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BINAURAL BEATS AND THE REGULATION OF AROUSAL LEVELS

by F. Holmes Atwater, BA

Abstract

This paper describes two studies. A first study measured the neural accommodation (changes in ongoing or overall brain-wave activity) associated with complex binaural-beat stimuli. A second study, based on the same protocol, measured changes in ongoing brain-wave activity associated with placebo stimuli.

A weak EEG frequency-following response to binaural beating and other rhythmic stimuli manifests using time-domain averaging brainwave analysis techniques. Theoretically, this frequency-following response emerges as a low-amplitude linked series of evoked-potential responses. It is important to note that these studies examined ongoing brainwave activity (in this case, central delta and occipital alpha) and not the frequency-following response.

Results of the two studies showed that during the binaural-beat stimuli, reductions in the percentages of occipital alpha (bipolar O1–O2) were significant (individually, $p < .05$, and together, $p < .001$) during five of six free-running EEG recording periods compared to baselines. During these same recording periods, reductions in the percentages of central delta (bipolar C3–C4) were similarly significant during four of six periods compared to baselines. Alpha- and delta-brainwave changes were nonsignificant during the placebo stimuli.

The extended reticular-thalamic activating system (ERTAS) may be the neural mechanism behind the observed brainwave changes. The reticular formation of the brain stimulating the thalamus and cortex (referred to as the ERTAS) governs cortical brainwave patterns. Acetylcholine, provided via cortico-thalamic projections, either inhibits or excites areas of the cortex by neutralizing or enhancing the effects of noradrenaline and serotonin coming to the cortex via "fountains" from the locus coeruleus and the raphe nuclei.

Key Words: ERTAS, reticular, frequency-following response, sound, binaural beats, brainwaves

Background

A look at the auditory phenomenon known as binaural beating provides a unique opportunity to understand the power of rhythmic sound and music to influence arousal. The sensation of "hearing" binaural beats occurs when two coherent sounds of nearly similar frequencies are introduced by stereo presentation one to each ear. Phase differences between these sounds engender a perceived vibrato or wavering at the frequency of the difference between the two (stereo left and right) auditory inputs called the binaural beat.

Binaural beating originates in the brain stem's two superior olivary nuclei (Oster 1973). Beating-frequency information neurologically passes to the reticular formation (Swann et al. 1982). This information is said to be simultaneously "volume conducted" to the cortex and

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objectively measured by EEG as a frequency-following response (Oster 1973; Smith et al. 1975; Marsh et al. 1975; Smith et al. 1978; Hink et al. 1980). This cortical measurement was termed the "frequency-following response" because its period (frequency in cycles per second) corresponds to the frequency of the beat stimulus and the oscillation present in the olivary nuclei and subsequently the reticular formation (Smith et al. 1975).

The EEG frequency-following response, an objective, instrumented observation, strongly suggests that the perceived binaural beating is, in fact, the result of a low-level coherent oscillation within the central nervous system and the brain stem in particular.

Binaural beats can easily be heard at the low frequencies that are characteristic of the brain-wave spectrum (Oster 1973; Hink et al. 1980; Atwater 1997). The existence of an externally initiated, internally present low-level coherent oscillation (perceived as binaural beating) within the central nervous system, and specifically the reticular formation, suggests a condition that may facilitate alterations of levels of cortical arousal.

There have been numerous anecdotal reports and a growing number of research efforts reporting changes in consciousness associated with binaural beats. The audio phenomenon known as binaural beating has been associated with changes in arousal leading to sensory integration (Morris 1990), alpha biofeedback (Foster 1990), relaxation, meditation, stress reduction, pain management, improved sleep (Wilson 1990; Rhodes 1993), health care (Carter 1993), enriched learning environments (Akenhead 1993), enhanced memory (Kennerly 1994), creativity (Hiew 1995), treatment of children with developmental disabilities (Morris 1996), the facilitation of attention (Guilfoyle and Carbone 1996), peak and other exceptional experiences (Masluk 1998, 1999), enhancement of hypnotizability (Brady and Stevens 2000), treatment of alcoholic depression (Waldkoetter and Sanders 1997), and promotion of vigilance performance and mood (Lane et al. 1998).

Theoretically, sound waves exhibiting a frequency-following response may be effective in the regulation of arousal levels by way of inducing fluxes in cholinergic neurons or the "gatelets" of the nucleus reticularis. The concept here is that the binding of acetylcholine to cholinergic neurons (Scheibel 1980; Macchi and Bentivoglio 1986; Groenewengen and Berendse 1994 [all cited in Newman 1997a]) or the "gatelets" of the nucleus reticularis is affected by these sounds when the rhythmic patterns become neural oscillations within the brain stem.

