

Psychophysiological Correlates of the Practice of Tantric Yoga Meditation

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• **Autonomic and electroencephalographic (EEG) correlates of Tantric Yoga meditation were studied in three groups of subjects as they progressed from normal consciousness into meditation. Groups differed in their level of meditation proficiency. Measures of skin resistance, heart rate, respiration, autonomic orienting response, resting EEG, EEG alpha and theta frequencies, sleep-scored EEG, averaged evoked responses, and subjective experience were employed.**

Unlike most previously reported meditation studies, proficient meditators demonstrated increased autonomic activation during meditation while unexperienced meditators demonstrated autonomic relaxation. During meditation, proficient meditators demonstrated increased alpha and theta power, minimal evidence of EEG-defined sleep, and decreased autonomic orienting to external stimulation. An episode of sudden autonomic activation was observed that was characterized by the meditator as an approach to the Yogic ecstatic state of intense concentration. These findings challenge the current "relaxation" model of meditative states.

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Meditation research since 1970 has been almost exclusively concerned with studies of Transcendental Meditation (TM), which uses techniques drawn from the Vedic tradition in India. As presented to the American public, TM employs a single-stage meditation during which the subjects sits quietly with eyes closed for 20 minutes twice a day and mentally repeats a specifically chosen Sanskrit word or *mantra*. The simplicity and uniformity of the technique make it relatively easy to teach. No philosophic or religious commitment is required of the practitioner. The TM meditation technique appears to have been chosen for its particular relaxing qualities; the now volumi-

nous research literature documents a physiological state of deep relaxation characterized by lowered autonomic nervous system arousal and by a relative deactivation of the electroencephalograph (EEG), resulting typically in a shift to the higher voltage, slower frequencies of alpha and theta.¹⁻³ High frequency beta activity has been occasionally observed,³ but the bulk of the reported findings present an EEG picture similar to drowsiness or stage 1 sleep.

With the exception of two field studies of Yoga in India by Das and Gastaut⁴ and Wenger and Bagchi,⁵ all researched meditations including Zazen and Indian Yoga appear similar to TM since they tend to produce states of lowered autonomic arousal and EEG deactivation. This convergence of EEG and autonomic findings supports the contention that meditation is primarily a state of deep physiological relaxation. The major reviews of the meditation literature by Kanellakos and Lukas,⁶ Woolfolk,⁷ and Davidson⁸ take this position.

However, the exceptions deserve further scrutiny. Das and Gastaut⁴ studied the meditations of seven highly experienced Yogis during Krya Yoga meditation, and reported clear signs of autonomic arousal and EEG activation, most pronounced during the deepest meditations of the most experienced subjects. They concluded that the techniques studied represented a state of intense concentration of attention that was probably not attained in Western students of Yoga. Wenger and Bagchi⁵ reported autonomic activation with increased heart rate and skin conductance during the meditation of four Yoga students and five older Yogis. The more advanced subjects demonstrated greater autonomic activation. The EEG results were unremarkable. They commented that meditation was an active process for the Yogis who demonstrated autonomic activation, not a passive relaxed contemplation. Taken together, these two studies characterize meditation in a distinctly different light than the relaxation model of meditation. They suggest that meditative techniques involving active concentration may produce physiological

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activation when performed by very experienced subjects. This is in contrast to the relaxation reported in studies of meditation techniques that are relatively more passive and that typically have been practiced by less experienced meditators.

It should be emphasized that there is a wide diversity in India among schools of Yoga and their various meditational techniques. Previous studies have failed to clearly define the nature of techniques under scrutiny. Often subjects appear to have been chosen on the basis of a global assessment of competence in "Yogic meditation." Thus, studies of Indian Yoga may have lumped together practitioners of techniques that produced distinctly different physiological changes. It is probably inadequate to conceptualize Indian "Yogic Meditation" as a unitary discipline such as Zen or TM.

For the above reasons, we chose to study Tantric Yoga, a type of meditation that seemed to clearly involve intense concentration of attention and the subjective sense of an ongoing struggle to achieve the ultimate union with the object of concentration and total self-absorption (*Samādhi*). The Tantric tradition has ancient roots that may antedate Yoga, but it has now been incorporated into the *Bhakti* or devotional tradition in Yoga. The Tantric tradition emphasizes that all the energies of the organism are potentially capable of transformation into the spiritual energy of union with the object of devotion. It is probable that the Kriya meditators studied by Das and Gastaut⁴ were from the Tantric tradition since their techniques utilized Tantric concepts of *kundalini* (spinal energy source) and *chakras* (spinal energy sites).

