none experienced intense emotions or physical discomforts, none used medicine, had alcoholic drinks, or took any additional rest in the form of sleep.

Procedure and Apparatus

Each of the subjects was measured in his own bedroom for two consecutive nights, by means of an ambulant 4-channel recorder, the Medilog 4-24 of the Oxford Medical Systems. Starting two days before the measurement, the subject filled out some diary forms which were examined every day by the person who took the measurement.

Measurement of the experimental group was done by the author; measurement of the control group and of the author serving as experimental subject was done by a medical student of the University of Limburg (The Netherlands). In this way, both groups were taken care of by a person with whom they were somehow familiar. During the two months' measuring period, the experimental and control subjects were measured alternately as much as possible.

Electrode placement was as follows: EEG electrodes, approximately on C4-P4 (fourth channel) and C3-P3 (third channel) (Jasper, 1958); EOG electrodes, above the left and below the right lateral corner of the eye (second channel); two EMG electrodes, below the chin (first channel); and two reference electrodes, on the forehead.

The skin was cleansed with a solution of 2/3 acetone and 1/3 denaturated alcohol (90%). The 9 mm silver/silver chloride disc electrodes were attached to the skin with collodion. The electrodes were then filled with S&W gel (neutral pH), and the electrode impedance was kept below 10 kohm as indicated by a Keithley 169 Multimeter. The electrophysiological signals were amplified near their source with miniscule Oxford HDX-82 pre-amplifiers. Electrodes, preamplifiers, and cables were attached to the skin once more with strong adhesive (elastic tape).

All these activities were carried out at the subject's home, between 8 and 11 p.m. When the subject went to bed, he himself chose the most comfortable place in bed for the recorder. According to the diary of the analyzed (second) night, every subject enjoyed a normal night's rest or was fully rested in the morning.

The registered signals were written out by means of a Siemens mingograph, connected to an Oxford PMD-12 Replay Unit. The vertical calibration was: EMG = 20 uV/cm; EOG = 100 uV/cm; and EEG = 50 uV/cm. The horizontal calibration or speed was 1.5 cm/sec. The low-pass filtering was put on 35 Hz, and the time constant was 0.3.

Analysis

Although the subjects had been measured in their own environment, a first night effect could be noticed and therefore only the second night was fully analyzed.

The periods of sleep and REM sleep were determined according to the criteria of Rechtschaffen and Kales (1968). The criteria of a REM in REM sleep involved: 1.) Amplitude $\geq$ 50 uV; 2.) Slope $\geq$ 80°; 3.) Effects clearly distinguished from the mere effect of the time constant; 4.) Prototypes, for standardization of the scoring of the borderline cases. The EOG registration did not allow for a distinction between horizontal and vertical REMs, but the literature reports that there are no differences between these two with regard to their frequency of occurrence (Petre-Quadens, 1969; Petre-Quadens, De Lee & Remy, 1971).

The experimental and control nights were analyzed by the author in alternate sequence. The total results of the two groups were compared with each other, making use of the nonparametric Mann-Whitney U-test, designed for two independent groups of small size.

Results

Quantitative Results

Table 2a,b, & c show the results concerning the REM sleep in its totality over the whole night. Of the total REM sleep, the ratio of the HF-REMs (interval I < 1 sec) to the LF-REMs (I $\geq$ 2 sec) was significantly higher in the group of TM-Sidhi practitioners than in the control group ($p < .002$; Mann-Whitney U-test) (Figure 1).

This higher ratio of REMs in the group of TM-Sidhi practitioners was effected by a much higher density of the HF- REMs ($p < .001$) (Figure 2), while the density of the LF-REMs was also significantly higher than in the control group, according to the rank-order test of Mann-Whitney ($p < .002$), but with an average that differed relatively little from the average of the controls (Figure 3). The total REM density or density of all the REMs, regardless of their frequency, was therefore also significantly higher in the TM-Sidhi group than in the control group ($p < .001$).

Table 2a
Total Night Results

	HF/LF		HF		LsF	
Subject	EXP	CON	EXP	CON	EXP	CON
A	2.77	0.79	935	219	338	276
B	2.40	2.09	697	689	290	330
C	2.03	1.32	510	400	251	304
D	2.68	1.21	601	353	224	292
E	2.39	1.10	652	146	273	133
F	3.19	1.25	485	380	152	304
Median	2.54	1.23	627	367	262	298
p*	< .002		< .013		N.S.	

Notes:

CON CONtrol group, not practising TM-Sidhi program.

EXP EXPerimental group of TM-Sidhi practitioners.

HF Total amount of High Frequency REMS (interval I < 1 second).

HF/LF Ratio of HF REMs to LF REMs.

HF-REMD	Density of HF REMs per 40 seconds of REM sleep.
LF	Total amount of Low Frequency REMs (interval I ≥ 2 seconds).
LF/REMD	Density of LF REMs per 40 seconds of REM sleep.
p*	EXP versus CON, Mann-Whitney U-test, one-tailed.
REM	Random Eye Movements, usually treated as indicators of dreaming.
REM%	Percentage of REM sleep time to total sleep time.
REMD	Density of all REMs, regardless of their frequency, for 40 seconds of REM sleep.
REMS	REM Sleep time, in minutes.
TST	Total Sleep Time, in minutes.

Table 2b Total Night Results

	HF-REMD		LF-REMD		REMD	
Subject	EXP	CON	EXP	CON	EXP	CON
A	7.36	1.27	2.66	1.60	12.22	3.57
B	6.01	3.91	2.50	1.88	10.59	6.81
C	6.00	2.78	2.95	2.11	11.48	5.90
D	6.26	1.99	2.33	1.65	10.61	4.51
E	6.59	1.21	2.76	1.10	11.43	2.79

F	6.74 1.69	2.11 1.35	10.49 3.64
Median	6.43 1.84	2.58 1.63	11.02 4.08
p*	< .001	< .002	< .001

Notes: See Table 2a

The total amount of HF-REMs in the REM sleep was also significantly higher in the experimental group than in the control group (p < .013), while the total amount of LF-REMs in the REM sleep did not significantly differ between both groups.

The REM sleep time and the total sleep time (including REM sleep time) were both significantly shorter in the experimental group (p < .002 and p < .004, resp.) (Figures 4 and 5). Because the difference was more pronounced for the REM sleep time, the percentage of the REM sleep time on the total sleep time reached also a significantly lower value in the experimental group than in the control group (p < .032).

All these REM sleep characteristics evolved during the course of sleep in a specific manner.

