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FIELD MODEL OF CONSCIOUSNESS: EEG COHERENCE CHANGES AS INDICATORS OF FIELD EFFECTS

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Changes in EEG coherence patterns were used to test a field model that posits a common field of "pure consciousness" linking all individuals. In ten trials, EEG was concurrently measured from pairs of subjects, one practicing Transcendental Meditation (TM) and the TM-Sidhi technique of "Yogic Flying" (YFg) — said to enliven the proposed field of consciousness — and the other performing a computer task. Box-Jenkins ARIMA transfer function analysis indicated that coherence changes in the YF's 5.7–8.5 Hz band, the band sensitive to TM and YFg, consistently led coherence changes in the other subject's 4.7–42.7 Hz band. A clear relationship was seen among subjective reports, coherence patterns, and strength of intervention effects. These data support a field model of consciousness. Alternate explanations are explored.

Keywords: Transcendental Meditation, EEG, coherence, field effects

A new paradigm of consciousness, detailed by Maharishi Mahesh Yogi, characterizes perceptual, cognitive, and affective processes not as isolated events, but as transformations or active levels of a continuum of "pure consciousness" common to all individuals (Maharishi, 1963; 1986). A testable prediction of this paradigm is that individuals' behavior can be affected from the field of pure consciousness (Maharishi, 1986).

This field prediction has been tested, and supported, by over thirty studies reporting specific changes in social indicators when groups contact the proposed field of consciousness through Transcendental Meditation (TM) and TM-Sidhi practice (see discussion for explanation of these technologies). The effects are dependent on the size of the group, i.e., the square root of 1% of a given population (Orme-Johnson & Dillbeck, 1987). For example, in cities with 1% of their population practicing TM, crime rate decreased after controlling for demographic variables known to influence crime (Dillbeck, Landrith, & Orme-Johnson, 1981). Two studies of large random samples of US cities and metropolitan areas reported evidence to support a causal influence of TM on crime: crime rate significantly decreased as the number of citizens practicing TM increased (Dillbeck, Banus, Polanzi, & Landrith, 1988). Eight studies have used direct intervention designs, employing Box-Jenkins time-series methodology to test change in various quality of life indicators — crime rate, unemployment, inflation, incidents of fires and accidents — coincident with the introduction of sufficiently large groups practicing the TM and TM-Sidhi program (Dillbeck, Cavanaugh, Glenn, Orme-Johnson, & Mittlefehldt, 1987; Orme-Johnson, Alexander, Davies, Chandler, & Larimore, 1988). These studies used powerful univariate and multivariate time-series measures to test for experimental effects independent of

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cyclical trends in the data. Even in the inherently noisy arena of natural social settings, this finding has been replicated many times.

This sociological evidence of field effects of consciousness has stimulated a research program to study the neurophysiological mechanisms of these effects, as reflected in measures such as serotonin turnover, and EEG coherence. Pugh, Walton, and Cavanaugh (1988) compared changes in excretion rates of 5-HIAA, a by-product of serotonin metabolism, with changes in the size of the TM and TM-Sidhi group. In four studies, two with TM subjects and two with subjects not familiar with TM, increases in the size of the group practicing the TM and TM-Sidhi program led to significant increases in urinary 5-HIAA concentrations as measured by transfer function fitting.

Orme-Johnson, Dillbeck, Wallace, and Landrith (1982) reported changes in "inter-subject" EEG coherence between subjects in Iowa, while a large group practiced one of the TM-Sidhi techniques known as "Yogic Flying" (YFg) in Massachusetts. The authors looked at YFg's effect because this technique is predicted to create the most influence on the environment (Maharishi, 1986). They calculated EEG coherence between signals from electrodes at the same locations (F_3, F_4, C_3, C_4) on pairs of subjects, running three pairs of subjects at the same time of day on six control and six experimental days. On the experimental days, the test sessions coincided with group practice of YFg; during the control days there was no group practice. Orme-Johnson et al. (1982) reported significant increases in alpha and beta coherence between subjects on experimental days, in contrast to the control days.