This study investigates a type of Tantric meditation practiced by Ananda Marga, which characterizes itself as an international society dedicated to the achievement of both social and individual spiritual goals. A considerable personal commitment is expected of the members. There is an emphasis on the ongoing relationship between the meditator and the Guru, or spiritual master. Advanced students meditate several hours a day. There are six lessons of progressively more advanced meditational techniques taught by traveling teachers or *Acharias*. Ananda Marga practitioners often report the subjective sense of energy discharges or "rushes" at times during these meditations. Ananda Marga is currently practiced in 50 countries and is active in India. There are an estimated 100,000 practitioners.

This study conceptualized meditation as a set of techniques designed to improve the meditator's ability to concentrate attention and to direct its focus either inward or outward. With extended practice of meditation, one could be expected to demonstrate increased control over these dimensions of attention. We compared three carefully balanced groups of subjects that differed only in their prior experience with Ananda Marga meditation techniques. This study is unique in that a relatively large number of extremely proficient meditators were employed, and its design required the control group to actually perform meditation techniques similar to the techniques used by the experienced meditators. This rigorous control allowed differences between groups that emerged during meditation to be attributed to the effects

of prolonged practice of meditation, rather than to the effects of the meditation techniques per se.

METHODS

Three groups of ten experimentally naive subjects (four women and six men) were paid to participate in the study. College student controls (mean age, 22.9 years) had no previous experience with meditation or attention control training. Trainees (mean age, 23.7 years) were recruited from the Ananda Marga Regional Training Center. They had been meditating for an average of 2.1 years and were meditating an average of 3.1 hours a day when studied. Experts (mean age, 25.8 years) were chosen by Ananda Marga as the ten most proficient meditators in the San Francisco area. They had been meditating for an average of 4.4 years and were meditating for an average of 3.4 hours a day when studied. All had met the spiritual leader of Ananda Marga during visits to India, and had received the most advanced set of meditation techniques. All subjects attended a laboratory orientation prior to the recording session and were asked to not use any drugs during the three days before the recording session. Informed consent was obtained after the nature of the procedures was fully explained.

For the recording session, subjects sat alone in a dimly lit, sound-attenuated room. Meditators sat in the half-lotus posture. Controls sat upright in a comfortable chair. A device that produced white noise when tipped by 45° was attached to the subject's head to signal overt sleep during the session.

Each subject received three 20-minute tone sequences with different instructions for each sequence. Each sequence consisted of 55-dB, 100-msec tones with a 10-msec rise-fall time presented at 1-second intervals by an overhead speaker. Within the sequence, an infrequent different frequency tone randomly replaced the frequent background tones with a ratio of 1:15 and occurred at intervals of 10 to 20 seconds. Frequencies of background and infrequent tones were either 500 or 800 Hz, balanced for order across subjects. These tones were presented to elicit cortical evoked potentials. Also, four 70-dB, 400-msec, white noise bursts were presented at approximately four-minute intervals to elicit the autonomic orienting response. A continuous 40-dB white noise masked extraneous laboratory sounds.

The three instruction conditions were designed to induce three states of consciousness. Condition order was fixed. Condition 1 was a baseline state of relaxed normal consciousness. Subjects were told to relax and pay attention to the background tone sequence. Condition 2 was a "withdrawal condition," taught by Ananda Marga as a preparation for meditation. Subjects were told to ignore external stimuli and pay attention to their breathing. Condition 3 was the Ananda Marga meditative state. Subjects were told to ignore external stimuli, pay attention to their breathing, and silently repeat a two-syllable word in phase with their breathing. Controls chose their own word, while meditators used their personal *mantras*, Sanskrit words chosen for this purpose by their meditation teachers. Instructions were read over an intercom to the subject before each tone sequence. After the recording session, subjects filled out a questionnaire dealing with their subjective experience during the sessions. Meditators rated the quality of their meditation on a ten-point scale. Room temperature was measured and sessions were conducted at either 4 or 6 PM, balanced for order across groups.