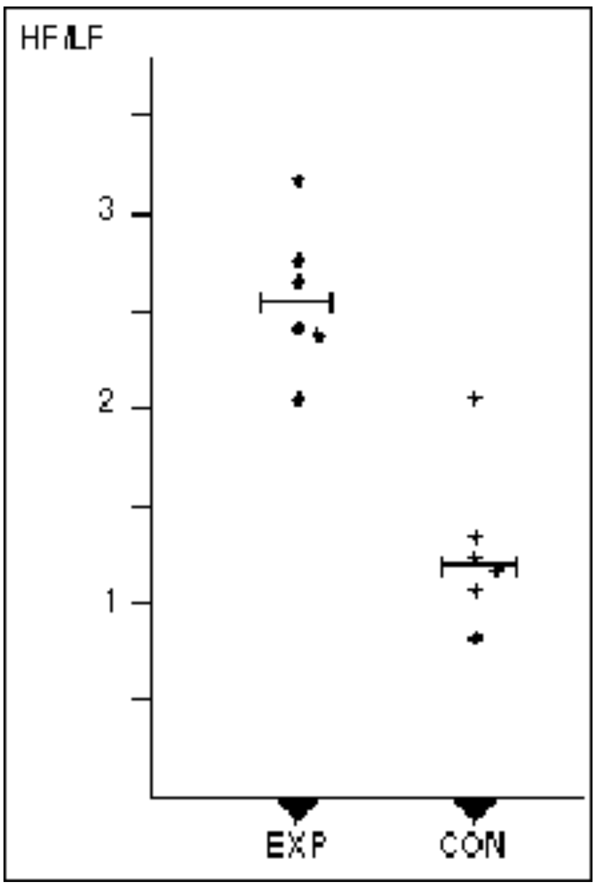
The differences between the results of the second half and the first half of the sleep time were similar to the differences between the results of the experimental group and the control group concerning the REM sleep of the total night. The ratio of the HF-REMs to the LF-REMs, the density of the HF-REMs and of the LF-REMs, the total REM density, and the maximal duration of REM bursts all reached a higher value in the second half of the sleep time than in the first half, as was the case for the total night in the experimental group in comparison with the control group. Only the REM sleep time formed an exception to this general rule of similar difference, by its higher value in the second half of the sleep time and its lower value (concerning the total night) in the experimental group. Nevertheless, the increase of the REM sleep time during the second half of the sleep time was less pronounced in the experimental group (+ 10.11 min.) than in the control group (+ 22.11 min.), while the increase of the other REM sleep parameters during the second half of the sleep time was clearly more pronounced in the experimental group than in the control group.

Table 2c

Total Night Results

	REMS		TST		REM %	
Subject	EXP	CON	EXP	CON	EXP	CON
A	85	115	372	430	22.76	26.84
B	77	117	318	388	24.29	30.24
C	57	96	308	427	8.42	22.48
D	64	118	269	420	23.82	28.10
E	66	81	398	397	16.58	20.32
F	48	150	279	538	17.22	27.88
Median	65	116	313	424	20.59	27.36
p*	< .002		< .004		< .032	

Notes: See Table 2a



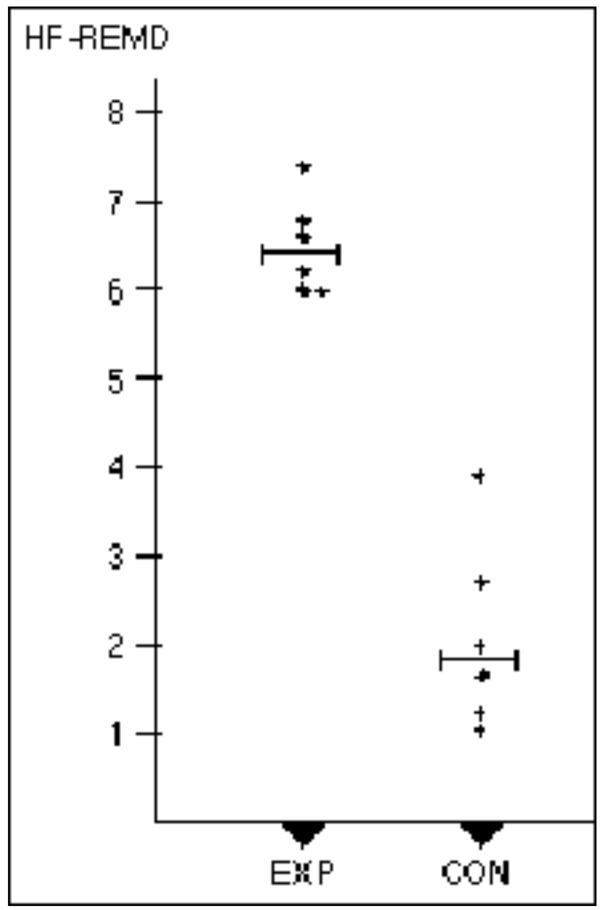
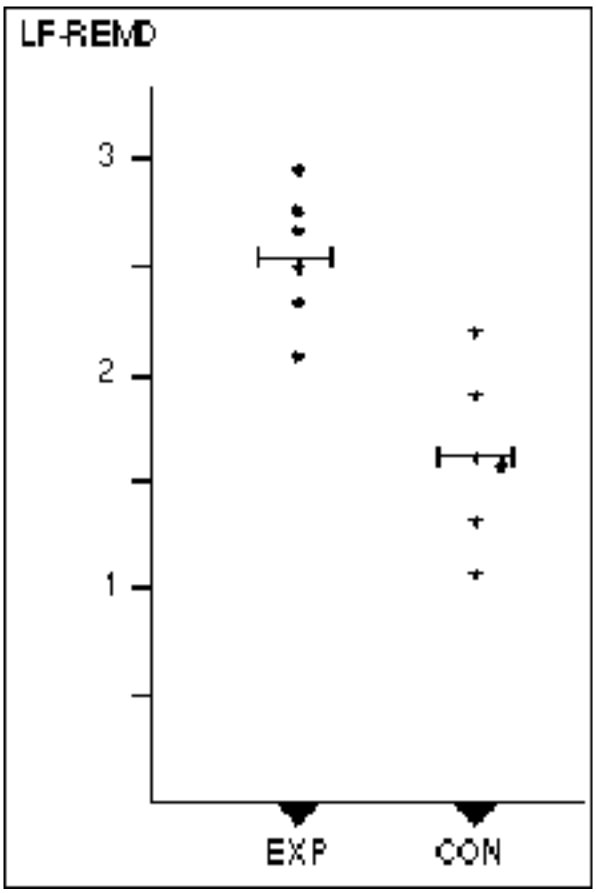


Figure 1 **Figure 2**

Figure 1. The ratio of high frequency REMs (HF) to low frequency REMs (LF) for REM sleep in TM-Sidhi practitioners (EXP) and controls (CON), as a measure for the order-creating capacity of the brain. **Figure 2**. The density of the high frequency REMs (HF) per 40 seconds of REM sleep, in TM-Sidhi practitioners (EXP) and controls (CON), as a measure for the intensity of the ordering of information in the brain.

