Brainwaves, Total Brain Functioning, and the Development of Higher States of Consciousness: A Tutorial

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Summary: The 100 billion human brain cells function in a 'sea' of electrical activity that can be detected by sensors placed on the scalp. Neuroscience considers brain cells which give off electrical signals in step with each other to be correlated or "coherent." Coherent waves of electrical activity in the brain represent a key sign of integrated or coordinated functioning in a brain which performs millions of separate tasks every second. The synchronous activity arising from millions of brain cells is constantly fluctuating. This endogenous oscillation is thought to represent the ongoing neural processing corresponding to the structure and content of our changing mental states. These endogenous rhythms periodically summate and allowing the electrical activity to reach the surface of the scalp to be recorded as brainwaves. Sensory experience represents a dynamic manipulation and phase resetting of the endogenous oscillations of the thalamocortical circuits. Integration of the vast diversity of brain activity supports our states of consciousness and the content of our conscious experience. The Transcendental Meditation technique, the TM-Sidhi program and Yogic Flying have been shown to greatly enhance brain integration. The progressive growth of global brain coherence closely correlates with the growth of human potential and well-being, reaching a state of total brain functioning in enlightenment.

Brainwave Short Tutorial

Part 1: Brain Electrical Activity—How Brainwaves are Created

Summary: Brainwaves represented the collected activity of millions of brain cells interacting through electrical and chemical messaging systems. When brain cells work together in a more correlated manner, the brain waves become enhanced in size.

- Brain cells—actually all cells—are like little batteries. They hold an electric charge to perform different functions. Unlike batteries, the electric charge created by the brain cell membranes is not constant, it fluctuates continuously.
- The continuous fluctuations of electrical voltage on the surface of brain cells are like ripples on the surface of a pond.
- Brain cells link together in complex arrays. From time to time, brain cells become active together functioning as an integrated assembly of neural cells.
- These electrical fluctuations set up currents within the space between cells that can travel and spread for some distance.
- The correlated fluctuations of many individual brain cells add up to create higher levels or amplitudes of electrical fluctuation—as if many pebbles are tossed into a pond at the same moment create higher waves on the surface. Correlated activity gives rise to bigger waves.
- When the fluctuations are added together, the enhanced height or amplitude of electrical activity reaches the surface of the brain and passes through the skull to be detected as very faint electrical signals, called brainwaves.

Part 2: Electroencephalograph—Technology to Measure Brainwaves

Summary: The EEG is able to detect very faint electrical signals on the surface of the head reflecting neural activity below. Different frequencies of oscillating waves are considered to represent different modes of brain and cognitive function.

- The Electroencephalograph machine (EEG; electro=electric; encephalo=brain; graph=patterns) is the standard tool to detect these extremely weak fluctuations and then amplifying them for detailed analysis.
- The EEG scalp sensors or electrodes detect fluctuations from a relatively large (a couple of inches in diameter) area of the brain surface and therefore detect the fluctuating activity of millions of cells. EEG can have between 2 and 200 sensors on the scalp. A widely used system (Biosemi) has 32 sensors shown below.

- Brain cells fluctuate in their activity at different rates (frequencies)—slow, medium and fast.
- EEG has known artifacts including eye movements and muscle movement, both of which produce large electrical fluctuations. These need to be minimized during acquisition and removed from the data collected.
- Each frequency has been correlated with a different style of brain functioning. The graph below shows four main frequencies: Delta, Theta, Alpha and Beta.
- Gamma activity is a fifth major frequency (25-60 Hz) now being extensively studied for its role in binding together diverse neural activity to create perceptual content to our awareness—more object-referral processes.
- Alpha activity is considered a basic rhythm of brain assemblies. Alpha is a electrical potential fluctuating up and down at a rate between 8 to 12 times per second, or cycles per second. Increased alpha activity indicates enhanced correlation or coherent cell functioning in that local area detected by the EEG scalp sensor.
- Generally, alpha is indicative of more *self-referral processes* (restful alert, self-oriented, inner perception, etc.) in brain functioning compared to faster brainwave fluctuations that strongly correlate with processing of outside events or objects, i.e., more *object-referral processes*.

