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ABSTRACT

Through observation of 26 subjects over a 3 month period, this research project measured the effects of transcendental meditation (TM) on concurrent heart rate, peripheral blood pulse volume, and the alpha wave frequency. The subjects were assigned randomly to three groups. One group practiced TM as prescribed by the International Meditation Society; another followed the meditation procedure but used an English mock mantra; the third made no change in daily routine. Two "blind" measurements were made of subjects before they learned and began their respective procedures and one measurement a month for three months during practice of thier procedures. Experimental results suggested that: (1) practice of TM or routine daily rests over a 3-month period had little effect on heart rate or peripheral blood pulse volumes; (2) when compared with practicing routine rest over 3 months, practicing TM appears to have little effect on, or possibly reduces, the relative frequency of appearance of the parietal alpha rhythm; and (3) there is some suggestion that practice of TM for 3 months may instill a state similar to that of sleep stage 1 during the meditating period. (Author/NM)

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THE EFFECTS OF TM ON CONCURRENT HEART RATE, PERIPHERAL BLOOD PULSE VOLUME, AND THE ALPHA WAVE FREQUENCY

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Brief Description of the Procedure*

Twenty-six subjects, assigned randomly to one of three groups, were observed over a three month period, during which time the groups practiced one of three procedures. Fourteen subjects practiced transcendental meditation (TM_1 group)† as prescribed by the International Meditation Society; a second group of seven followed the meditation procedure as closely as possible, except that they thought about or repeated a mock mantra in English. This group (CA_1 - active control), as well as the third group (CP_1 - passive control), attended weekly group sessions to encourage them to continue their procedures and to discuss subjective phenomena that may have occurred during their procedures. The five subjects comprising the last group (CP_1) were not asked to change their daily routine in any way; they simply reported for the physiological measurement sessions but did not practice any form of actual or mock meditation.

The subjects were measured twice (once a month) before learning of and beginning their respective procedures, and once a month for three months

*The papers by Leon Otis and Arthur Vassiliadis presented on August 24, 1973 at the APA meeting contain more complete descriptions of the procedures.

†The subscript 1 refers to subjects whose physiological measures underwent the analyses described herein, while subscript 2 refers to the analytic techniques of Vassiliadis.

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during practice of their procedures. Typically the measures were obtained about every 30 days. Thus, in the tables presented later under "Results," session 2 measures were obtained just before the subjects began their procedures, and session 5 measures were obtained after the subjects had been practicing the TM or control procedures for about 90 days.

Each measurement session consisted of the five sequential test periods: Eyes Open, Eyes Closed, Rest or TM, Eyes Closed, and Eyes Open. Each of the "Eyes Open" and Eyes Closed" periods was about 10 minutes long, and the "Rest or TM" period lasted about 20 minutes.

Data Analysis

It is important to note that scoring of the records for heart rate, blood pressure volume, alpha frequency, and sleep stage 1 was done in the "blind" by individuals who have had much relevant experience. For example, the individual who scored the records for alpha content and sleep stage 1 has been scoring sleep EEG records for about five years. Scoring records in the "blind" is important since it precludes the scorer from reading the records in favor of some preconceived notions. The scorers had no information about which particular record belonged to which particular subject, when it was obtained, or what a particular session might mean in terms of its significance to the experimental design.

The measurements were made on each subject in each session during two 40-second epochs near the middle of each of the Eyes Open and Eyes Closed periods and four non-contiguous 40-second epochs near the middle of the Rest or TM period. Epochs near the middle of the periods were selected to minimize possible effects of sudden verbal instructions (presented at the beginning of each period), or movements and changes in the subjects "sets" when they may have been anticipating a change in instructions, or spontaneous changes resulting from boredom or fatigue that seemed more likely near the end of a period. On occasion the record originally selected was unusable for one reason or another, in which case the next closest 40-second epoch was selected for analysis. The records for each session for each pair of subjects were then coded, scrambled, and passed on to the scorers for the analyses described below.

A. Heart Rate

For each subject each 40-second epoch was subdivided into two 20-second subperiods, and the number of beats were counted for each subperiod. Each subject's heart rate for any particular test period was the average derived from the number of 20-second subperiods selected for that particular test period: four in each of the Eyes Open and Eyes Closed test periods, and eight from the Rest or TM period.