With respect to the individual REM phases, the density of the HF-REMs showed a tendency to increase according to a pattern of alternately low and high values from one REM phase to the other (Figure 6). This pattern was most clearly distinguishable in the experimental group.

With respect to the distribution of the REMs within one REM phase, the following pattern emerged: first, a gradual increase of the amount of the HF-REMs; then, a maximal amount of the HF-REMs in the middle of the REM phase; and subsequently, a gradual decrease of the amount of the HF-REMs. This pattern was most clearly distinguishable in the nights of five of the six experimental subjects (A, B, C, E, and F), and one of the six control subjects (A).



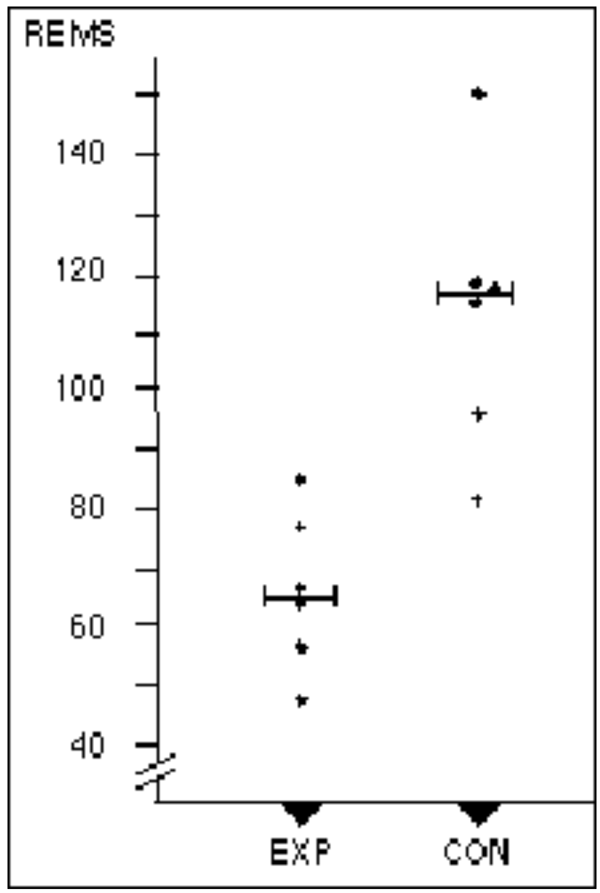


Figure 3 **Figure 4**

Figure 3. The density of the low frequency REMs (LF) per 40 seconds of REM sleep, in TM-Sidhi practitioners (EXP) and controls (CON), as a measure for the intensity of the "background noise" in the brain. **Figure 4.** REM sleep time (in minutes) of TM-Sidhi practitioners (EXP) and controls (CON), as a measure for the total efficiency of

REM sleep.

Qualitative Results

With regard to the shape of the REMs during the REM sleep, it was found that in the experimental group the REMs displayed a larger amplitude and were more differentiated than in the control group.

With regard to the EEG signals before, during, and after the REM phases and immediately before and after the sleep, it was observed that in general a larger ratio of HF-REMs to LF-REMs went hand in hand with a larger amount, a larger amplitude, and a lower frequency of alpha activity and sleep spindles (12-14 Hz). Control subject A made an exception to this general rule by his small ratio of REMs (= 0.79) and his large amount of well- differentiated sleep spindles. The EEG alpha activity of control subject A was nevertheless very poor, and therefore in accordance with the general rule.

Spindles were frequently noticed during the REM bursts in the REM phases, and in some cases immediately before and after a particular REM, but they were never found to completely coincide with REMs. Alpha activity during the REM bursts was only observed in the experimental subject B.

Immediately before and after the sleep, an almost continuous, high amplitude alpha activity was found in all experimental subjects, except subject C; this activity was also found in the control subject B. In the case of the experimental subjects B and F, this strong alpha activity was accompanied by rhythmical eye movements, the whole pattern showing much similarity to activity recorded during Transcendental Meditation (Figure 7). In the experimental subject B, this picture returned before and after each of the five sleep phases during the night, as a kind of transition stage between waking and sleeping.

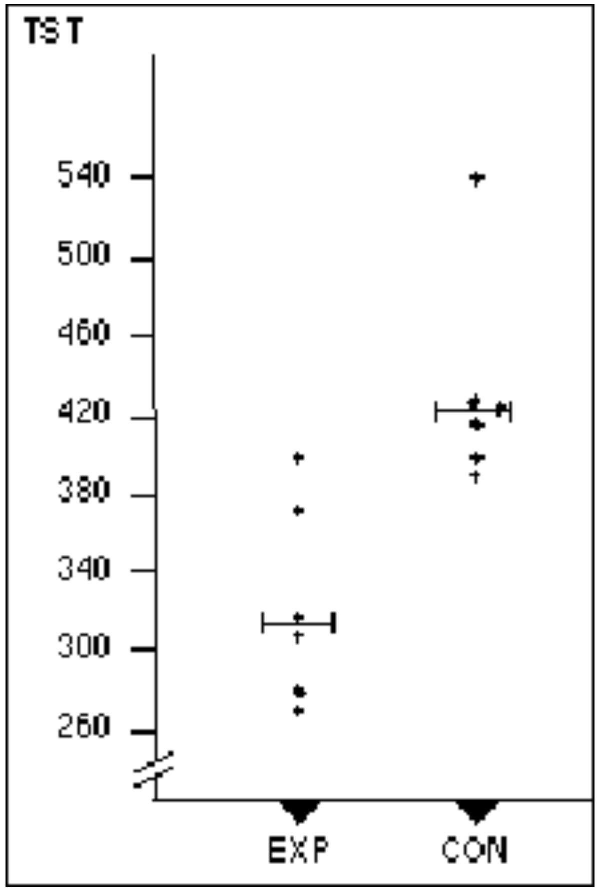


Figure 5. The total sleep time (in minutes) of TM-Sidhi practitioners (EXP) and controls (CON), as a measure for the total efficiency of sleep.