Gamma (25-50 waves/sec) Active, Sensory integration

Beta (13-25 waves/sec) Active, outer-oriented

Alpha (8-12 waves/sec) Relaxed, inner-oriented awareness

Theta (4-8 waves/sec) Dream Sleep, Creativity

Delta (1-4 waves/sec) Deep Sleep, no awareness

Part 3: EEG Power—A Measure of Local Coherent Brain Activity

Summary: Brainwave POWER is a measure of the strength or amplitude of electrical signal detected. Thus, the power detected by EEG is directly related to the degree of correlated fluctuations or activity of the local underlying mass of brain cells at that moment of time. Power fluctuations within different frequency bands suggest different modes of brain computation and awareness.

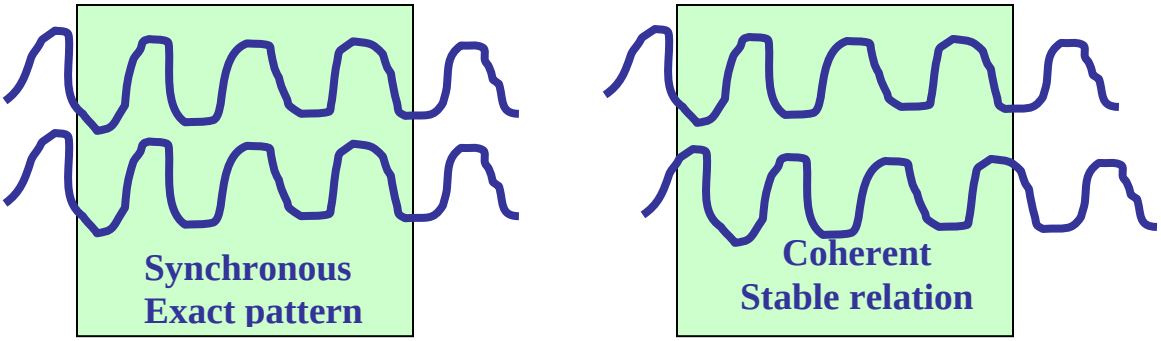
- Since the activity of cell assemblies varies continuously over time, brainwave power will vary as well.
- Since POWER is a measure of the degree of correlated or coherent cell activity, a small percentage of cells acting coherently can create great changes in power because the diverse activity of most of the cells fluctuating in a local area tends to cancel and prevent any significant level of electrical power from summating
- Thus, EEG power indicates coherent, integrated functioning of cells in a local brain area.
- Because brain cells can fluctuate in their activity at different rates or frequencies--slow, medium and fast—we can measure power for each frequency.
- Alpha activity represents the electrical potential fluctuating up and down at a rate between 8 to 12 times per second, or cycles per second. Alpha power is a measure of the strength of this very basic rhythm of brain assemblies.
- Increased alpha power indicates enhanced correlation or coherent cell functioning in that local area detected by the EEG scalp sensor.
- Generally, increases in alpha power is indicative of more self-referral processes (restful alert, self-oriented, inner perception, etc.) in brain functioning compared to power in faster brainwave fluctuations that strongly correlate with processing of outside events or objects, i.e., more object-referral activity.

Part 4: EEG Coherence—Measure of Orderly Brain Function

Summary: Coherence is a standard measure of correlated activity. In addition to power measures which indicate *local* values of correlated brain cell activity, correlated brain activity can also be detected and measured between neural assemblies separated by large *distances*. This distant correlation is referred to as EEG coherence. Elevated brainwave coherence during the Transcendental Meditation technique is significantly correlated with a variety of positive, desirable mind-body characteristics.

- *In general scientific language*, coherence (COH) and synchrony (SYNCH) denote a similar phenomenon—correlated activity of a number of elements in a system: people, cells, EEG signals, etc. In physical systems, laser light is coherent light. In biological systems, a small percentage of brain cells working coherently can control attention and consciousness.
- Coherence is used similarly to POWER (as discussed above). The key difference is that coherence that the correlated functioning is not local but between widely separated neural assemblies in the brain, for example, between cells on the left and right side of the brain, while power refers to correlation in a small region. Coherence compares brainwaves from two different areas of the brain. Mathematical analysis generates a measure of the degree of COH. COH is generally calculated over a period of 1-2 seconds.
- In contrast, POWER arises from the coherent functioning of cells relatively close together.