The EEG was recorded with subdermal pins (C_z referenced to joined mastoids) for frequency, evoked response, and sleep stage analysis.¹⁰ The EEG and electro-oculogram (EOG) were recorded and amplified as described in previous publications.⁹ Heart rate was recorded with Ag-AgCl disk electrodes using a lead II configuration, and amplified for FM tape recording. Skin resistance was recorded with Ag-AgCl disk electrodes (thenar eminence referenced to the abraded ventral forearm). The signal was passed through a skin resistance coupler adjusted for a

constant current density of 10 $\mu\text{amp}/\text{sq cm}$. A forehead disk electrode grounded the subject. Respiration rate and depth were recorded from a midthoracic strain gauge whose signal was passed through a strain gauge coupler. All signals were recorded on a multichannel FM tape recorder for subsequent analysis and printout on paper charts. Conductive electrolyte electrode paste was used except for the skin resistance measure in which water-soluble lubricating jelly was used.

Data Analysis

Galvanic skin response (GSR) data were scored from the output of a coupler that combined resistance base level and resistance response on a single channel. Base level was averaged for each five-minute period and expressed as \log_{10} skin conductance. Spontaneous responses greater than 1 kohm (excluding responses occurring within one minute of the start of each condition or of the presentation of the orienting stimuli) were summed over each condition. The GSR orienting responses, defined as the maximum decrease in resistance within ten seconds of the orienting stimuli, were measured in kohms and expressed as a change \log_{10} conductance score ($\log_{10} \text{conductance}_{\text{max}} - \log_{10} \text{conductance}_{\text{min}}$). Respiratory rate and amplitude were determined by averaging one-minute samples from each five-minute epoch of each condition. Heart rate base level was determined by averaging the number of QRS complexes in a 60-second sample of each 90-second epoch of each condition. Heart rate orienting response was determined by subtracting the mean velocity of the three heart beats before the orienting stimulus from the velocity of each of nine beats following it. The resulting heart rate profiles for each of the four orienting stimuli were averaged, yielding a single profile for each subject in each condition. Theta and alpha frequencies of the EEG were quantified by passing the EEG signal through band-pass filters (effective dropoff, -48 dB per octave) centered at 6 and 11 Hz, and through resetting integrators to yield alpha and theta power. The EEG and EOG responses to 512 frequent and 80 infrequent tones were summed separately to yield averaged evoked responses (AER) as described previously.⁹ Three components—P, (maximum positivity between 40 and 100 msec), N, (maximum negativity between 90 and 170 msec), and P₂₋₃ (maximum positivity between 170 and 270 msec)—were visually identified and height above or below a prestimulus baseline calculated by hand. Analysis of variance (ANOVA) was applied to these data; where appropriate, further statistical tests were conducted.

RESULTS

Autonomic Measures

Table 1 presents means and standard errors for the measures not presented in graphic form. Unless otherwise noted, results of ANOVA failed to indicate significance.

The ANOVA for base skin conductance indicated a significant ($F(4,54) = 3.61$; $P < .05$) groups \times conditions interaction. Meditators increased skin conductance relative to controls as they went from normal consciousness into meditation (Fig 1, top). A Kruskal-Wallis test on the skin conductance change score (meditation minus normal) indicated a significant ($P < .05$) difference between meditators and controls. Likewise, the ANOVA for skin resistance responses (Fig 1, bottom) indicated a significant ($F(4,54) = 2.54$; $P < .05$) groups \times conditions interaction. Meditators increased skin resistance lability relative to controls as they went from normal consciousness into meditation. A significant ($F(2,54) = 18$; $P < .001$) condition effect indicated that skin resistance lability increased with meditation.

The ANOVA for basal heart rate (Table 1) failed to indicate significance. Meditators tended to increase heart

rate relative to controls as they went into meditation.

The ANOVA for respiratory rate (Table 1) demonstrated rate slowing ($F(2,54) = 22.8$; $P < .001$) for all groups as they went into meditation. The ANOVA for respiratory amplitude (Table 1) indicated a significant ($F(2,54) = 11.1$; $P < .001$) condition effect. Across groups, respiratory amplitude increased with meditation. Surprisingly, controls achieved peak amplitude in the withdrawal condition, resulting in a significant ($F(4,54) = 3.60$; $P < .05$) groups \times conditions interaction.

The ANOVA for heart rate orienting response indicated a significant ($F(36,486) = 1.60$; $P < .05$) groups \times conditions interaction (Fig 2). Meditators showed a predominantly biphasic response during normal consciousness that became a predominantly acceleratory response during meditation. Controls showed a predominantly biphasic response during normal consciousness that became a predominantly deceleratory response during meditation. The ANOVA for skin conductance orienting response (Table 1) indicated a nonsignificant trend for meditators to have smaller skin conductance responses than controls for all conditions. The mean experimental temperature for the three groups was 25.2°C (control), 26.2°C (trainee), and 25.6°C (expert).