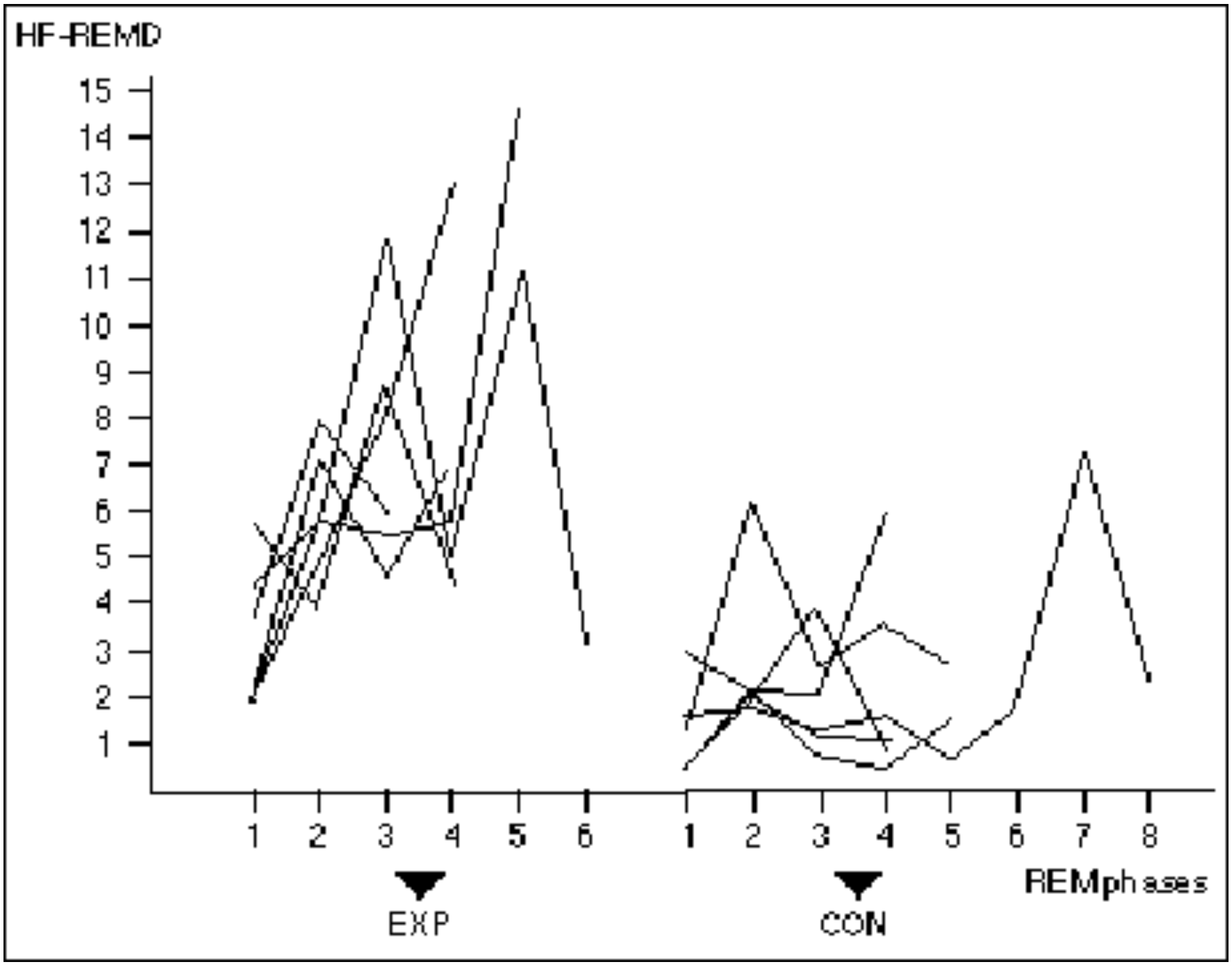


Figure 6. The density of high frequency REMs (HF) per 40 seconds of REM sleep during successive REM phases of the night, in TM-Sidhi practitioners (EXP) and controls (CON). The pattern of alternately low and high values from one REM phase to the other, related in previous research with maturity, is most clearly distinguishable in the TM-Sidhi group.

Experimental subject B and an additional TM-Sidhi practitioner exhibited so-called 'sleep spindles' or alpha spindles (12-14 Hz) during the waking stage at the beginning of the night's rest.

Finally, it has to be mentioned that the experimental subject A showed, during the middle of a sleep stage 2, a two seconds' long burst of five REMs.

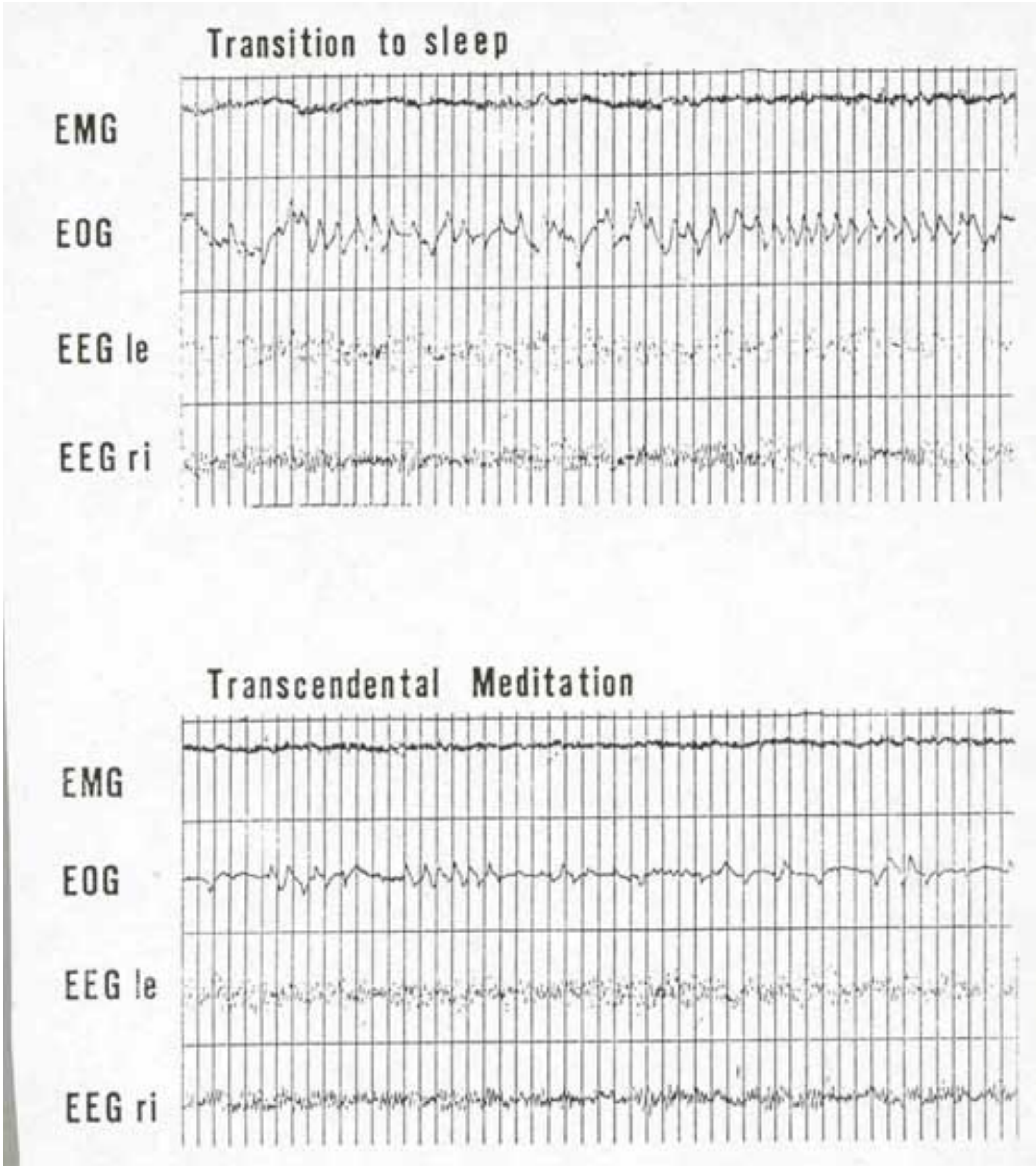


Figure 7. Rhythmical eye movements and an almost continuous, high amplitude alpha activity, before the first sleep stage ("Transition to Sleep"), similar to Transcendental Meditation Session (Transcendental Meditation), both in TM-Sidhi practitioner B.