B. Blood Pulse Volume

Every fifth pulse (i.e., approximately once every 5 seconds) in each 40-second epoch was measured, summed, and averaged over the number of pulses measured (16 for each Eyes Open and Eyes Closed test periods, and 32 for the Rest or TM test period). This technique for selecting the pulses to be measured apparently prevented a bias from entering into the results because (1) the 40-second epochs studied were effectively random since unscorable records were discarded and since there was some uncertainty of exactly where a particular test period began, (2) if the selected pulse could not be measured the nearest measurable pulse before or after it was measured, and every fifth pulse thereafter was measured, and (3) if fractional parts of a pulse began the epoch, these parts were ignored and the next full pulse was counted.

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C. Alpha Frequency

The alpha frequency is the total number of 1/2-second intervals of unambiguous alpha activity found in the epochs of each test period. Such activity is defined as brain waves of 9-11 Hz emanating from the parietal area with respect to the contralateral ear lobe, with the wave frequency readily discernable throughout the 1/2-second. A single individual scored all the alpha records, but some ten epochs selected from the records of the different test subjects were scored independently by two scorers. In this test of scorer reliability, 95 percent of the 1/2-second intervals were scored identically by both scorers with respect to unambiguousness of alpha activity.

Results

A. Heart Rate and Peripheral Blood Pulse Volume

In general only slight and statistically insignificant differences were obtained between the TM and control groups with respect to heart rate (HR) and blood pulse volume (BPV). The data supporting this conclusion are discussed below. However, it should be noted initially that the data of groups CA_1 and CP_1 were combined because the number of subjects in both groups was small (7 and 5 respectively), and combining them would increase the representativeness of the results.

1. With respect to the initial measure of heart rate (arbitrarily set at zero during the first Eyes Open test period) the largest changes were found in the control groups (CA_1 and CP_1) during the test periods of session 5. As illustrated in Table 1, the most notable changes in heart rate (on the average) occurred during the second Eyes Closed condition, that is, immediately after the 20-minute Rest or TM period; the control groups also showed a larger decrease in HR in all the

Table 1

ALGEBRAIC SUM OF CHANGES IN HEART RATE
WITH RESPECT TO THE INITIAL EYES-OPEN RATE OF EACH SESSION.
(The changes for each subject were measured with respect to his own initial heart rate.)

Group (N)	Session (No. of data points)	Session Period (Sequence of Test Periods)				
		Eyes Open	Eyes Closed	Rest or TM	Eyes Closed	Eyes Open
CA_1 and CP_1 (12)	2 (12)	0	-6.5	-6.7	-3.5	-3.0
	5 (10*)	0	-6.5	-9.9	-14.8	-4.3
TM_1 (14)	2 (14)	0	-8.6	-8.2	-10.8	-9.1
	5 (14)	0	-0.5	-6.7	-10.0	-3.3
Average Change			-5.5	-7.9	- 9.8	-4.9

*Data from two subjects unscorable

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Table 2

MEAN HEART RATES DURING TWO TEST PERIODS OF TWO SESSIONS
(Beats per 20 seconds)

Session	Test Period	Group	Mean	N	Standard Deviation	t
2	First Eyes Open	CA_1 and CP_1	23.46	12	2.50	0.440 N.S.*
		TM_1	22.93	14	3.61	
	Rest	CA_1 and CP_1	22.63	12	2.54	0.238 N.S.
		TM_1	22.37	14	3.04	
5	First Eyes Open	CA_1 and CP_1	25.38	10	3.28	1.611 N.S.
		TM_1	23.21	14	3.21	
	Rest or TM	CA_1 and CP_1	24.39	10	3.51	1.248 N.S.
		TM_1	22.66	14	3.11	

*Not statistically significant.

periods of session 5 than did the TM group. In part, these results may reflect the "law of initial values." The initial HR of the control subjects (see Table 2) was about six beats per minute higher during session 5 than during session 2, while that of the TM subjects was only about one beat faster; thus a larger change was possible in the control groups.

Although a detailed analysis of the BPV of each subject has not been conducted, inspection of the data suggests that the BPV levels were at their lowest--that is, greatest dilation of the peripheral vascular system--during the second Eyes Closed test periods, i.e., coincident with slowest heart rates.

2. Analysis of the average HR and BPV indicated that the groups had almost identical HRs and BPVs during the first Eyes Open period of session 2 and session 5. Similar results were obtained with respect to these measures during the Rest or TM period of sessions 2 and 5. These data are presented in Tables 2 and 3.

3. The mean heart rate and blood pulse volume obtained by both the TM and control groups during the first Eyes Open period of session 5 were compared statistically with those obtained during the Rest or TM period of session 5; no significant differences were found (the t's obtained were about 0.5 for both measures).