EEG Measures

The ANOVA for theta power (Fig 3) indicated significant ($F(2,27) = 3.61$; $P < .05$) group and ($F(2,54) = 5.21$; $P < .01$) condition effect. Meditators increased theta with meditation more than controls. A Kruskal-Wallis test showed the group difference in theta to be significant ($P < .05$) only during normal consciousness, with expert meditators showing greatest theta power. Three of 20 meditators failed to increase theta power (binomial test, $P < .05$, two-tailed); four of ten controls failed to increase theta power.

The ANOVA for alpha power (Table 1) failed to indicate significant effects. Alpha power tended ($F(2,54) = 3.07$; $P < .10$) to increase as subjects meditated. Meditators increased alpha power with meditation more than controls. Three of 20 meditators failed to increase alpha power (binomial test, $P < .05$, two-tailed); four of ten controls failed to increase alpha power.

The ANOVA on AER data failed to indicate significant group or groups \times conditions interaction effects. The principle finding was a significant ($F(2,54) = 18.7$; $P < .001$) condition effect, reflecting a progressive decrease in the mean amplitudes of the N, AER component to the frequent and infrequent tones (-7.4 to -4.9 μV) as subjects went into meditation. Amplitude of the P₂₋₃ AER component to the infrequent tones decreased (6.8 to 3.3 μV) as subjects went into meditation, whereas the same component of the AER to the frequent tones increased slightly (2.5 to 3.5 μV). This differential response of the P₂₋₃ AER component to the frequent and infrequent tones was reflected in a significant ($F(2,54) = 8.27$; $P < .001$) tones \times conditions interaction effect. The AER decrements observed are compatible with either an active withdrawal of attention from the tones, or with the known effects of habituation^{11,12} on the AER. For this reason results will not be discussed further.

Table 1.—Means and Standard Errors of Autonomic Measures

Measure	Controls			Trainees			Experts		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Basal heart rate, beats/min									
Mean	66.6	67.1	67.0	65.0	65.0	65.8	69.4	71.0	72.8
SE	4.3	4.1	4.2	2.9	3.3	2.9	3.3	3.2	3.1
Respiratory rate, cycles/min									
Mean	15.1	10.2	9.7	14.7	12.5	9.8	16.6	13.0	11.7
SE	1.5	1.7	1.9	1.1	1.4	1.4	1.5	2.1	2.2
Respiratory amplitude, mV									
Mean	739.8	1,274.3	1,049.7	518.2	661.7	868.8	682.7	774.0	777.6
SE	76.5	210.0	134.6	43.5	71.0	117.9	166.5	155.0	119.4
Skin conductance orienting responses, log ₁₀ μmV									
Mean	0.1273	0.0986	0.1181	0.0409	0.0458	0.0209	0.0762	0.0887	0.0609
SE	0.0585	0.0445	0.0631	0.0113	0.0125	0.0060	0.0248	0.0304	0.0139
EEG alpha power relative units									
Mean	70.5	72.2	70.4	62.9	68.6	72.5	81.0	84.5	94.8
SE	7.9	5.4	4.6	5.2	6.8	6.9	8.8	9.1	13.3