Discussion

Discussion of the Quantitative Results

REM Ratio and the Order-Creating Capacity of the Brain: Previous REM sleep research has given indications that the ratio of the HF-REMs to the LF-REMs of REM sleep could be considered as a measure of the order-creating capacity of the brain (Hoffmann & Petre-Quadens, 1979; Petre-Quadens, 1980; Quadens & Green, 1984; Quadens, Green, Stott & Dequae, 1984). Research has given indications that the practice of the TM and TM-Sidhi techniques increases order in brain functioning, as expressed by increased EEG synchrony (Banquet, 1973; Hebert & Lehmann, 1977; Wallace, 1970; Wallace, Benson & Wilson, 1971) and EEG coherence (Badawi, Wallace, Orme-Johnson & Rouzere, 1984; Dillbeck & Bronson, 1981; Farrow & Hebert, 1982; Levine, 1976; Orme-Johnson & Haynes, 1981) and by improved central processing of auditory information (Kobal, Wandhofer & Plattig, 1975; McEvoy, Frumkin & Harkins, 1980; Wandhofer, Kobal & Plattig, 1976). In this study, the HF-REMs/LF-REMs ratio for total REM sleep is greater in the group of TM-Sidhi practitioners in comparison with a control group, giving further support to the concept of the HF-REMs/LF- REMs ratio as an index of negative entropy in the brain.

Density of HF-REMs and Maturation of the (Frontal) Cortex: The development of the HF-REMs of REM sleep in the process of ontogenesis has been attributed to the maturation of the cortical brain, in particular the frontal cortex (De Lee & Goffe, 1973; Petre-Quadens, De Lee & Remy, 1971). The increase in maturity or order (as expressed by EEG coherence) due to the TM and TM-Sidhi programs, has been found to be more localized in the frontal cortex than in the central cortex (Levine, 1976) or occipital cortex (Dillbeck & Bronson, 1981). In the present study, the ratio of REMs in the group of TM-Sidhi practitioners is greater because of a greater density of the HF-REMs, which supports the concept that the development of these HF-REMs in REM sleep is indeed the result of a maturation process, in particular of the frontal cortex.

Density of HF-REMs and Cerebral Assimilation of Information: The density of the HF-REMs of REM sleep has been found in previous research to reflect the intensity of the ordering or assimilation of information in the brain during REM sleep (Chevalier, 1982; Petre-Quadens, 1969; 1978; Quadens & Green, 1984). Psychological research has found that participation in the TM and TM-Sidhi programs improves the cognitive and affective functioning in children as well as adults (Aron, Orme-Johnson & Brubaker, 1981; Dillbeck, Assimakis, Raimondi, Orme-Johnson & Rowe, 1986; Gelderloos, 1987; Warner, 1986). Therefore, the greater density of the HF-REMs of the REM sleep in our group of TM-Sidhi practitioners is in agreement with the interpretation of these HF-REMs as a measure for the intensity of the information-ordering process taking place in the brain during REM sleep.

Density of HF-REMs and Clarity of Mind: A greater density of REMs during REM sleep has been found to correlate with a greater amount of information to which the subjects are exposed. For example, Westerners who are daily exposed to a greater flux of information than the Asian tribes of Temiars and Ibans (Petre-Quadens, 1980), and astronauts who receive more vestibular information during microgravity than during earth-gravity (Quadens & Green, 1984; Quadens, Green, Stott & Dequae, 1984), showed a much higher REM density in their REM sleep. Perhaps one would therefore expect in the group of TM-Sidhi practitioners of the present study a smaller REM density in REM sleep, because of the daily hours of quiet meditation practice. The fact that, on the contrary, a greater density of REMs -- and in particular of HF-REMs -- is found in the TM-Sidhi practitioners agrees with the interpretation that it is primarily the alertness or clarity of mind, as it is generated by the TM and TM-Sidhi program, that makes one receptive to stimuli and capable of integrating this information.

REM Ratio and Independency of the Cerebral Integrating Capacity: Nevertheless, the density of REMs during REM sleep -- interpreted as a measure for the stimulation of the brain -- seems to remain dependent on the amount of information to which the subject is exposed. This can be deduced in the present study from the comparison of the experimental subject A with the experimental subject F. During the day preceding the analyzed night, the experimental subject A had been exposed to an unusually large amount of sensory information, whereas the experimental subject F had stayed in his routine of quiet, intellectual work. Consequently, the first showed an extremely high REM density during the REM sleep, while the latter scored the lowest (total) REM density of the whole experimental group (Table 2). The difference between the two subjects was even more pronounced with regard to the total amount of HF-REMs and total amount of LF-REMs in the REM sleep. However, when the HF-REMs are placed in relation to the LF-REMs to express the cerebral integration of information, then this difference disappears and the score of the REM ratio of both these subjects attain the highest value in the study. This agrees with their strong subjective experience of the TM-Sidhis and of the maintenance of pure consciousness during their sleep (Table 1). Previous research has found an enhanced information processing (ideational fluency) and EEG coherence in those with clear experiences of pure consciousness and of the TM-Sidhi techniques (Orme-Johnson & Haynes, 1981). It also illustrates the independency of this cerebral integrating capacity parameter with regard to the amount of information to which the subject is exposed.

REM Ratio and Psychological Health: In previous research, the values of the ratio of the HF-REMs to the LF-REMs of the REM sleep came to an average of 1 to 1.4 after normal day activity (Hoffmann & Petre-Quadens, 1979; Petre- Quadens, 1980; Quadens, Green, Stott & Dequae, 1984), and rose to 2 after critical situations, such as ascending and descending with a spaceship and the accompanying stimulation of mental alertness (Quadens, Green, Stott & Dequae, 1984). The values of the REM ratio also showed a slow but distinct increase with increasing age in cross-sectional studies. In the present study, the values of the REM ratio reach an average of 1.23 in the control group and 2.54 in the experimental group. When located on that same line of increasing alertness and maturity, mentioned in previous research with regard to an increasing REM ratio, then this average of the TM-Sidhi group could be considered as a reflection of a more evolved stage in psychological health. This interpretation is supported by the doctoral research of Gelderloos (1987) in which the practitioners of the TM and TM-Sidhi program were found to score higher on five central characteristics of psychological health, including the qualities of integration of personality, autonomy, self-sufficiency, independency, control or mastery over the situation, experience of transcendence or God, orientation in life, creativity, and dynamism. The TM-Sidhi group scored consistently higher than the TM group, and the TM group consistently higher than the non-TM group.