In a second study, EEG of test subjects not familiar with TM were measured during a computerized concept learning task as a group practiced YFg in another building approximately 1000 meters across campus (Travis, 1988). In this pilot study, test subjects were tested five times each with YFg overlapping different times of the test session. EEG coherence was averaged across frontal, central, parietal, and occipital leads and smoothed over ten 1.06-second epochs, yielding 112 averages for the 20-minute test session. Time series intervention analysis was used to test the effect of YFg on the test subjects' coherence.[1] During the YFg intervention, one test subject showed significantly higher EEG coherence across all frequency bands ($t(106) = 3.42$, $p < .0005$); the second subject showed significant increases only in the 40-Hz band ($t(111) = 2.63$, $p < .005$).[2] Both subjects also identified more new concepts during the YFg intervention periods. This pilot study suggested that EEG coherence and task performance may be sensitive measures of field effects.

To replicate and extend these findings, EEG was recorded simultaneously from a test subject (TS)(not familiar with TM and YFg) performing a concept learning task, and from a subject (YF) practicing TM and YFg. To control for individual differences in experience during TM and YFg, the same YF was used as the "intervention" with five test subjects, who were run two times each. The dynamic relationship between the EEG coherence of the YF-TS pairs was modeled with linear transfer function fitting, which tests how well one times series, called the "leading indicator variable" or "independent variable," explains the behavior of a second time series (Vandaele, 1983). Both the YF's and the TS's coherence were used as indicator variables to see

[1] Time series analysis enables significant conclusions to be drawn from single subjects by measuring their behavior over time (at least 50 consecutive observations). Natural (endogenous) cycles are removed from the series to yield independent data points, which are then tested for intervention effects.

[2] The degrees of freedom in time series analysis equal the number of independent data points after the time-dependent structure has been removed from the series. For instance, in the first subject, the 112 original data points, representing coherence values averaged every 10.6 seconds, were reduced to 106 points after ARIMA modeling. These 106 independent points were then used in the transfer function fitting.

whether the effect was one-way, or if there was a feedback relationship. To minimize subjective bias in model selection, the Aikeike Information Criterion (AIC) was used to choose between competing models (Liu & Hudak, 1986).

METHOD

Subject Six subjects were asked to participate in the study. One was a YF, age 33.1 years, who was experienced in TM and TM-Sidhi practice; the other five subjects (TSS), average age 31.8 years (SD = 7.4 years, range 23 to 43 years), were not familiar with the TM and TM-Sidhi program. Since sex and handedness affect coherence patterns (French & Beaumont, 1984), all subjects were right-handed males.

Apparatus The YF's and TS's EEG were recorded on separate Grass 78D polygraphs with 1-Hz low filter settings and 100-Hz high filter settings, and the signals were fed into the same DEC 11/23 computer, digitized at 240 points/s, and stored for later editing of artifacts and spectral analyses. To test for possible crosstalk between the two polygraphs, a 200 μV peak-to-peak sine wave at 6 Hz, 8 Hz, 10 Hz and 12 Hz was fed into one polygraph while no signal was fed into the other (no electrodes were selected on the panel). The data — eight channels with 200 μV signals from one polygraph and eight channels with low-amplitude amplifier noise from the other — were concurrently digitized on-line by the same Data Translation a/d board in the DEC 11/23 computer. No peaks at the test signal's frequencies were seen in the power spectra from the second polygraph. Therefore, even in this worst case of a high amplitude signal on one polygraph and a low amplitude signal on the other, there was no crosstalk.

Concept learning task The concept learning task, programmed on an Apple IIe computer, presented test grids, evaluated the subject's response from a hand-held button box, and gave feedback every three trials. In the task, the same concept was used until the subject responded correctly six times in succession. The subject was then told that a new concept would be presented. New concepts were randomly chosen, and the starting pattern of the concepts were randomized to lessen the chance that the subject would recognize the patterns.

PROCEDURE

Each YF and TS pair was tested twice on separate days in the EEG lab in mid-afternoon, when there was no TM and TM-Sidhi practice occurring in the area that could confound the findings. During one session, TM (5 minutes) and YFg (5 minutes) overlapped the computerized task; during the other, YFg (5 minutes) and supine rest (5 minutes) overlapped the task. The order of intervention was quasirandomized and counterbalanced to control for sequence effects.