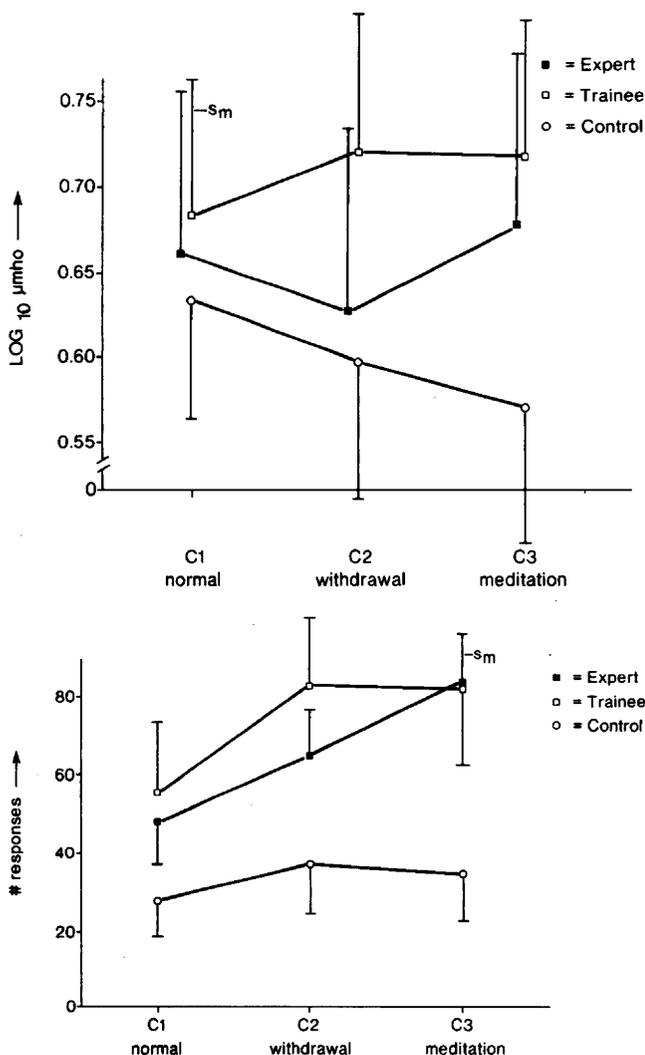


Fig 1.—Top, Base level skin conductance. Bottom, Spontaneous skin resistance responses.

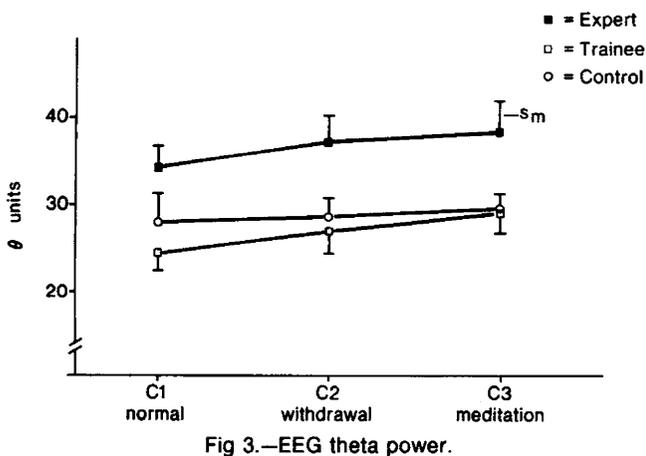
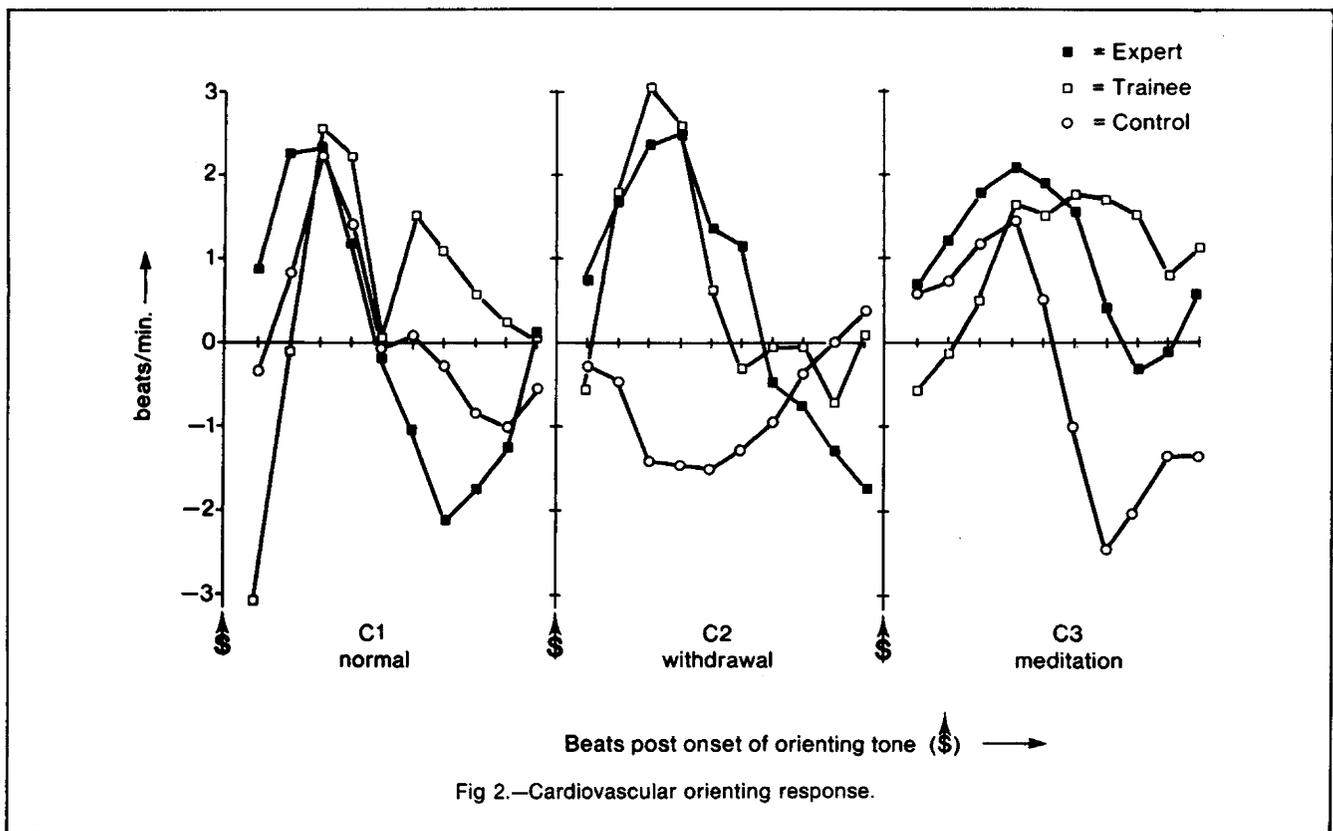
Sleep-scored EEG data are presented in Table 2. Data are percentage of 30-second epochs in each sleep stage. All three subject groups spent less time in light sleep (stage 1 and 2) as they went into meditation. Controls spent 23% of normal consciousness time in light sleep and 8% of meditation time in light sleep. Meditators spent 19% of normal consciousness time in light sleep and 5% of meditation time in light sleep. Experts consistently slept less than trainees. No rapid eye movement, stage 3, or stage 4 epochs were seen. The ANOVA on the number of awake (stage 0) epochs failed to demonstrate a significant group or groups × conditions effect. A significant ($F(2,54) = 4.47; P < .05$) condition effect indicated that subjects slept less as they went into meditation.