These changes within the cholinergic neurons can be externally initiated using auditory drubbing found in rhythmic music, drumming, or the unique phenomenon known as binaural beating. Perceived binaural beating indicates the presence of a coherent oscillation within the brain stem's two superior olivary nuclei as evidenced by the cortically measured frequency-following response (Oster 1973; Hink et al. 1980). As with other rhythmic sound patterns, the low-level coherent oscillation (within the superior olivary nuclei) that accompanies binaural beating appears to regulate arousal states by providing frequency information to the extended reticular-thalamic activating system (ERTAS) and thereby inducing fluxes in cholinergic neurons or the "gatelets" of the nucleus reticularis.

First Study

The first study examined the degree to which complex binaural beats influenced ongoing brainwave activity (in this case, central delta and occipital alpha). Ongoing or dominant brainwave activity can be referred to as cortical levels of arousal.

Hypothesis

Listening to binaural beats for several minutes will modify ongoing brainwave activity. Increasing the amplitude of delta-frequency binaural-beat stimuli while decreasing the amplitude of alpha-frequency binaural-beat stimuli will result in comparable changes in arousal as measured by free-running EEG.

Method

During this study 20 volunteer subjects remained supine in a darkened, sound-attenuating chamber. Subjects reported normal hearing with the exception of one subject who had a bilateral hearing loss and for whom the volume of the stimuli was raised to a comfortable level to compensate for said hearing loss. None of the subjects reported a history of mental, emotional, or nervous-system disorders.

The experimental binaural-beat stimuli consisted of mixed sinusoidal tones producing complex frequency patterns (waveforms) changing over a period of 45 minutes. The stimuli were presented with stereo earphones at 40 dB above subjective threshold. The volunteer subjects first experienced a no-stimulus baseline condition during which a 90-second EEG recording was taken. Next, each subject listened to the same 45-minute sequence of changing binaural beats (see Figure 1) during which six 90-second EEG recordings were taken at regular intervals. To reduce the influence of expectation, subjects were blind as to the character of the tones presented during the stimulus condition. Finally, during a no-stimulus post-baseline condition, a 90-second EEG recording was made (see Figure 2).

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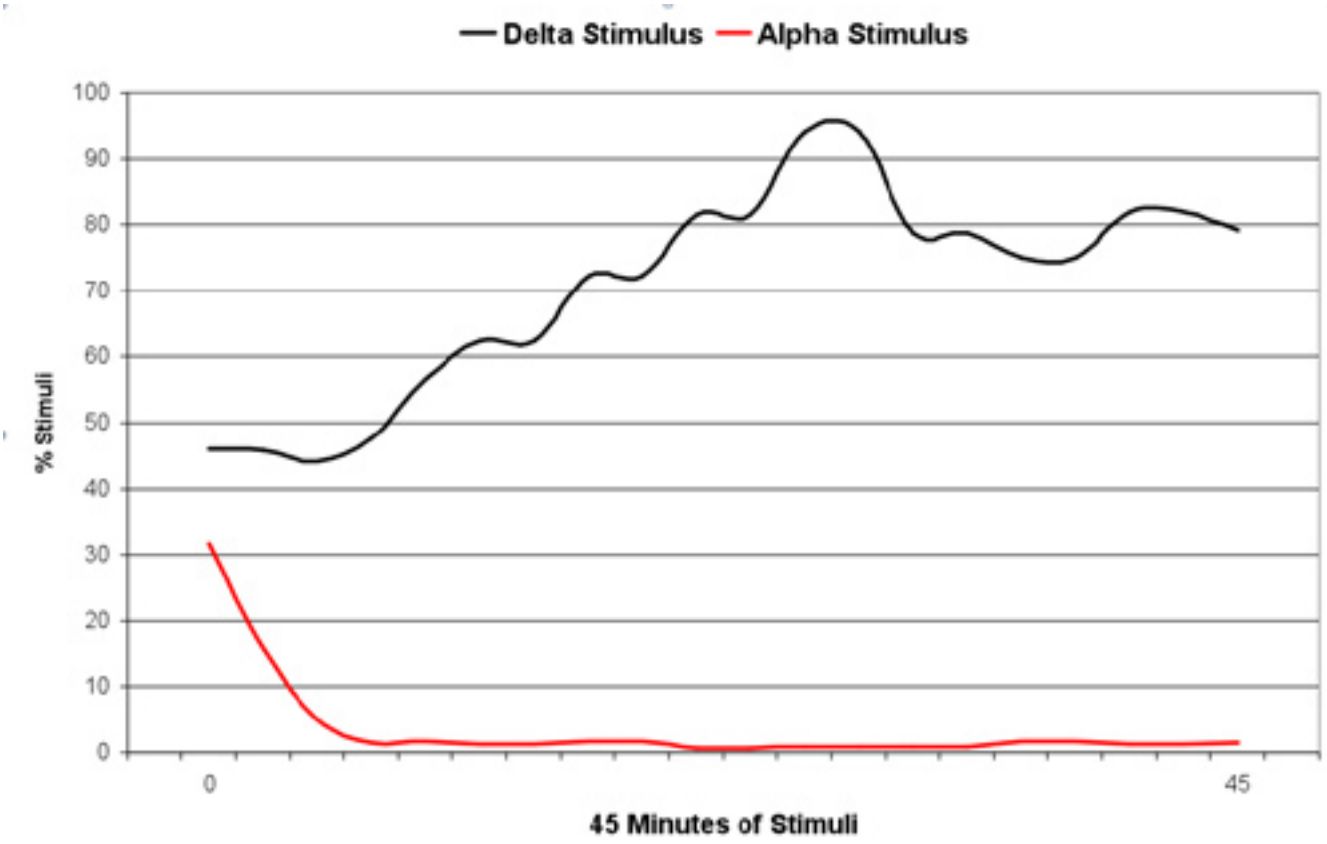