B. Alpha Wave Frequency

The distributions of 1/2-second intervals of unambiguous parietal alpha during the test periods of session 2 were significantly different. The total number of 1/2-second epochs available for analysis are shown in Table 4, and Table 5 shows the measured 1/2-second intervals of unambiguous alpha as a percentage of this total. It will be seen

Table 3

MEAN BLOOD PULSE VOLUME AMPLITUDE
DURING TWO TEST PERIODS OF TWO SESSIONS
(Millimeters)

Session	Test Period	Group	Mean	N	Standard Deviation	t
2	First Eyes Open	CA_1 and CP_1	10.84✓	12	3.98	0.746 N.S.*
		TM_1	9.67	13	3.85	
	Rest or TM	CA_1 and CP_1	10.12	12	4.75	0.734 N.S.
		TM_1	11.40	14	4.03	
5	First Eyes Open	CA_1 and CP_1	10.58	10	3.88	0.052 N.S.
		TM_1	10.67	14	4.56	
	Rest or TM	CA_1 and CP_1	8.74	10	4.11	0.569 N.S.
		TM_1	9.76	14	4.61	

*Not statistically significant

✓The Blood Pulse Volume Transducer operates in such a way that its output amplitude is inversely related to pulse amplitude; increases in transducer output indicate vasoconstriction.

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Table 4

TOTAL NUMBER OF ONE-HALF SECOND INTERVALS ANALYZED FOR UNAMBIGUOUS ALPHA (9-11 Hz) Activity

Group	No. of Subjects	Test Period: Eyes Open (1st & 2nd)	Test Period: Eyes Closed (1st & 2nd)	Test Period: Rest or TM
CA_1	7	1120	1120	2240
CP_1	5	800	800	1600
TM_1	14	2240	2240	4480

Table 5

PERCENTAGE OF ONE-HALF SECOND INTERVALS SHOWING UNAMBIGUOUS ALPHA (9-11 Hz) ACTIVITY DURING SESSION 2

Group	Test Period					Average Number of One-Half Second Intervals/Subject
	Eyes Open	Eyes Closed	Rest	Eyes Open	Eyes Closed	
CA_1	3.2	12.5	7.9	18.0	5.0	87.1
CP_1	0.4	2.4	3.3	4.0	0	21.4
TM_1	0.5	3.7	4.4	10.1	0.5	37.7

$X^2 = 73.27$, 8 df, $p < 0.001$

in the right-hand column of Table 5 that the "alpha producers" of group CA_1 produced significantly more alpha than did those of groups CP_1 or TM_1. (Alpha producers are individuals who characteristically generate alpha waves when relaxed with their eyes closed.) Among the 26 subjects, ten (five in the TM_1 and a total of five in the control groups) did not produce any alpha with eyes closed, but two of the ten (one a TM_1 subject and one a control) showed some alpha activity during the Eyes Closed periods of session 5.

In general during session 2, the subjects attained more alpha in the second Eyes Closed test period than they did in the first. Group CA_1 showed significantly more 1/2-second intervals of alpha than did either TM_1 of CP_1. In contrast, during session 5, all the groups showed increases in the amount of alpha (see Table 6). The smallest gains (see the last column of Table 6) were observed in group CA_1 who had comparatively high levels during session 2, while the largest gains (up 313 percent) were found in group CP_1. The TM_1 group showed a gain of 93.6 percent in alpha activity between sessions 2 and 5.

More important than the gains in absolute frequency of alpha, however, may be the shifts in the distribution of alpha between sessions 2 and 5. As seen in Table 7, the two control groups showed significant increases in alpha during the rest period of session 5, compared with their frequencies during session 2. The TM_1 group, however, showed a decrease in the frequency during the Rest or TM period of session 5, compared with the frequency obtained during session 2.

To insure that the results reported in Tables 5 and 6 were not due to some chance occurrence (such as one subject suddenly and inexplicably showing a great deal of alpha, while another subject suddenly

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Table 6

PERCENTAGE OF ONE-HALF SECOND INTERVALS
SHOWING UNAMBIGUOUS ALPHA (9-11 Hz) ACTIVITY DURING SESSION 5

Group	Test Period					Average Number of One-Half Second Intervals	% Increase over Session 2
	Eyes Open	Eyes Closed	Rest or TM	Eyes Closed	Eyes Open		
CA_1	5.4	16.5	17.9	13.9	7.1	126.0	44.6
CP_1	0.4	9.8	19.7	4.9	0.9	88.4	313.1
TM_1	0.6	11.4	5.9	15.6	6.3	73.0	93.6