One expert meditator reported the experience of "having my breathing taken over by the mantra" during the meditation condition, and felt it might represent what she termed a "near-Samādhi" experience. The concurrent respiratory record (Fig 4, top) showed a pattern of respiratory acceleration with little change in respiratory amplitude followed by cessation of respiration for approximately 100 seconds. Figure 4, bottom, presents respiratory rate, heart rate, and skin resistance measures plotted for each ten-second interval during the event. A dramatic decrease in skin resistance of approximately 200 kohms preceded the respiratory acceleration.

Visual inspection of the meditation EEG record of this subject disclosed large amounts of high amplitude (up to 100 μV) alpha range frequencies and also large amounts of theta range frequencies (up to 150 μV). Occasionally there were discrete bursts of theta range frequencies of amplitudes up to 300 μV. No particular EEG changes were associated with the "near-Samādhi" event.

Questionnaire Data

Subjects' questionnaire responses showed that all meditators thought they had been able to meditate. Experts' meditation ratings varied from fair to excellent, allowing



Condition	% of Subjects			
	Awake	Stage 1	Stage 2	Stage 3-4
Controls				
Normal (C1)	76	20	3	0
Withdrawal (C2)	80	14	5	0
Meditation (C3)	91	8	0	0
Trainees				
Normal (C1)	72	28	0	0
Withdrawal (C2)	85	14	1	0
Meditation (C3)	90	9	1	0
Experts				
Normal (C1)	90	10	0	0
Withdrawal (C2)	93	7	0	0
Meditation (C3)	100	0	0	0

COMMENT

Our results indicate that the meditators became physiologically activated during their meditations while the control subjects became relaxed. This differential change is evident in the significant groups \times conditions interactions for the measures of basal skin conductance and frequency of spontaneous GSR responses. The heart rate of the meditators also increased during meditation relative to the control period, although the increase was not statistically significant. Controls demonstrated relaxation similar to that reported in previous studies of TM,^{1,2,13} whereas meditators demonstrated activation similar to the previously cited field studies of Indian Yoga.^{4,5} The one previous study of Ananda Marga meditation by Elson et al¹⁴ used meditators with an average of 1.8 years' experi-

the computation of a Spearman correlation between the physiological measures and the meditation ratings. There was a significant ($P < .01$) negative correlation between the experts' meditation ratings and their skin conductance levels. Values of r were -0.89 , -0.80 , and -0.85 for the three conditions, respectively. Corresponding correlations were not significant for the trainees, possibly due to the more uniform quality of their meditation ratings. Other correlations were not significant.

In general, the three subject groups were remarkably similar in their reports of subjective experience. No group reported significant restlessness or difficulty staying awake. All groups reported increased euphoria and a continued state of relaxation as they moved from normal consciousness into meditation.