Figure 1. Changing delta and alpha binaural-beat stimuli

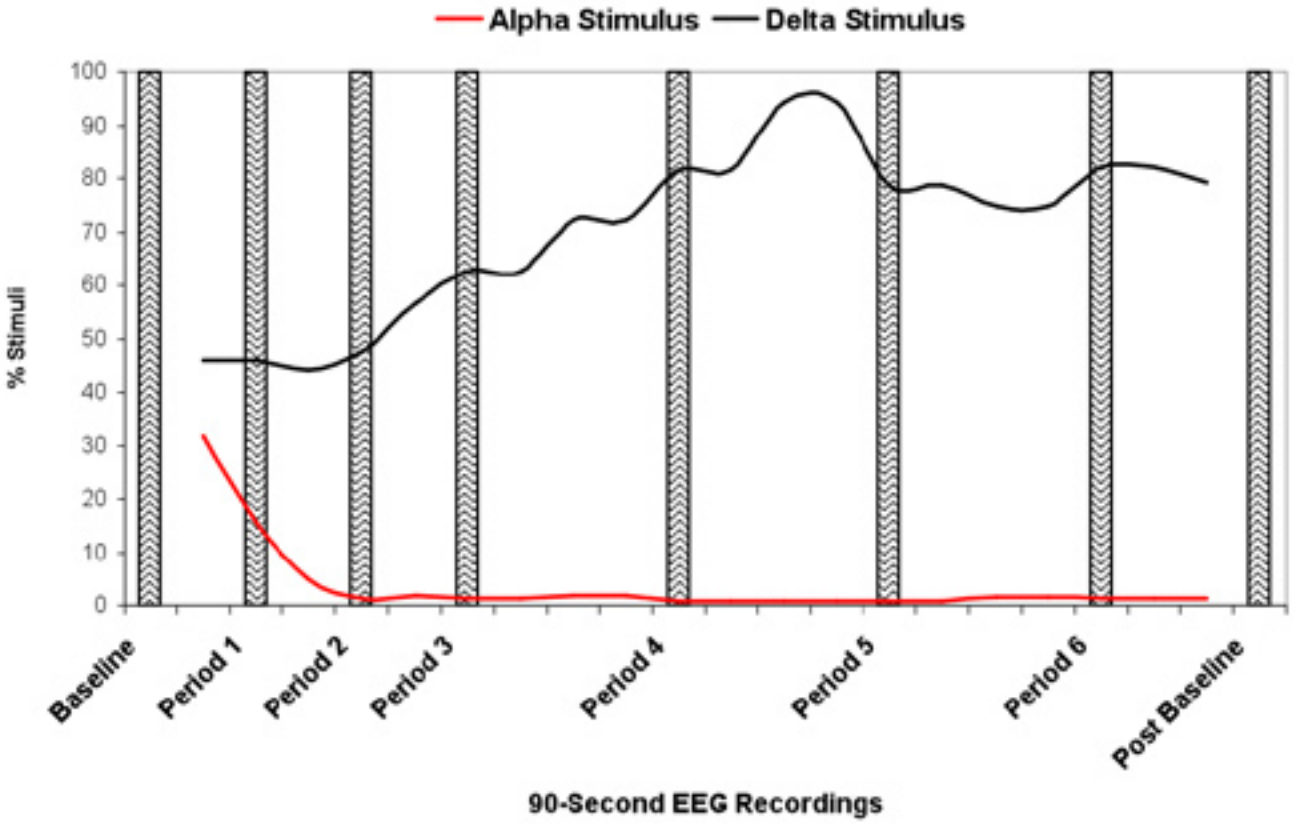

Figure 2. EEG recording periods

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Subjects were connected to a 24-channel digitizing EEG computer (NRS-24, Lexicor Medical Technology Inc., Boulder, Colorado) using V151 software and the entire standard 10/20 International System montage of electrodes. The 19 active EEG channels and reference electrode placements were tested to ensure the lowest possible contact resistance and balanced impedance level. A sampling rate of 256 samples per second was used, which provided for an EEG frequency response of 1-64 Hz (less 60 Hz, due to a notch filter), a frequency resolution of 1 Hz, and a temporal resolution of one second.

The audio patterns cross-faded smoothly from one complex stimulus waveform to another during the 45-minute binaural-beat protocol. Detailed below are the audio stimuli experienced by the subjects during the designated EEG recording periods:

Left-Ear	Right-Ear	Volume	EEG Recording Periods	
50 Hz	50.75 Hz	40%	First	@ 3 Minutes
100 Hz	101.5 Hz	32%		
200 Hz	207 Hz	28%		
50 Hz	50.75 Hz	40%	Second	@ 8 Minutes
100 Hz	101.5 Hz	32%		
200 Hz	205 Hz	28%		
50 Hz	50.5 Hz	29%	Third	@ 14 Minutes
75 Hz	75.75 Hz	26%		
100 Hz	101.5 Hz	24%		
200 Hz	204 Hz	21%		
50 Hz	50.75 Hz	20%	Fourth	@ 22 Minutes
100 Hz	101.5 Hz	18%		
125 Hz	126.25 Hz	25%		
200 Hz	204 Hz	15%		
200 Hz	202 Hz	22%		
50 Hz	50.75 Hz	24%	Fifth	@ 30 Minutes
100 Hz	101.5 Hz	23%		
200 Hz	204 Hz	35%		
325 Hz	328.5 Hz	12%		
525 Hz	530.25 Hz	6%		
50 Hz	50.75 Hz	29%	Sixth	@ 38 Minutes
100 Hz	101.5 Hz	28%		
200 Hz	204 Hz	36%		
850 Hz	858.5 Hz	4%		
1,375 Hz	1,397.25 Hz	3%		

Results