REM Sleep Time and Efficiency of REM Sleep: The REM sleep time in the experimental group was about half of that in the control group. Taking into account that all subjects reported that they had enjoyed a normal night's rest or felt well rested in the morning, these results argue for a greater efficiency of the nocturnal REM sleep in the group of TM-Sidhi practitioners -- the more so, as during this shorter REM sleep time in the TM-Sidhi group, the density of the HF-REMs was more than three times as great as during the longer REM sleep time in the control group (Table 2), indicating a more intense cerebral assimilation of information during the REM sleep in the TM-Sidhi practitioners.

The interpretation of a more efficient REM sleep in the TM- Sidhi group would agree with the finding of Miskiman (1977), that TM practitioners need less compensatory REM sleep time after 40 hours of sleep deprivation than do control subjects. That the REM sleep time before the sleep deprivation did not differ between his two groups can be ascribed to the small number of months of TM experience of his experimental subjects (5-7 months).

REM Sleep Percentage and Sensitivity to Order: The percentage of the REM sleep time relative to the total sleep time was also notably smaller in the TM-Sidhi group than in the control group. This shows that the REM sleep is more susceptible than the total sleep is to the order- or efficiency-stimulating impact of the TM and TM-Sidhi programs. This greater sensitivity of REM sleep to a stimulus of order may be related to the already spontaneously occurring greater ordering during REM sleep, in comparison with the sleep stages 3 and 4, as was measured by Banquet (1983) in normal subjects via the EEG coherence parameter.

The smaller REM sleep percentage in the TM-Sidhi group, who at the same time gave evidence of a greater maturity via the other REM sleep parameters, is in accordance with the smaller REM sleep percentage that Hoffmann and Petre-Quadens (1979), in their study with female subjects, found associated with a greater endocrinological maturity in the luteal phase of the ovulatory cycle and in the growth from prepuberty to menopause.

Evolution of Temporal Characteristics and Maturity: Previous studies have found, as characteristics of a greater maturity, that: 1.) Cerebral order during the REM phases of sleep, expressed in the density of the HF-REMs, gradually increases in the course of sleep (Petre-Quadens, 1969; Petre-Quadens, De Lee & Remy, 1971); 2.) This increase of the density of the HF-REMs happens according to a pattern of alternately low and high values, from one REM phase to the other (Petre-Quadens, De Lee & Remy, 1971) ; 3.) The density of HF-REMs within one REM phase gradually increases, reaches a maximum in the middle of the phase, and subsequently again gradually decreases (Petre-Quadens, 1969).

About 430 research studies on TM and TM-Sidhi practitioners have found physiological, psychological, or sociological data which could be interpreted in terms of greater health and maturity (For examples and summaries, see Chalmers, Clements, Schenkluhn & Weinless, in press; Orme-Johnson & Farrow, 1977; Wallace, Orme-Johnson & Dillbeck, 1989).

In the present study, the density of the HF-REMs is greater in the second half of the sleep time than it is in the first, and this difference is more pronounced in the TM-Sidhi group. The pattern of alternately low and high values from one REM phase to the other, with which the HF-REMs density increases during the course of the night, is most clearly distinguishable in the TM-Sidhi group. The distribution of the HF-REMs within a REM phase in a pattern of gradual increase to a maximum, and then gradual decrease, is most regular in the TM-Sidhi group. All these temporal characteristics, seen in their evolution with the progress of sleep during the night, seem like indicators of the level of maturity.

Discussion of the Qualitative Results

Shape of REMs and Intelligence or Maturity: Feinberg, Braun, Shulman, and co-workers (1969) found that the REMs in mentally retarded subjects take a less clear form and are therefore more difficult to score. Petre-Quadens (1969) found that the

REMs in oligofrenic subjects (debilitas) are smaller and more difficult to identify than in normal subjects and that the REMs in pregnant women increase in amplitude with the progress of the pregnancy.

In the present study, the REMs reach a higher amplitude and are more differentiated in the experimental group than in the control group, justifying the method of qualitative observation in distinguishing intelligence and maturity.

<u>EEG Alpha Activity and Intelligence or Maturity</u>: Feinberg, Braun, Shulman, and co-workers (1969) found that the EEG alpha activity in mentally retarded subjects is poorly developed and of a lower frequency.

The TM and TM-Sidhi techniques have been found to increase in the EEG the occurrence and amplitude of alpha and theta waves (Banquet, 1973; Hebert & Lehmann, 1977; Wallace, 1970; Wallace, Benson & Wilson, 1971).

The present study shows that the subjects with a greater REM ratio have an EEG alpha activity which is more abundant and of a greater amplitude and lower frequency. This finding, again, is in accordance with the interpretation of the REM ratio as a measure for intelligence and maturity.

<u>Sleep Spindles and Cerebral Assimilation of Information</u>: Petre-Quadens (1969) found that the sleep spindles in pregnant women increase in quantity and amplitude from the 20th to the 30th week of pregnancy (after the 30th week, the same trend continues, although with fluctuations), and that the sleep spindle activity is poorly developed in debilitas children.

Feinberg and co-workers (1967; 1969) also found a poorly developed sleep spindle activity in mentally retarded adults, and in both normal and senile elderly people.

Andersen and Andersson (1968) suggested that the sleep spindles form a reflection on the level of the cortex of the rhythmical reverberation of information in the thalamocortical network with which the brain would assimilate this information. This assimilation of information takes place more efficiently when the activity of the sleep spindles can proceed in a more undisturbed manner and the electrocorticogram is more synchronized.

In the present study, the TM-Sidhi group, which has the greater REM ratio, also shows a sleep spindle activity which is more abundant and displays a higher amplitude and a lower frequency. This finding -- when taken together with the greater synchronization and coherence in the electrocorticogram and the improved cognitive and affective functioning in TM and TM-Sidhi practitioners -- agrees with the hypothesis that both sleep spindles and REM ratio reflect the cerebral assimilation of information during sleep.

REMs and Sleep Spindles and Excitation and Inhibition: It was suggested (Petre-Quadens, 1969) that the REM activity as an excitation process is kept in balance by an equivalent spindle activity which could be considered as an inhibition process, and that therefore both activities never take place at the same time.