The TSs came into the laboratory individually before the experimental session and practiced the concept learning task. All TSs were told the same strategy to maximize performance on the task: Use one concept for three grids and then evaluate that choice based on the feedback. Each TS then practiced the task until he reached a minimum efficiency level of 1.5 new concepts/minute.

EEG was recorded from six electrodes: F_3, F_4, C_3, C_4, and the center points of P_3, O_1, T_5 and P_4, O_2, T_6, and referenced to linked ears with a F_{pz} ground. These locations have been reported to show maximum sensitivity to TM practice (Levine, 1976; Farrow & Hebert, 1982) and YFg (Travis & Orme-Johnson, 1989). An eye electrode was placed below and to the right of the right canthus to aid in artifacting.

The electrodes were first applied, using the Electro-cap system, to the YF, who then went into a sound attenuated room. When the TS arrived and his electrodes were applied, he moved into a sound attenuated room adjacent to the YF's, and performed the concept learning task for 12 minutes. To control for warmup effects, the first two minutes of data were discarded.

Because the YF heard the TS come and go, as he remained in the experimental room (about two hours), the YF could not be completely blind to the research hypothesis. He was, however, blind to the details of the research design; he did not know that each TS was being tested twice and that YFg would overlap different parts of the test session.

The TSs were blind to the research hypotheses, being told they were participating in a test of stability of EEG rhythms. They were tested in a sound-attenuated room whose exhaust fan masked outside sounds. The ambient noise level of both the YF's and TS's rooms was 50–52 dbA, reflecting exhaust fan noise. During YFg, there was the additional sound of the YF landing on the foam, a dull thump that averaged 58–60 dbA in the YF's room, and 52 dbA in the TS's room. After the second session, TSs were asked if they had been aware of other people in the lab or had heard any strange noises during the experimental session; none reported that they had.

Analysis The data were conditioned with a 10% tapered cosine bell window and spectral analyzed (Fast Fourier transformed) in 0.94-Hz bands between 4.7 and 42.5 Hz. Coherence estimates were smoothed over ten 1.06-second epochs, yielding 56 values for the ten-minute session. The YF's global coherence (15 coherence pairs for the six sites recorded) was averaged in the high theta/low alpha frequency band (5.7–8.5 Hz) because peak activity in that band has been reported during TM practice (Wallace, 1970; Banquet, 1973; Levine, 1976; Farrow & Hebert, 1982) and during YFg (Travis & Orme-Johnson, 1989) and therefore is the band most likely to reflect contact with the field of consciousness during TM and YFg. The TS's global coherence was averaged across all frequencies (4.7–42.5 Hz), because these subjects were alternately engaged in a task (beta activity) and resting (theta and alpha activity).

The dynamic relationship between the TS's and the YF's time series was assessed with time series transfer function fitting, using Liu's maximum likelihood method (Liu & Hudak, 1986) in the time series software version 3.2 from Scientific Computer Associates. In the maximum likelihood method of transfer function fitting, after checking for stationarity of the series and differencing or transforming the series if needed, the dependent (output) variable is modeled as a function of possible autocorrelation and moving average parameters, a constant, and the independent (leading or input) variable. Only significant parameters are retained in the model. The order of the significant lags and the nature of the model (a sudden change or a gradual change over time) is determined by the impulse response weights, which are the estimates of the input variable's effect on the output variable at successive lags. To reduce subjective bias in model selection, the model with the lowest AIC was chosen (Liu & Hudak, 1986). The goodness of fit of the model is assessed by: (1) testing that the model's residuals are white noise (a random series), and (2) testing that the cross correlation function of the prewhitened independent variable and the model's residuals are white noise.