The data on two subjects were rejected due to movement artifact. WINKS Professional Edition statistical software (TexaSoft, Cedar Hill, Texas) was used to provide a multiple comparison procedure following a one-way ANOVA (Dunnett's test) comparing the combined baselines as a control mean with the binaural-beat stimulus periods for the remaining 18 subjects. This analysis showed that the reductions in the percentages of occipital alpha (bipolar O1–O2) during stimuli conditions were significant (individually, $p < .05$) during five of six stimulus periods compared to baselines (see below).

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Analysis Summary for Occipital Alpha - Stimulus Condition

Means and standard deviations for percent occipital alpha:

Baselines:	mean = 30.469	s. d. = 6.6197	n = 18
Period 1:	mean = 27.186	s. d. = 5.8456	n = 18
Period 2:	mean = 25.2613	s. d. = 5.2129	n = 18
Period 3:	mean = 23.9439	s. d. = 6.5893	n = 18
Period 4:	mean = 24.4362	s. d. = 6.8506	n = 18
Period 5:	mean = 23.2225	s. d. = 5.4852	n = 18
Period 6:	mean = 21.6931	s. d. = 4.5623	n = 18

Analysis of Variance Table

Source	-S.S.-	-DF-	-MS-	-F-	Approx. p
Total	5090.45	125			
Treatment	901.35	6	150.23	4.27	< .001
Error	4189.1	119	35.2		

Error term used for comparisons = 35.2 with 119 d. f.

Dunnett's Comp. (two-tailed)	Difference	P	Q	Critical q (.05)	
Mean Baselines - Mean Period 1	3.2829	2	1.66	1.98	
Mean Baselines - Mean Period 2	5.2077	3	2.633	2.241	*
Mean Baselines - Mean Period 3	6.5251	5	3.299	2.471	*
Mean Baselines - Mean Period 4	6.0328	4	3.05	2.381	*
Mean Baselines - Mean Period 5	7.2465	6	3.664	2.55	*
Mean Baselines - Mean Period 6	8.7758	7	4.437	2.601	*

Comparisons marked with an asterisk "*" are significantly ($p < .05$) different.