The sleep spindles, observed during the REM bursts of REM sleep in the present study, indeed never completely coincided with the individual REMs.

Spindles, Instead of Sleep Spindles: It was stated that the activity in the thalamocortical circuits responsible for the generation of the sleep spindles would be inhibited during the waking state (Hernandez-Peon, 1965). This statement is contradictory to the present study, in which so-called "sleep spindles" or alpha spindles of 12-14 Hz were observed during the waking stage, long before the beginning of sleep.

Alpha Transition Stage and Transcendence: Immediately before and after sleep in all experimental subjects (except subject C) and in the control subject B, and immediately before and after each of the five sleep phases during the night in the experimental subject B, a kind of prolonged transition stage between normal waking and sleeping occurred

which, with its almost uninterrupted, high amplitude alpha activity and rhythmical eye movements, showed much similarity with Transcendental Meditation. This agrees with the reports of the experimental subjects in question that the degree to which the meditative state of restful alertness (here, integrated with waking) is experienced at the beginning of the sleep determines how "pleasingly" and "refreshingly" the sleep proceeds. It is also reminiscent of the vision of Maharishi Mahesh Yogi (1967; 1969); Alexander, Cranson, Boyer & Orme- Johnson, 1986) that Transcendental Meditation eventually develops in its practitioners a fourth major state of consciousness, termed "transcendental" or "pure" consciousness, which can be clearly experienced as a "continuous, fundamental reality," either in its pure form during the short transition stages between waking, dreaming and sleeping (which, by the very definition of the word "transition", can comprehend neither waking, dreaming nor sleeping), or during the states of waking, dreaming and sleeping, which are enriched thereby.

Conclusion

To conclude, the fact that all the group results of the present study, without any exception, show coherently, according to the definitions and findings of previous sleep research, a greater neurophysiological order in

the TM-Sidhi group, adds further support to the main hypothesis that the HF-REMs/LF-REMs ratio is a measure of the cerebral capacity to structure "order" out of "noise." The fact that the experimental values on this REM ratio were far higher than the values reported in the literature could be interpreted as indicating the onset of a new dimension of consciousness: a continuum of restful alertness, serving as a background of order, extending to the night's sleep. It would, therefore, deserve further investigation. One could use larger samples of subjects, extend the measurement to four consecutive nights, and score the REMs automatically (provided the necessary software is available). Perhaps one could also use subjects as their own controls before and after their start with the TM and TM-Sidhi programs, to measure more directly the role of this practice with respect to order or intelligence. If one places the EEG electrodes in a strictly standardized manner, and measures with a low-noise apparatus, one could simultaneously analyze the EEG signals for coherence or long-range spatial order in the brain.

References

Alexander, C.N., Cranson, R.W., Boyer, R.W. & Orme-Johnson, D.W. (1987). Transcendental consciousness: A fourth state of consciousness beyond sleep, dreaming and waking. In J. Gackenbach (Ed.), *Sleep and dreams: A sourcebook* (pp. 282-315). New York: Garland.

Andersen, P. & Andersson, S.A. (1986). *Physiological basis of the alpha rhythm*. New York: Appleton.

Aranya, S.H. (1963). *The yoga philosophy of Patanjali*. Calcutta: Calcutta University Press.

Aron, A., Orme-Johnson, D. & Brubaker, P. (1981). The Transcendental Meditation program in the college curriculum: A 4-year longitudinal study of effects on cognitive and affective functioning. *College Student Journal*, *15(2)*, 140-146.

Badawi, K., Wallace, R.K., Orme-Johnson, D.W. & Rouzere, A. (1984). Electrophysiologic characteristics of respiratory suspension periods occurring during the practice of the Transcendental Meditation program. *Psychosomatic Medicine*, *46(3)*, 267-276.

Banquet, J.P. (1973). Spectral analysis of the EEG in meditation. *Electroenceph. Clin. Neurophysiol.*, *35*, 143-151.

Banquet, J.P. (1983). Inter- and intrahemispheric relationships of the EEG activity during sleep in man. *Electroenceph. Clin. Neurophysiol.*, *55*, 51-59.

Banquet, J.P. & Sailhan, M. (1974, April). *Quantified EEG spectral analysis of sleep and Transcendental Meditation*. Paper presented at the second European Congress on Sleep Research, Rome, Italy.

Bujatti, M. & Riederer, P. (1976). Serotonin, noradrenaline, dopamine metabolites in Transcendental Meditation technique. *J. Neural. Trans*. *39*, 257-267.

Castaldo, V. (1969). Down's syndrome: a study of sleep patterns related to level of mental retardation. *Am. J. Ment. Defic*., *74*, 187- 190.

Chalmers, R.A., Clements, G., Schenkluhn, H. & Weinless, M. (in press). *Scientific Research on the Transcendental Meditation and TM-Sidhi Programme. Collected Papers: Volumes 2-4*. Vlodrop, The Netherlands: MIU Press.

Chevalier, B. (1982). Learning effects on paradoxical sleep in man. *Proceedings of the 6th European Congress on Sleep Research*, Zurich, p. 166.

De Lee, C. & Goffe, B. (1973). Contribution of the stochastic analysis to the study of eye movements during sleep. In W.P. Koella & P. Levin (Eds.), *Sleep: Physiology, biochemistry, psychology, pharmacology, clinical implications* (pp. 560-563). Basel: Karger.

Dillbeck, M.C., Assimakis, P.D., Raimondi, D., Orme-Johnson, D.W., & Rowe, R. (1986). Longitudinal effects of the Transcendental Meditation and TM-Sidhi program on cognitive ability and cognitive style. *Perceptual and Motor Skills, 62*, 731-738.

Dillbeck, M.C. & Bronson, E.C. (1981). Short-term longitudinal effects of the Transcendental Meditation technique on EEG power and coherence. *International Journal of Neuroscience*, *14*, 147-151.

Farrow, J.T. & Hebert, J.R. (1982). Breath suspension during the Transcendental Meditation technique. *Psychosomatic Medicine*, *44*, (2), 133-153.

Feinberg, I., Braun, M. & Shulman, E. (1969). EEG sleep patterns in mental retardation. *Electroenceph. Clin. Neurophysiol*., *27*, 128-141.

Feinberg, I., Koresko, R.L. & Heller, N. (1967). EEG sleep patterns as a function of normal and pathological aging in man. *J. Psychiat. Res., 5*, 107-144.

Gelderloos, P. (1987). *Valuation and Transcendental Meditation*. Lelystad, The Netherlands: Soma Scientific Publisher.

Hebert, R. & Lehmann, D. (1977). Theta bursts: An EEG pattern in normal subjects practising the Transcendental Meditation technique. *Electroenceph. Clin. Neurophysiol., 42*, 397-405.