RESULTS

The coherence series for the six of the ten trials that could be analyzed are presented in Figure 1. Because the other four trials lost 14% or more of their data points due to movement artifacts, transfer function fitting could not be run, as time series requires consecutive data points.[3] Each point on the graph represents coherence averaged over 10.6 seconds. The solid line represents the YF's 5.7–8.5 Hz coherence; the dotted line represents the TS's 4.7–42.5 Hz coherence. In the first two graphs, KOS and CMC, the TSs' series are generally higher than the YF's. These TS's series were also higher than a series created from the YF's coherence across all frequency bands. Although the YF's coherence was not consistently higher than the TS's, the series

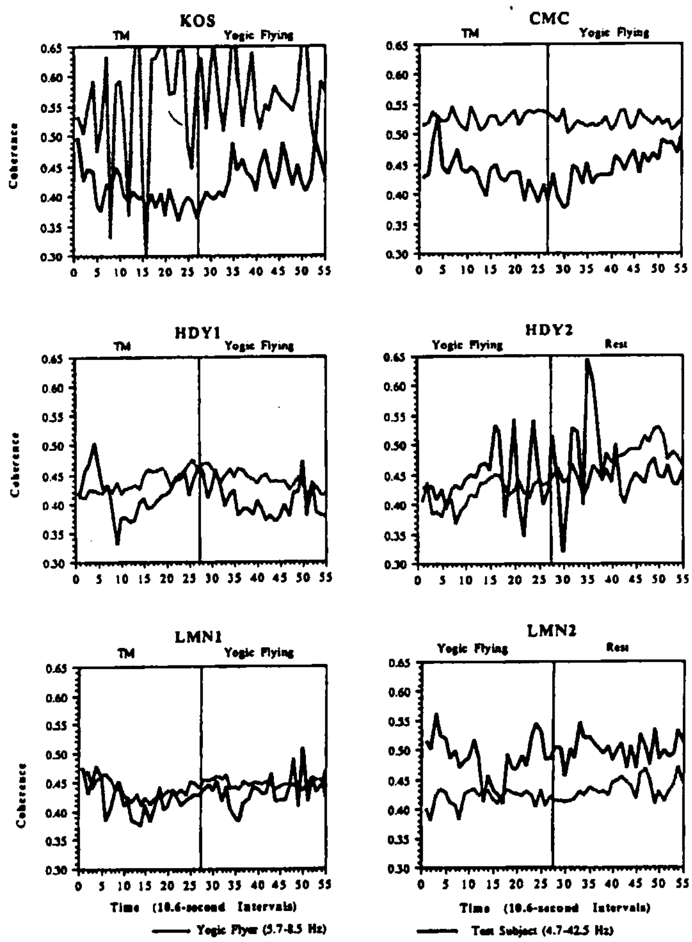

FIGURE 1 The Yogic Flyer's coherence in the 5.7–8.5 Hz band (solid line) and the control's coherence in all frequencies (dashed line) for the six sessions in which transfer function fitting was run; each data point represents coherence averaged over 10.6 seconds. The three-letter code above each graph identifies the subject.

[3]In KOS and HDY2 one data point was lost; that point was estimated by forecasting from the previous points to give a continuous series.

TABLE I

Intervention effects, as measured by times series transfer function fitting, of the Yogic Flyer's (YF) 5.7–8.5 Hz coherence on the test subject's (TS) 4.7–42.5 Hz coherence. The seven columns in this table present: (1) type of intervention—TM and YFg, or YFg and rest; (2) the lag of the effect of the YF's coherence on the TS's; (3) the magnitude of the effect, quantified by the steady state gain: the change in the output variable from a unit change in the input variable; (4) and (5) the t-ratio and p-value (two tailed) of the effect; (6) the degrees of freedom, which equal the independent points in the series after the time-dependent structure has been removed; and (7) the Aikeike Information Criterion (AIC). The "xxx" indicates that too many data points were lost in those sessions due to movement artifacts, so the transfer functioning analysis could not be done.