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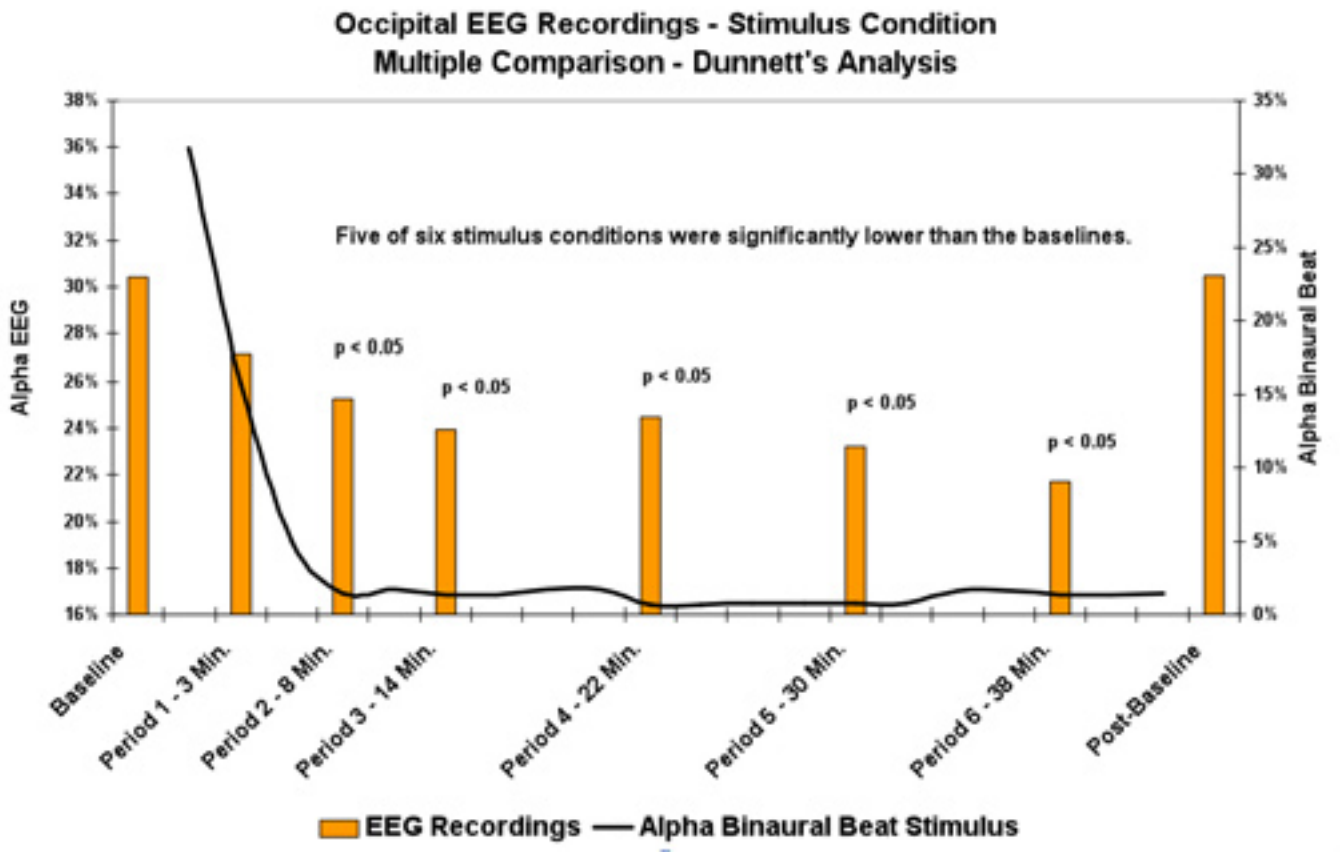

Figure 3. Changes in occipital-alpha EEG

Statistical analysis of the data also showed that the increases in the percentages of central delta (bipolar C3–C4) during stimuli conditions were significant (individually, $p < .05$) during four of six stimulus periods compared to baselines (see below).

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Analysis Summary for Central Delta - Stimulus Condition

Mean s and standard deviations for percent central delta:

Baselines:	mean = 18.4534	s. d. = 2.7744	n = 18
Period 1:	mean = 21.1218	s. d. = 3.3948	n = 18
Period 2:	mean = 21.457	s. d. = 3.5	n = 18
Period 3:	mean = 25.1393	s. d. = 7.4027	n = 1
Period 4:	mean = 25.218	s. d. = 6.4961	n = 18
Period 5:	mean = 24.7991	s. d. = 7.0691	n = 18
Period 6:	mean = 25.1343	s. d. = 5.5444	n = 18

Analysis of Variance Table

Source	-S.S.-	-DF-	-MS-	-F-	Approx. p
Total	4,344.82	125			
Treatment	788.73	6	131.46	4.4	< .001
Error	3,556.08	119	29.88		

Error term used for comparisons = 35.2 with 119 d. f.