- When distant brain cell assemblies are functioning holistically together over a period of time, they tend to display similar or correlated electrical fluctuations, and they display very similar brainwave patterns.
- Based on similar brainwave patterns, we say these different widely distributed assemblies are functioning in a more integrated, coherent or synchronous fashion.
- Thus, COH and SYNCH occurs when different brain areas, serving different processing functions, come to be correlated in their activity.
- *In more analytic language*, COH and SYNCH have specific definitions.
- COH is a measure of stability or endurance of alignment of the fluctuations of two electrical signals. This is called phase stability of the signals. COH is calculated between two given EEG leads over a short period of time, usually a second or so. These values of coherence can then be plotted in a graph over time depicting the level of correlation over time for a specific frequency band like the alpha band.
- SYNCH is specific type of COH requiring that the two brainwaves are exactly alike, or nearly so. Notice in the graph below left, during the period of analysis (green box) the two waves are nearly identical in shape and alignment.



- Like SYNCH, COH brainwaves move together over time but, in contrast to SYNCH, COH brainwaves do not have to be identical or perfectly aligned at each moment (see graph on right). Whatever the alignment is and whatever the difference may be, it is maintained for the one or two seconds used to calculate the value.
- Alpha coherence, especially in the frontal brain areas, is found highly correlated during the experience of Self, Transcendental Consciousness during the Transcendental Meditation technique. With growth of higher states of consciousness, alpha coherence is also found during deep sleep and waking activity.
- EEG coherence has been significantly correlated with a wide variety of mind-body characteristics (See the graph on right).

- In general, the highly coherent brainwaves indicate increased brain orderliness which future research is very likely to significantly correlate with improvements in all aspects of mind-body health, like cardiovascular health, mental health, etc.

- *Important exceptions:* High coherence can also be found in two other types of brainstates, but the EEG pattern is fundamentally different, usually involving very slow rhythms and altered states of awareness. In deep sleep, for example, the very slow delta waves can be coherent, but the individual is asleep. Delta waves are not found in meditation unless an individual has a sleep deficit and falls asleep in meditation. Another example, is epilepsy, in which unique pathological very slow brain waves and spikes can occur, again generally associated with loss of consciousness. Therefore, very slow brainwave coherence, in the delta frequency has no connection with the unique restful alert state during Transcendental Meditation practice shown by research studies associated with highly coherent theta and alpha and mind-body health (see more below).

Part 5: Total Brain Functioning--

Summary: The human brain can be cultivated to function from the deepest levels of nature's functioning through the regular practice of Transcendental Meditation which permits the development of human potential in total brain functioning.

- Normally, in non-meditators, the electrical activity of different brain areas is only partially correlated and only for very brief periods of time. This more fragmented, less correlated, less coherent style of brain function is associated with a less effective or successful style of functioning.
- When, through the practice of Transcendental Meditation, all the areas of the brain begin to function in a more correlated manner, the brain is acting more holistically, in a more integrated manner.
- The experience of transcending cultivates correlation or integration of neural assemblies.
- This habit of correlated function through regular practice produces over time a more holistic style of brain functioning, total brain functioning, full integration. Total brain function can be understood in terms of the co-existence of Self-Referral and Object Referral functioning.
- The development of maximum brain integration makes available more comprehensive and reliable knowledge to support thought and action for success in life. When the brain becomes globally coherent, awareness can have access to the total structure of nature's intelligence in transcendental consciousness.
- Transcendental Consciousness is the level of Veda, total knowledge. Hence, the human brain has the inherent for total brain functioning and access Veda through cultivating the brain structure with regular experience of transcending balanced by daily activity.
- The spontaneous ability to function from the level of Veda to maximum creative intelligence is called Vedic brain functioning (see next section).

Overview of Brainwave Research and Growth of Higher States of Consciousness

Summary: Since 1970 and Dr. R. K. Wallace's ground-breaking research at University of California at Los Angeles, brainwave studies of the Transcendental Meditation Technique have shown remarkable changes in brainwave coherence—indicative of increased integration and holistic functioning. These changes can:

(1) appear within a short time of learning the practice,
(2) appear within moments of sitting and beginning to meditate,
(3) be global in extent,
(4) can be at very high levels, and
(5) with regular meditation practice, brainwaves patterns indicative of Transcendental Consciousness coexist with waking and sleep states of consciousness — indicating growth of Higher States of Consciousness.

Much of the research shows increased coherence in frontal areas of the brain, the executive controls centers or CEO of the brain. This indicates the profound nature of integration of brain functioning. Brainwave coherence from the practice is associated with dramatic improvements in many areas of cognitive, emotion and physiological function.