Intervention	Lag	Steady State Gain	*t*-ratio	*p*-value	*df*	AIC
			KOS			
TM/Fly	0+	0.2052	0.83	.405	54	−140.6
Fly/Rest	xxx	xxx	xxx	xxx	xxx	xxx
			MMV			
TM/Fly	xxx	xxx	xxx	xxx	xxx	xxx
Fly/Rest	xxx	xxx	xxx	xxx	xxx	xxx
			HDY			
TM/Fly	2+	0.1046	1.65	.106	47	−268.2
Fly/Rest	4+	0.1166	3.27	.002	47	−263.7
			LMN			
TM/Fly	2+	0.0884	1.75	.086		
	4+	0.1140	2.43	.019	50	−321.0
Fly/Rest	0+	0.0985	1.41	.167	56	−248.1
			CMC			
TM/Fly	1+	0.1262	2.17	.038	51	−317.6
Fly/Rest	xxx	xxx	xxx	xxx	xxx	xxx

calculated from the YF's 5.7–8.5 Hz coherence consistently led the TS's coherence in every session analyzed, as seen in Table 1. These effects were significant (two-tailed) for three interventions (HDY2, LMN1 at lag 4, CMC), a near trend for two others (HDY1, LMN1 at lag 2, LMN2), and a very small positive effect for the last one (KOS). This represents six replications of the same experiment; the chi-square test for significance of repeated experiments (Winer, 1971) was highly significant ($\chi(12) = 35.8, p < .001$). The magnitude of effect, shown in the third column of this table, was about a 10% change in the TS's coherence for each unit change in the YF's coherence.

The YF's subjective experience paralleled the strength of the effect. For the session with the smallest effect on the TS's coherence (KOS), the YF mentioned that he was sick and "should have been home in bed." In the two sessions in which the measured effect only tended toward significance, the YF mentioned that he felt fatigued during one session (HDY1), and not very settled during the other (LMN2). For the sessions with significant intervention effects, the YF mentioned that the YFg session was better than the previous ones (CMC), and that he felt alert (HDY2) and settled (LMN1).

To test if other series other than the YF's 5.7–8.5 Hz series would have a consistently leading effect, a second series was calculated from the YF's 4.7–42.5 Hz coherence, the same frequency range used with the TSs' data. The series calculated from the YF's 4.7–42.5 Hz coherence had a varied effect on the TS's series; sometimes the effect was negative, sometimes positive, and sometimes insignificant.

DISCUSSION

Changes in the YF's 5.7–8.5 Hz coherence led to parallel changes in the TS's coherence even though there was no direct interaction between the subjects. The effect was one way—the YF affected the TS—in both intervention conditions, TM/YFg, and YFg/rest. There was also a clear relationship between subjective reports, coherence patterns, and strength of intervention effects.

How did the observed effects propagate? With no direct or indirect interaction between the YF and the TS, the effects must have propagated not on the "classical" level of direct interaction, but via a "field." In exploring a possible field theoretic to account for the observed results, the fields identified by physics were first considered.

Of the four basic physical fields, only the electromagnetic (EM) force is reported in the literature as affecting physiology and behavior of organisms (Adey & Bowan, 1977). Strong and weak forces operate in the atomic nucleus, and the force of gravity between individuals is too weak to have a measurable effect (Hagelin, 1987). Tourenne (1985) has proposed a mechanism for radiation of EM fields from cortical activity. He suggests that propagation of charges along the cellular membranes of cortical pyramidal cells acts like an oscillating dipole, which would radiate high-frequency waves in the microwave range (1–5 GHz).

This electromagnetic explanation was not directly tested by this study. Although we could test whether the effects are attenuated when the YF practices in an EM shielded room (Faraday cage), this would not be a critical test because Faraday cages typically shield out frequencies of 100 Hz and higher, attenuating the amplitude of frequencies below 100 Hz by only 3 db (50%) (Schulz, Plantz, & Brush, 1965). Since activity in the 5.7–8.5 Hz frequency band seemed to mediate the effect (no consistent effect was seen with the 4.7–42.5 Hz series), a Faraday cage might not greatly attenuate the observed effects.

These data do, however, address the EM explanation indirectly. If the observed effects were due to EM radiation from coherent cortical activity, then *both* the TS and the YF should be radiating EM waves and the one emitting the stronger field would affect (lead) the other. In two instances, the TS's coherence was actually higher than the YF's (KOS and CMC).[4] However, the YF led the TS in all sessions.