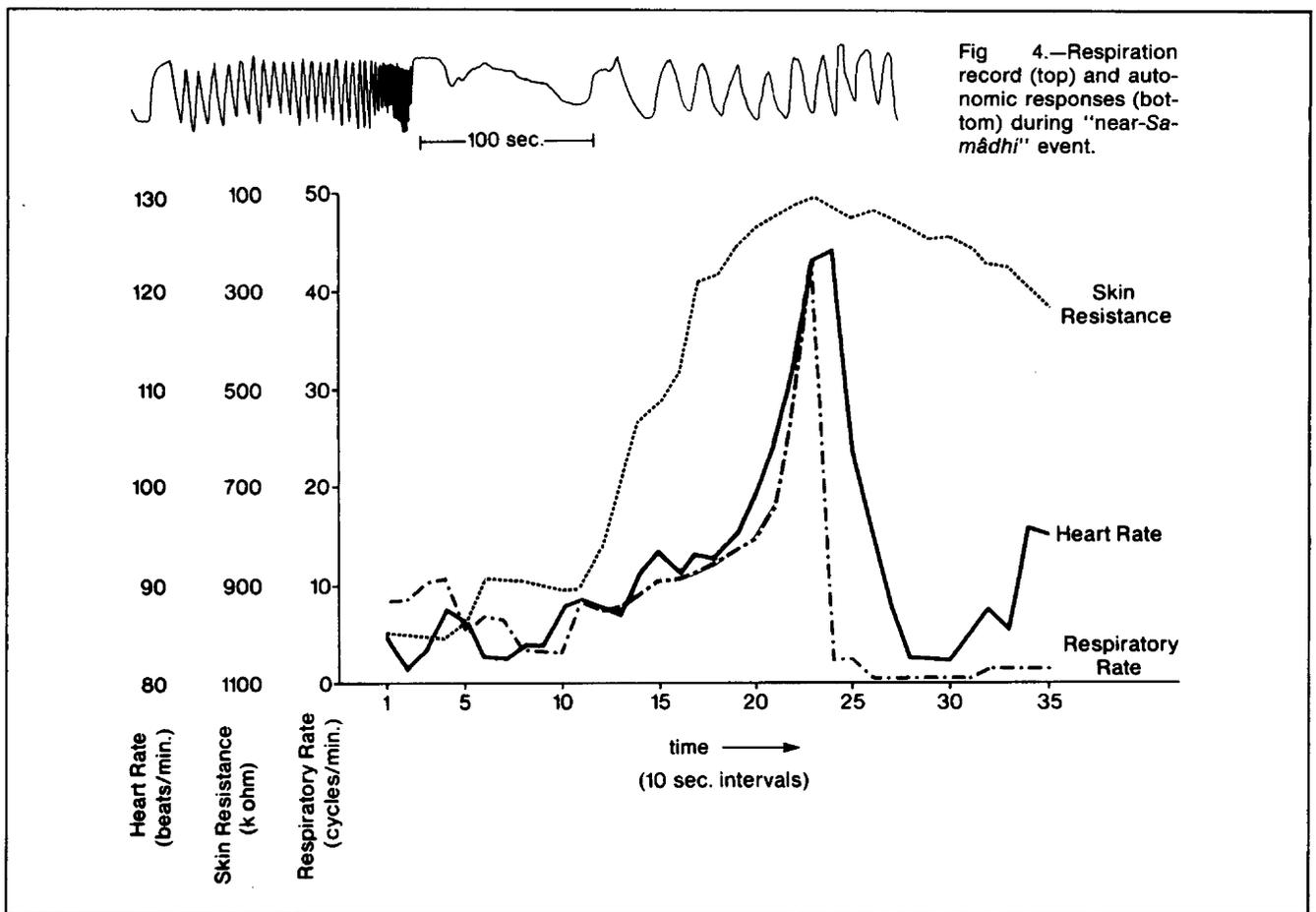


Fig 4.—Respiration record (top) and autonomic responses (bottom) during "near-Samâdhi" event.

ence in Ananda Marga techniques. Their responses are similar to the responses of the controls in this study.