$X^2 = 373.24$, 8 df, $p < 0.001$

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Table 7

FREQUENCY OF ONE-HALF SECOND INTERVALS OF UNAMBIGUOUS ALPHA (9-11 Hz) DURING SESSION 2 AND 7 IN THE THREE TEST GROUPS

Group	Session	Test Period					X^2	p
		Eyes Open	Eyes Closed	Rest or TM	Eyes Closed	Eyes Open		
CA_1	2	36 5.9%	140 23.0%	176 28.9%	202 33.1%	56 9.2%	62.74	0.001
	5	61 6.9%	185 21.0%	401 45.5%	156 17.7%	79 9.0%		
CP_1	2	3 2.8%	19 17.8%	53 49.5%	32 30.0%	0 0%	40.93	0.001
	5	3 0.7%	78 17.6%	315 71.3%	39 8.8%	7 1.6%		
TM_1	2	12 2.3%	82 15.5%	197 37.3%	226 42.8%	11 2.1%	87.12	0.001
	5	14 1.4%	256 25.0%	263 25.7%	349 34.1%	140 13.7%		

lost alpha), the data were normalized for each subject, as described below. It would have been advantageous if each alpha-producing subject showed some alpha during the first Eyes Closed test period of session 2; however, this was not the case. Therefore, the average percentage of alpha (number of 1/2-second intervals with alpha in the total number of 1/2-second intervals possible) occurring during the six test periods (the first Eyes Closed, the Rest or TM, and the second Eyes Closed periods of both sessions 2 and 5) was calculated for each subject, and this percentage was divided into the subject's percentage of alpha obtained during each test period of sessions 2 and 5. The resulting number is, in effect, the fractional part of alpha the subject obtained in any particular test period with reference to the total amount of alpha he obtained during those segments of the two sessions during which his eyes were closed. The results of this analysis, averaged over the number of subjects in the group, are presented in Table 8. It is seen there that in the CA_1 and CP_1 groups, the average normalized frequency of alpha during the Rest or TM period of session 5 was greater than it was during session 2, but in the TM_1 group the normalized frequency of alpha was only slightly higher (about 0.07) during the Rest or TM period of session 5 than it was in session 2. In addition, the control groups showed more alpha during the Rest or TM period of session 5 than they did during the Eyes Closed periods, while the TM_1 group showed less alpha during the meditation period. It may be noted that the distribution of average normalized frequencies between the different test periods in the two sessions for each group is in the same direction as was found for the average percentage of alpha (Tables 5 and 6).

The meditational state may be similar to sleep stage 1, as indicated by the increase in frequency of alpha shown in the control groups compared with its decrease in the TM group after practicing meditation

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Table 8

AVERAGE OF RATIOS OF ONE-HALF SECOND INTERVALS
OF UNAMBIGUOUS ALPHA (9-11 Hz) ACTIVITY IN EACH TEST PERIOD
TO THE TOTAL PERCENTAGE OF THE ALPHA INTERVALS OBSERVED
IN EACH SUBJECT DURING EYES-CLOSED TEST CONDITIONS

Group	Session	Test Period				
		Eyes Open	Eyes Closed	Rest or TM	Eyes Closed	Eyes Open
CA_1	2	.22	.90	.51	.78	.24
	5	.23	.69	.79	.62	.32
CP_1	2	.13	.40	.57	.16	0
	5	.13	.92	1.1	.47	.19
TM_1	2	.04	.43	.36	.74	.02
	5	.10	1.03	.43	1.31	.90

for about three months (Table 7), and by some of the subjective, i.e., phenomenal, effects reported by meditators. In order to test this hypothesis the records of the 40-second epoch of each subject were scored dichotomously as to whether or not sleep stage 1 was observable. The results, shown in Table 9, indicate that the EEGs of the meditator group were more frequently scored as sleep stage 1 than were the EEGs of non-meditators. During session 5, the percentage of epochs scored as sleep stage 1 increased on the average over the percentage during session 2. However, a comparison of percentages during the Rest or TM period of the two sessions shows that the percentage of epochs scored as sleep stage 1 more than doubled for the meditators from sesson 2 to session 5, whereas for the controls, the percentage during session 5 was only 1-1/2 that of session 2. Moreover, ten of the TM_1 subjects showed sleep stage 1 EEG during the Rest or TM period of session 5 whereas only 4 of the controls did so. Fisher's exact test* indicates a statistical probability of 0.05 that 10 of 14 TM subjects would obtain at least one epoch scored as sleep stage 1 during the Rest or TM period of session 5, compared with 4 of the 12 control subjects. It appears, therefore, that during the Rest or TM period of session 5, a significantly larger number of meditators obtained at least one 40-second epoch of sleep stage 1 than did the control subjects.