This is an important point. Since the magnitude of EEG coherence did not determine who led whom, it seems that the observed effect was not mediated by EEG activity itself—coherence *per se* did not seem to be the causal factor. Just creating higher EEG coherence would not be predicted to have field effects, i.e., lead to EEG changes in nearby individuals or changes in social indicators. Rather, changes in the YF's 5.7–8.5 Hz coherence signified activity that underlied the observed field effect. Changes in 5.7–8.5 Hz coherence are seen during the experience of pure consciousness during TM practice (Badawi et al., 1984; Farrow & Hebert, 1982) and during YFg (Travis & Orme-Johnson, 1989). Therefore, it could be argued that contact with pure consciousness mediated the observed effect.

Alternate explanations Possibly the TSs heard the YF and oriented to the sound of the YF's body landing on the foam, even though they did not report hearing anything because the sounds were unfamiliar and in the background. Even though YFg was

[4]The raw coherence values can not be meaningfully compared, since the two subjects were doing quite different activities: eyes closed TM-YFg, and eyes open responding to a computerized task. However, comparison of the change in coherence patterns over time could test possible interactions between the subjects.

just half the session, it could be argued that a strong correlation between the TS's and YF's series, due to orienting, along with a random correlation during the other half of the session, could yield an erroneous positive effect with transfer function fitting.

If orienting had occurred, it would have led to desynchronized (low coherence) low-voltage EEG. Continuing with this logic, every time the YF hopped, the TS would have oriented to the sound, thus lowering his own coherence; because YFg is characterized by higher coherence (Travis & Orme-Johnson, 1989), this would result in a negative effect between the two subjects. This negative effect was not seen; the rise and fall of coherence in the YF consistently led to a similar rise and fall of coherence in the TSs. Also, if orienting accounted for the results, maximum effects would be seen at lag 0. The effects seen at lag 0 (KOS and LMN2) were the least significant of the measured effects.

A second alternate explanation is subject reactivity: The YF may have wanted the TS's EEG to change, or the TS may have wanted to "look good" on the concept learning task. This may have been the case; however, neither of these explanations could adequately account for the data. Either explanation requires that one subject not only knew when his coherence was high, but also could affect the other's.

Although the YF did affect coherence changes in the TS, it was done innocently. He had not been trained to know when his EEG coherence was high and to then affect the TS. Rather, he simply practiced TM and YFg, and the reported EEG relationships were observed.

The conclusion that individuals interact through an underlying field of consciousness is admittedly bold, but it seems to be the most parsimonious explanation for the observed results. Changes in the YF's 5.7–8.5 Hz coherence consistently led changes in the TS's coherence in six different trials as assessed by transfer function fitting. The YF's 4.7–42.5 Hz series did not have a consistent effect on the TSs'. This amounts to six replications of observed field effects.

Modern psychology considers consciousness to be a functional property of the human nervous system; the proposed field paradigm considers consciousness, more fundamentally, to be a self-interacting field that sequentially gives rise to the diversity of nature (Maharishi, 1986).[5] In this view, the functioning of the nervous system allows the continuum of consciousness to be localized as individual thought and attention. The proposed field of consciousness is said to be directly experienced through TM and YFg as self-referral awareness in which individual attention is aware of itself and not actively processing information (Maharishi, 1967). Bringing this field to conscious awareness through TM and YFg is theorized to make the field functionally significant in individual consciousness, bringing balance to the functioning of individual personality and behavior, and harmony to society (Maharishi, 1972; Orme-Johnson & Farrow, 1977).

While sociological research has demonstrated the practical utility of field effects, the present research design holds promise as a means to probe the mechanism of field effects of consciousness. By investigating field effects in the laboratory, where possible confounds can be systematically controlled, the functional characteristics of these effects may be delineated, leading to a fuller understanding of human potential and our relation with the environment.

[5]This concept is consonant with current unified field theories in physics that identify the source of all matter and force fields in the self-interactions of a single unified field (see Hagelin, 1987).

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