Part 1: Brainwave patterns during the Transcendental Meditation technique

Summary: Some 35 years of research have shown that the effortless practice of the Transcendental Meditation technique leads to remarkable levels of correlation of brain activity leading to both local and global coherence and integration. A few of these studies reported on brainwave activity during specific substates that can be identified during meditation.

- **Increase of amplitude of frontal theta and alpha brain waves** during practice of the Transcendental Meditation technique was first reported in Dr. R. Keith Wallace's doctoral dissertation at UCLA (Wallace, 1970). This increase in brainwave amplitude or power arises from increasingly coherent functioning cells beneath the EEG leads during the practice.
- **Very high frontal coherence (inter-hemispheric coherence) and very high frontal-central coherence (intra-hemispheric coherence)** were the first published findings of coherence in meditation reported by Dr. Paul Levine, a pioneer in the measurement of brain wave coherence (Levine, 1976).
- **Enlivenment of the brain's latent resources** reported by Dr. Lyubimov, Director of the Brain Research Institute in Moscow. Lyubimov stimulated the nerve of the thumb during practice of the Transcendental Meditation technique. During practice of the Transcendental Meditation technique, he found the brain's response to this simple stimulation showed greatly expanded frontal areas of activation and analysis compared to the usual restricted zone of processing (Lyubimov, 1999).

- **Higher frontal alpha coherence and higher global alpha power** were reported by Dr. Travis and colleagues during the process of transcending (inward stroke), and compared to the brain activity during the outward stroke. Also reported were lower breath rate and higher 'respiratory sinus arrhythmia' (the normal increase and decrease in heart rate or rhythm associated with each inhale and exhale). This latter measure indicates the level of parasympathetic activity—the "rest and restoration" part of the nervous system (Travis, 2001).
- **Higher frontal coherence** during the first minute of Transcendental Meditation practice compared to eyes-closed rest. Transcendental Meditation practice was also characterized by lower breath rate, higher respiratory sinus arrhythmia, lower skin conductance levels. This latter measure indicates the level of sympathetic activity—the "fight or flight" part of the nervous system (Travis and Wallace, 1999).
- **High broadband (6-45 Hz) frontal coherence** is reached during the TM practice in a relatively short period of time, at just two months practice of the Transcendental Meditation technique compared to eyes-closed resting before beginning the practice. Broadband coherence includes the coherence measures for most of the EEG frequencies: Theta, Alpha, Beta and Gamma. As a longitudinal EEG study**, t**his same high level of broadband frontal coherence during the practice was also seen at 6 and 12 months of practice of the Transcendental Meditation technique (Travis and Arenander, 2005 in review).

Part 2: Brainwaves During the Experience of Transcendental Consciousness

Summary: The subjective experience of Transcendental Consciousness correlates with the appearance of spontaneous quiescence of the breath. Brainwave measures during this period of time in meditation show increased coherence.

- **Transcendental Consciousness** is identified objectively by a spontaneous change in breathing of the meditator. A period of suspension of normal respiration lasting from less than a second to half a minute—spontaneous breath quiescence—is the most consistent pattern reported corresponding to the subjective experience of Transcendental Consciousness. (Farrow, 1982; Badawi et al, 1984; Travis and Wallace, 1997)
- **Coherence** during periods of spontaneous breath quiescence (Transcendental Consciousness) increases in specific slow frequencies—Theta and Alpha (Farrow and Hebert, 1976). EEG coherence was also reported to increase when all frequencies were added together (Badawi etal, 1984).
- **Skin conductance** changes, indicating that ones attention or perceptual orientation has shifted, has also been reported at the beginning of spontaneous breath quiescence periods (Travis and Wallace, 1997).