Dunnett's Comp. (two-tailed)	Difference	P	Q	Critical q (.05)	
Mean Baselines - Mean Period 1	2.6685	2	1.464	1.98	
Mean Baselines - Mean Period 2	3.0036	3	1.648	2.241	
Mean Baselines - Mean Period 3	6.6859	6	3.669	2.55	*
Mean Baselines - Mean Period 4	6.7646	7	3.712	2.601	*
Mean Baselines - Mean Period 5	6.3358	4	3.477	2.381	*
Mean Baselines - Mean Period 6	6.681	5	3.666	2.471	*

Comparisons marked with an asterisk "*" are significantly (p < .05) different.

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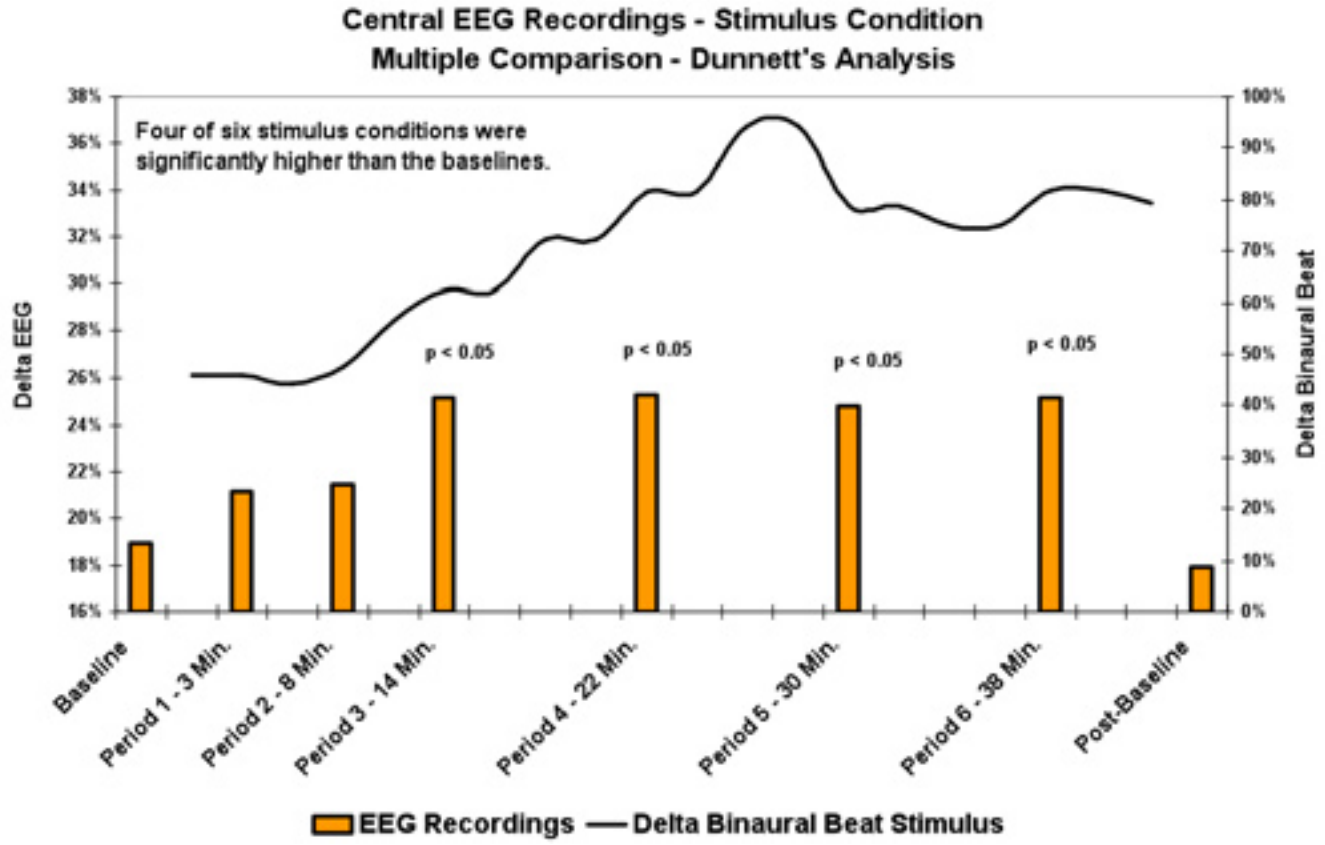

Figure 4. Changes in central-delta EEG

The results of this first study significantly distinguished brainwave activity during the stimulus periods from the baseline recordings both with increased central-delta EEG levels and decreased occipital-alpha EEG levels. Decreases in alpha amplitudes coupled with increasing delta activity indicate reduced cortical arousal (Berger et al. 1968). The mounting changes over the course of the stimuli suggest a deepening trend of progressive relaxation and falling asleep. Some so-called altered states of consciousness can also be associated with increased delta (Empson 1986) and a suppression of occipital alpha.