Discussion

On the whole, the results reported herein do not support those reported by Wallace.† It may be argued with some justification that

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*S. Siegel, Nonparametric Statistics for the Behavioral Sciences, pp. 96-101 (McGraw-Hill Book Company, New York, New York, 1956).

†R. K. Wallace, "The Physiological Effects of Transcendental Meditation: A Proposed Fourth Major State of Consciousness," Ph.D. dissertation, submitted to Department of Physiology, UCLA, Los Angeles, California (June 1970).

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Table 9

PERCENTAGE OF 40-SECOND EPOCHS
IN WHICH SUBJECT'S EEGs WERE SCORED AS BEING SLEEP STAGE 1

Group	Session	Test Period			Number Epochs in each Test Period	Number Subjects Showing Stage 1
		Eyes Closed	Rest or TM	Eyes Closed		
CA_1 and CP_1 (12 Sub)	2	12.5	14.6	4.2	48	4
	5	16.7	22.9	25.0	48	9
TM_1 (14 Sub)	2	14.3	16.1	7.1	56	5
	5	25.0	39.3	14.3	56	12

since Wallace's subjects had been meditating much longer (about 33 months on the average, compared with the three months of our subjects), similar results are not to be expected. However, our control subjects were observed for the same span of time as were the TM subjects, and one might anticipate that some shifts in the physiological measures of the TM subjects would be larger than those of the controls and in the direction observed by Wallace.

Clearly this was not the case. The controls, on the average, showed greater slowing in heart rate during the course of the fifth session than was found in the meditation group. Wallace, in contrast, reported an average decrease of almost five beats per minute in 11 meditators, with little change in a group of controls.

With respect to peripheral blood pulse volume, our TM_1 subjects showed slightly greater vasoconstriction (increased adrenaline and stress, presumably) than did the controls during the Rest or TM period of session 5. In fact, the control groups showed greater vasodilation during the couse of session 5 than did the TM_1 group; between the Eyes Open and the Rest or TM periods of session 5, the control groups obtained a vasodilation proportional to about 1.8 mm of pen deflection while the TM_1 group obtained about one-half (0.9 mm) that deflection. Presumably, therefore, the blood pressure of the control groups dropped more during session 5 than did that of the TM_1 subjects. Further, if we compare the pulse volumes of the controls and meditators during the Eyes Open periods (a condition similar to that when the blood pressures were actually obtained) of sessions 2 and 5, a similar conclusion is reached: the average blood pressure of the TM group, if it had been measured simultaneously with blood volume, should have increased (from about 9.7 to about 10.7 mm of deflection) while that of the control should have remained the same or dropped slightly (from about 10.8 mm during session 2 to about

10.6 mm during session 5). It must not be presumed that changes suggested above will be or are reflected in actual and long lasting blood pressure changes, since many factors determine such changes, and the innocuous procedures followed by our subjects are unlikely to have produced significant or long lasting changes.

Wallace reported slow alpha waves (8-9 Hz) to "increase in intensity... in the central and frontal regions" in experienced meditators during meditation. Our results indicate that, after three months of practice, meditators show a reduction in the frequency of 1/2-second intervals of unambiguous parietal alpha during the meditation period compared with the Eyes Closed periods. Both control groups, on the other hand, showed increases in the frequency of alpha during their Rest period, i.e., a period analogous to the meditation period. Of greater importance, however, may be the finding that the passive control group, who followed no special procedure of rest or meditation during this experiment, showed the greatest increases in the frequency of alpha intervals. This finding, and the general increase in frequency of alpha in the three groups throughout the test periods of session 2, and the general trends noted in Wallace's data (see below) suggest that, in part, the findings of Wallace may be attributed to a rapid accommodation, on the part of his subjects, to the laboratory and/or the measurement procedures.

It is worthwhile to note here that Wallace used the first of two control period measures (precontrol, in his terminology) as a comparative data point with respect to the middle of three meditation period values. Since the sequential mean values of the two measurements he obtained during the control period typically were changing in the direction (up or down) observed during meditation, it appears that the use of the first measure of the control period as a reference point biased his data analysis to maximize the probability of finding statistically significant differences.