Part 3: Brainwave Patterns During the Experience of Cosmic Consciousness

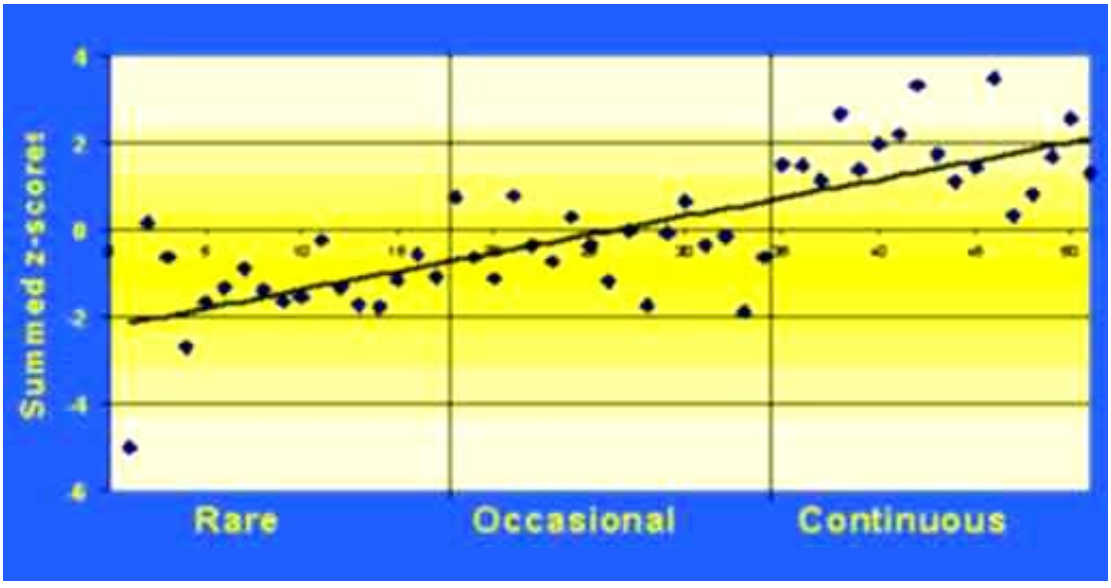
Summary: When the brain activity can support simultaneous unbounded, self-referral consciousness along with daily waking and sleep consciousness, research studies show existence of brainwave patterns indicative of both states occurring simultaneously.

- **Subjective Criteria for Cosmic Consciousness.** Cosmic Consciousness is the first of several Higher States of Consciousness and is defined as the co-existence of Transcendental Consciousness (TC) along with waking, sleeping and dreaming states of consciousness. This experience of co-existence of states of consciousness is commonly called 'witnessing.'

- **Objective Criteria for Cosmic Consciousness.** Cosmic Consciousness requires that characteristic physiological patterns of two states—TC with W, D or S—are found to co-exist. In published research below to types of experiments document this co-existence.
- **During Sleep: Greater theta and alpha amplitude** is seen during sleep in individuals reporting the experience of higher states of consciousness. These individuals show "normal" levels of delta activity indicative of deep sleep (Mason et al, 1997). In graph, note some of the alpha waves highlighted in red circles 'riding' the large amplitude delta waves.

- **During Waking**: A number of unique brainwave patterns were identified in individuals in the waking state (during mental tasks involving reaction time) who report the experience of higher states of consciousness. These three measures are used to produce an index or scale of integration of brain function called the Brain-Based Integration Scale (see graph below). Three groups of individuals reporting distinctly different experiences were examined with EEG and neuropsychological test. Individuals were assigned to a group if they had little or no experience of witnessing (rare group), inconsistent, varying experience of witnessing (occasional group) or constant experience of witnessing (continuous group). The main EEG measures were:
    - **Greater broadband (6-45Hz) frontal coherence**.
    - **Greater alpha** (associated with restful alertness) and **lower gamma** amplitude (associated with object perception).
    - **More appropriate/efficient brain response during problem solving** as measured by averaging the brain response (Travis et al, 2002).