A basic question raised by this study was the role of binaural-beat stimulation in solely or directly causing the state changes observed. Several of the subjects had considerable previous experience with binaural-beat audio recordings. It may be that the subjects in this study were naturally adept at altering levels of arousal or that they had acquired this ability through repeated practice. Additionally, the deepening trend over time suggests the need to take naturally occurring, progressive state changes associated with falling asleep into consideration.

Second Study

To address these concerns a second study measured the changes in ongoing brainwave activity during a placebo stimulus (without binaural beats). This study examined the degree to which monotonous tones in the same environment as the first study influenced ongoing central-delta and occipital-alpha brainwave activity.

Hypothesis

Listening to monotonous tones for several minutes will result in habituation of the stimuli, a slowing of ongoing brainwave activity (increased delta and decreased alpha), and a progressive state of relaxation.

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Method

The second study also included 20 volunteer subjects. The subjects remained supine in a darkened, sound-attenuating chamber as in the first study. Subjects reported normal hearing. None of the subjects reported a history of mental, emotional, or nervous-system disorders.

The placebo stimuli consisted of the same mixed sinusoidal tones changing over a period of 45 minutes used with the first study, with the exception that they did not produce binaural beating. The stimuli were presented with stereo earphones at 40 dB above subjective threshold. The volunteer subjects first experienced a no-stimulus baseline condition during which a 90-second EEG recording was taken. Next, each subject listened to the same 45-minute sequence of changing tones during which six 90-second EEG recordings were taken at regular intervals. To reduce the influence of expectation, subjects were again blind as to the character of the tones. Finally, during a no-stimulus post-baseline condition, a 90-second EEG recording was made.

Subjects were connected to a 24-channel digitizing EEG computer in the same manner as in the first study. As in the first study, a sampling rate of 256 samples per second was used, which provided for an EEG frequency response of 1-64 Hz, a frequency resolution of 1 Hz, and a temporal resolution of one second.

The placebo tones cross-faded smoothly from one to another during the 45-minute protocol. Detailed below are the audio stimuli experienced by the subjects during the designated EEG recording periods:

Left-Ear	Right-Ear	Volume	EEG Recording Periods	
50 Hz	50 Hz	40%	First	@ 3 Minutes
100 Hz	100 Hz	32%		
200 Hz	200 Hz	28%		
50 Hz	50 Hz	40%	Second	@ 8 Minutes
100 Hz	100 Hz	32%		
200 Hz	200 Hz	28%		
50 Hz	50 Hz	29%	Third	@ 14 Minutes
75 Hz	75 Hz	26%		
100 Hz	100 Hz	24%		
200 Hz	200 Hz	21%		
50 Hz	50 Hz	20%	Fourth	@ 22 Minutes
100 Hz	100 Hz	18%		
125 Hz	125 Hz	25%		
200 Hz	200 Hz	15%		
200 Hz	200 Hz	22%		
50 Hz	50 Hz	24%	Fifth	@ 30 Minutes
100 Hz	100 Hz	23%		
200 Hz	200 Hz	35%		
325 Hz	325 Hz	12%		
525 Hz	525 Hz	6%		
50 Hz	50 Hz	29%	Sixth	@ 38 Minutes
100 Hz	100 Hz	28%		
200 Hz	200 Hz	36%		
850 Hz	850 Hz	4%		
1,375 Hz	1,375 Hz	3%		

Results

The data on two subjects were rejected due to movement artifact, leaving 18 subjects as in the first study. A multiple comparison procedure following a one-way ANOVA (Dunnett's test) comparing the combined baselines as a control mean with the placebo stimuli periods showed nonsignificant reductions in the percentages of occipital alpha (bipolar O1–O2) during stimuli conditions compared to baselines (see below).

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Analysis Summary for Occipital Alpha - Placebo Condition
Means and standard deviations for percent occipital alpha:

Baselines:	mean = 30.3427	s. d. = 9.7672	n = 18
Period 1:	mean = 29.8544	s. d. = 9.2752	n = 18
Period 2:	mean = 27.7227	s. d. = 8.0999	n = 18
Period 3:	mean = 26.3955	s. d. = 7.771	n = 18
Period 4:	mean = 28.6144	s. d. = 8.6961	n = 18
Period 5:	mean = 24.5212	s. d. = 6.3118	n = 18
Period 6:	mean = 27.5927	s. d. = 8.7169	n = 18

Analysis of Variance Table

Source	-S.S.-	-DF-	-MS-	-F-	Approx. p
Total	8914.46	125			
Treatment	433.67	6	72.28	1.01	0.4194
Error	8480.78	119	71.2		

Error term used for comparisons = 71.27 with 119 d. f.