The general similarity of the respiratory responses of the controls and meditators in this study makes it unlikely that respiratory factors account for the differential autonomic activation of the meditators and controls. The significant decrease in respiratory rate has been reported for previously studied meditation techniques.⁷

The EEG sleep scoring confirmed the general picture of increased activation during the meditation of the meditators. As a group, the 20 meditators spent only 5% of their meditation time in light sleep. Controls spent 8% of their meditation time in light sleep. Meditation significantly decreased the incidence of sleep in the EEG records of the entire subject group. These findings contrast to sleep studies of TM^{15,16} reporting that up to 40% of the meditation time of experienced TM meditators was spent in overt sleep (stages 2 through 4), and are in accord with the prior Ananda Marga study¹⁴ in which none of the meditators were found to enter sleep stages 2 through 4 during meditation.

The EEG frequency analysis disclosed that 17 of the 20 meditators increased EEG alpha and theta power during meditation. Similar results have been reported for previously studied meditation techniques⁷ and for the Elson et al¹⁴ study. Like Elson and colleagues, we found more proficient subjects to have higher theta power in their EEG records. The significantly increased theta power

in the EEG of the experts during normal consciousness is particularly interesting since meditation practitioners assert that meditation changes the quality of normal consciousness. It appears possible that either subjects with a high EEG theta power selectively become expert meditators or that prolonged practice of this meditation technique results in increased EEG theta power even during normal consciousness.

Meditators had consistently smaller skin conductance orienting responses in each condition than did the controls. The heart rate response is reported to be biphasic in nature, with an early acceleration associated with the warning or threat value of the stimulus followed by a later deceleration associated with the subject orienting.^{17,18} Meditators showed progressively less of the later (orienting) component as they went into meditation than did controls. Thus, the orienting response data from both skin conductance and heart rate measures suggest that meditators oriented less than controls. This observation is in general agreement with field studies of Indian Yogis demonstrating decreased responsiveness of meditators to external stimuli during states of profound meditation.^{4,19}

The significant negative correlation in the expert group between meditation rating and skin conductance level suggests that although this group's meditation was associated with increased activation, within the group more relaxed subjects tended to have better meditations. Also, initially relaxed subjects tended to remain relaxed relative

to their subject group throughout the study. Greater relaxation before meditation may facilitate access to a good meditation state even though the meditation produces a physiological activation.

We were extremely fortunate to have observed the "near-Samadhi" event. *Samadhi* is the Yogic term for the ecstatic state of complete concentration and self-absorption. Results of a detailed autonomic and respiratory analysis indicated that the skin resistance activation preceded respiratory and heart rate activation. Thus it is unlikely that the event merely represents a hyperventilation episode. These observations are similar to those reported by Wenger and Bagchi⁵ in which profound meditation was associated with autonomic activation without EEG activation. Das and Gastaut⁴ also observed autonomic activation during the Yogi ecstatic state, although they observed concomitant EEG activation.

In conclusion, this study reports the physiological correlates of a form of Tantric meditation as practiced by Ananda Marga. This study differs from previous studies of meditation in several respects. First, the meditators studied were unusually experienced with meditation techniques. As a group, their daily meditations of approximately three hours were much longer than the 20-minute, twice-a-day meditations of most other studies. Our expert group had been meditating an average of 4.4 years and was meditating an average of 3.4 hours a day when studied. Such expertise is unusual in meditation studies with the exception of the field studies conducted in India. Second, the design of this study required all subjects to practice meditation techniques. We were thus able to study the physiological characteristics of different levels of proficiency in meditation.

It appears that proficiency in this form of Tantric meditation is characterized by physiological activation by EEG and autonomic criteria. This activation is consistent with the Tantric emphasis on the struggle to achieve union with the object of concentration. The activation appears to be associated with proficiency rather than the techniques per se since the inexperienced control subjects tended to relax rather than become activated. The decreased orienting to external stimuli reflects the inward focus of attention characteristic of this meditation. These findings tend to discount the current assumption that meditation is indistinguishable from states of deep relaxation. Rather, they suggest that meditative techniques may give access to a variety of physiological and subjective states, depending on the technique and the proficiency of the meditator. It appears inadequate to conceptualize Yogic meditation as one unified technique.

The autonomic activation might be expected to prevent the intrusion of overt sleep into the meditation. We

speculate that meditative techniques in general permit access to a state of consciousness in the borderline between sleep and wakefulness. Those techniques that employ longer meditations, such as Zazen and Ananda Marga, would be expected to be accompanied by greater physiological activation than shorter meditation techniques such as TM. The activation may reflect progressive conditioning as subjects attempt to meditate without falling asleep, or it may also be a direct result of the meditation technique. For example, Zazen meditators keep their eyes open and focused in front of them during meditation. This technique would appear to maintain activation and prevent sleep.

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