Hernandez-Peon, R. (1965). Cit in: O. Petre-Quadens, Contribution a` l'etude de la phase dite paradoxale du sommeil, *Acta Neurol.Belg., 69*, 121.

Hoffmann, G. & Petre-Quadens, O. (1979). Maturation of REM-patterns from childhood to maturity. *Waking and Sleeping 3,* 255-262.

Hoffmann, G., Vanderbeken, H. & De Cock, W. (1977). Mesure des effets d'un processus stressant sur les parame`tres du sommeil. *Waking and Sleeping 1,* 375-381.

International Association for the Advancement of the Science of Creative Intelligence. (1978). *Enlightenment and invincibility*. Rheinweiler, West Germany: MERU Press.

International Association for the Advancement of the Science of Creative Intelligence. (1984). *Maharishi technology of the unified field: Results of scientific research on the Transcendental Meditation and TM-Sidhi programme*. Fairfield, Iowa: MIU Press.

Jasper, H.H. (1958). The Ten-Twenty System of the International Federation. *Electroenceph. Clin. Neurophysiol., 10,* 371.

Kobal, G., Wandhofer, A. & Plattig, K.H. (1975). EEG power spectra and auditory evoked potentials in Transcendental Meditation (TM). *Pflugers Archiv, 359,* R 96. (Abstract No. 191).

Kochabhakdi, N.J. & Chentanez, C. (1980, January). Paper presented at International Congress, Research on Higher States of Consciousness, Bangkok, Thailand.

Levine, P.H. (1976). The coherence spectral array (COSPAR) and its application to the study of spatial ordering in the EEG. *Proceedings of the San Diego Biomedical Symposium, 15,* 237-247.

Maharishi Mahesh Yogi. (1967). *The science of being and art of living*. Fairfield, Iowa: MIU Press.

Maharishi Mahesh Yogi. (1969). *On the Bhagavad-Gita: A new translation and commentary*. Baltimore: Penguin Press.

McEvoy, T.M., Frumkin, L.R. & Harkins, S.W. (1980). Effects of meditation on brainstem auditory evoked potentials. *International Journal of Neuroscience, 10,* 165-170.

Miskiman, D.E. (1977). The effect on the Transcendental Meditation program on compensatory paradoxical sleep. In D.W. Orme-

Johnson & J.T. Farrow (Eds.), *Scientific research on the Transcendental Meditation program. Collected papers* (Vol 1, pp. 292-295). Rheinweiler, West Germany: MERU Press.

Orme-Johnson, D.W. & Farrow, J.T. (Eds.). (1977). *Scientific research on the Transcendental Meditation program. Collected papers: Volume 1.* Livingston Manor, New York: MERU Press.

Orme-Johnson, D.W. & Haynes, C.T. (1981). EEG phase coherence, pure consciousness, creativity, and TM-Sidhi experiences. *International Journal of Neuroscience, 13,* 211-217.

Petre-Quadens, O. (1967). Ontogenesis of paradoxical sleep in the human newborn. *Journal of Neurological Science, 4,* 153-157.

Petre-Quadens, O. (1969). Contribution a` l'etude de la phase dite paradoxale du sommeil. *Acta Neurol. Belg., 69,* 769-898.

Petre-Quadens, O. (1978). Logic and ontogenesis of some sleep patterns. *Totus Homo, 10(8),* 15-19, 60-72.

Petre-Quadens, O. (1980). Physiologie du sommeil et environnement. *Totus Homo 12(10),* 14-22.

Petre-Quadens, O. & De Lee, C. (1974). Eye movement frequencies and related paradoxical sleep cycles: Developmental changes. *Chronobiologia, 1,* 348-355.

Petre-Quadens, O., De Lee, C. & Remy, M. (1971). Eye movement density during sleep and brain maturation. *Brain Res., 26,* 49-56.

Prasada, R. (1978). *Patanjali's yoga sutras.* New Delhi: Oriental Books Reprint Corporation.

Quadens, O. & Green, H. (1984). Eye movements during sleep in weightlessness. *Science, 225,* 221-222.

Quadens, O., Green, H.L., Stott, S.F.D. & Dequae, P.A. (1984). Eye movements during sleep and EEG in zero-gravity. *35th Congress of the International Astronautical Federation,* 192.

Rechtschaffen, A. & Kales, A. (Eds). (1968). *A manual of standardized terminology, techniques, and scoring system for sleep stages of human subjects.* U.S. Government Printing Office.

Wallace, R.K. (1970). Physiological effects of Transcendental Meditation. *Science, 167*, 1751-1754.

Wallace, R.K. (1987). *The Maharishi technology of the unified field: The neurophysiology of enlightenment*. Fairfield, Iowa: MIU Press.

Wallace, R.K., Benson, H. & Wilson, A.F. (1971). A wakeful hypometabolic physiologic state. *American Journal of Physiology, 221*, 795-799.

Wallace, R.K., Orme-Johnson, D.W. & Dillbeck, M.C. (Eds.). (1989). *Scientific research on Maharishi's Transcendental Meditation and TM-Sidhi program. Collected Papers: Volume 5.* Fairfield, Iowa: MIU Press.

Wandhofer, A., Kobal, G. & Plattig, K.H. (1976). Shortening of latencies of human auditory evoked brain potentials during the Transcendental Meditation technique. *Zeitschrift fur Elektroenzephalographie und Elektromyographie, 7*, 99- 103.

Warner, T.Q. (1986). Transcendental Meditation and developmental advancement: Mediating abilities and conservation performance. *Dissertation Abstracts International, 47,* 3558-B.

Wuttke, W., Arnold, P., Becker, D., Creutzfeldt O, Langenstein, S. & Tirsch, W. (1975). Circulating hormones, EEG, and performance in psychological tests of women with and without oral contraceptives. *Psychoneuroendocrinol., 1*, 141-152.

[i] I wish to thank Dr. O. Petre-Quadens for the valuable discussions about REM sleep research and TM-Sidhi research, her assistant-engineer P. Dequae, and Dr. G. Tangelder for the practical advice regarding the measurement and the analysis of the data, G. Gerritsma for measuring both the control subjects and the author, and G. van Gasteren for

---

technical assistance throughout the research project. I also wish to express my gratitude to Oxford Instruments (Rijswijk) and the EEG department of the Kempenhaeghe Epilepsy Center (Heeze) for permitting us to freely use their EEG equipment, and the Foundation for Scientific Education (SWOL; Limburg) and several private individuals for their financial support.

[ii] "Witnessing" one's own sleep is said to be the most unambiguous subjective indicator that the transcendental state, characterized by maximum restful alertness, can be maintained even during the inertia of deep sleep (Maharishi Mahesh Yogi, 1969). [EDITORS NOTE: For a discussion of the relationship between lucid dreaming and witnessing ones sleep see the panel discussion in this issue of *Lucidity Letter* on Lucid Dreaming and Higher States of Consciousness.]