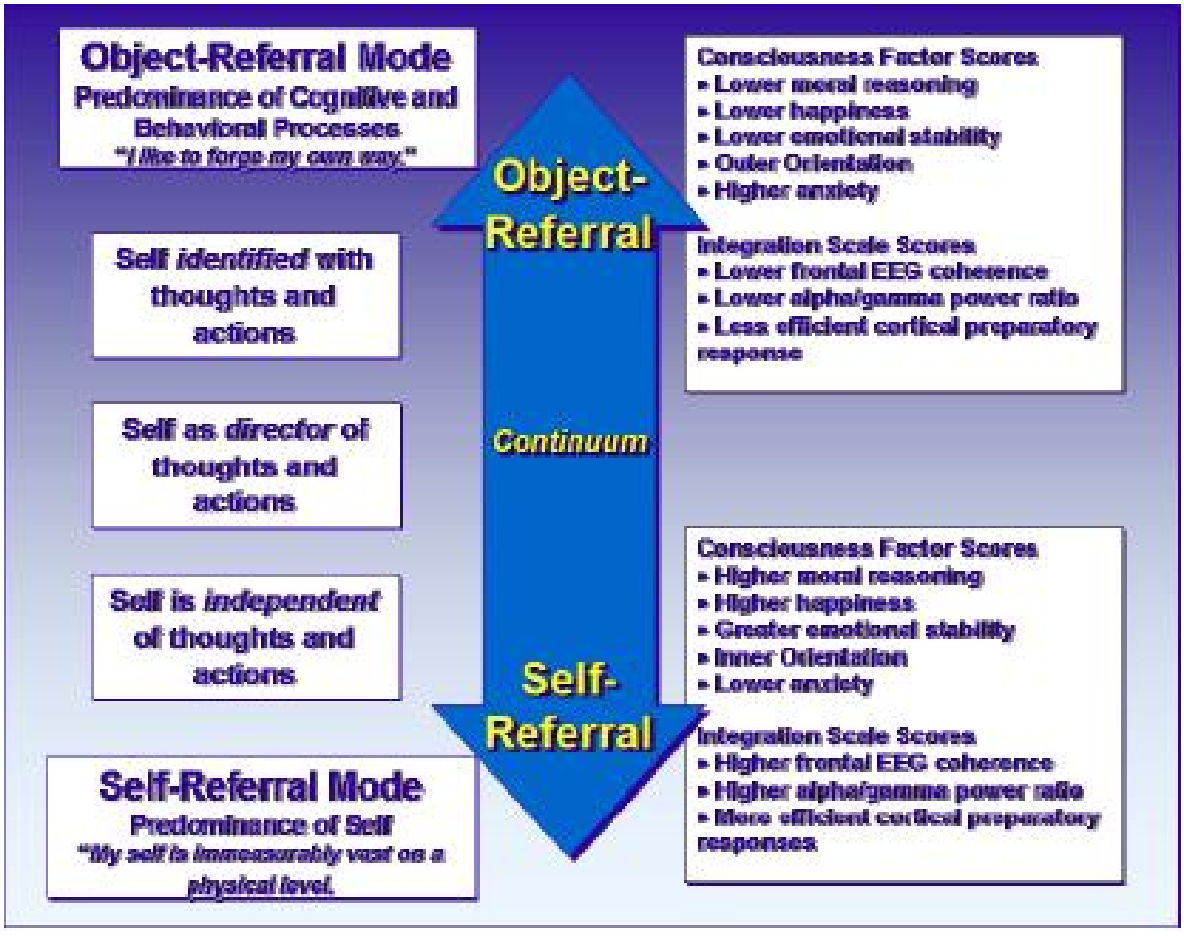
Brain-based Integration Scale of Growing Enlightenment



- **Subjective**, **self-reported descriptions** of sense-of-self development of higher states of consciousness.
    - **Object-referral predominant sense of self**—Non-meditating individuals identified their self with their thoughts and actions.
    - **Intermediate state of self recognition**—Meditating individuals, who did not report clear experiences of higher states of consciousness, described their selves as the director of all their thoughts and actions.
    - **Self-referral predominant sense of Self**—Meditating individuals reporting the experience of higher states of consciousness described their selves as underlying and independent of all thoughts and actions—a silent awareness lying under all activity (Travis et al, 2004).

- **Neuropsychological standard tests** also show significant levels of self-development in individuals reporting higher states.
    - Higher moral reasoning
    - Higher emotional stability
    - More inner orientation of life
    - Lower anxiety (Travis et al, 2004).

- **Brain Integration Report Card** is derived from a combination of the above brainwave and personality measures. This analysis allows an individual to follow their growth in brain integration over time.



- **Higher States of Consciousness**: Ongoing brainwave research will help us to distinguish individuals primarily reporting experience of Cosmic Consciousness, God Consciousness, and Unity Consciousness.

- **Yogic Flying and Brainwave Integration:** Yogic Flying is a component of Maharishi's TM-Sidhi Program and, over the last 25 years, the practice of Yogic Flying has been scientifically documented to enhance brainwave coherence and to improve the quality of life for the individual and society (see separate section on website at: http://brainresearchinstitute.org/research/yogic_flying/index.html).

- **Vedic Recitation and Brainwave Response.** Ongoing research indicates that while listening to the sounds of Veda and the Vedic Literature, the brain becomes highly synchronous. This suggests that Vedic sounds can enliven brain integration and facilitate the development of total brain functioning.