Dunnett's Comp. (2-tailed)	Difference	P	Q	Critical q (.05)
Mean Baselines - Mean Period 1	0.4883	2	.174	1.98
Mean Baselines - Mean Period 2	2.62	4	.931	2.381
Mean Baselines - Mean Period 3	3.9472	6	1.403	2.55
Mean Baselines - Mean Period 4	1.7283	3	.614	2.241
Mean Baselines - Mean Period 5	5.8215	7	2.069	2.601
Mean Baselines - Mean Period 6	2.75	5	.977	2.471

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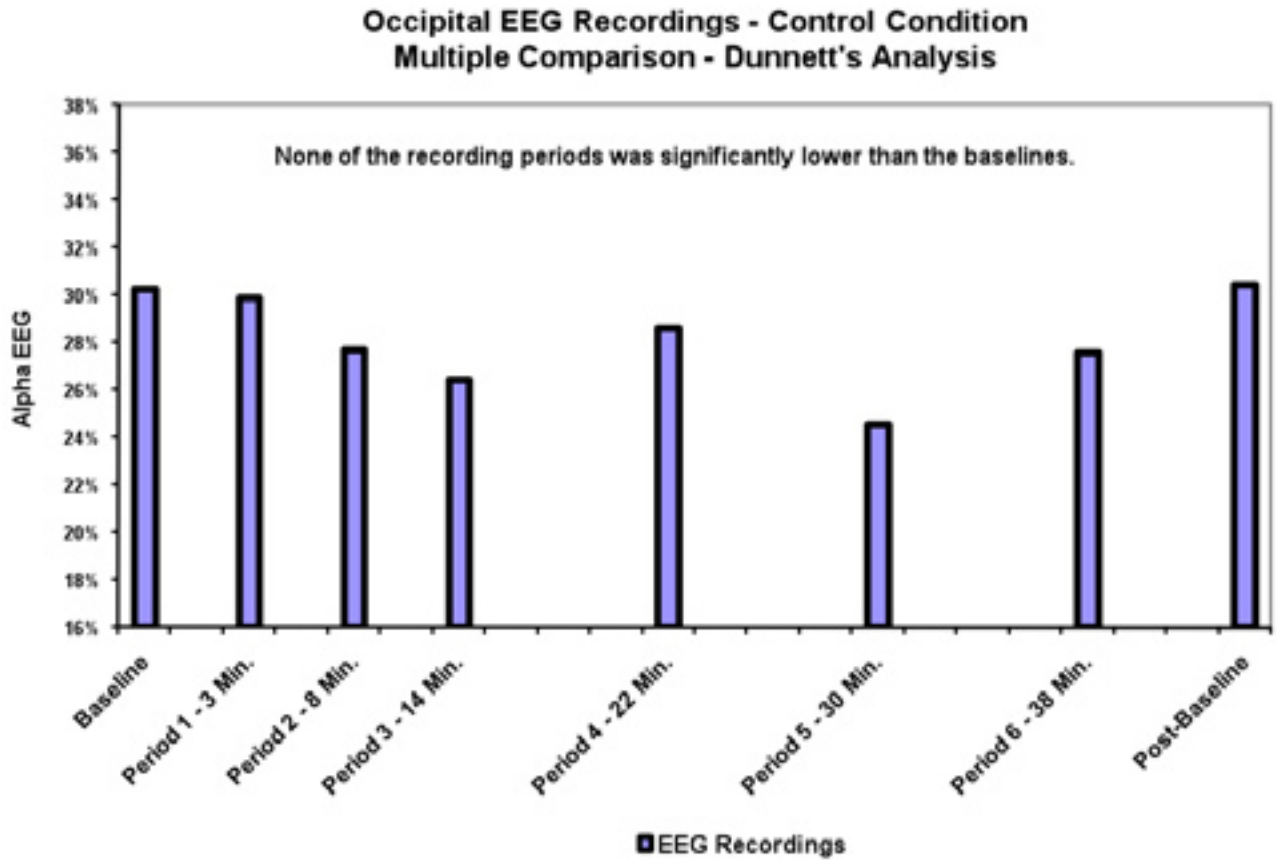

Figure 5. Occipital-alpha EEG

Statistical analysis of the data also showed the nonsignificant increases in the percentages of central delta (bipolar C3–C4) during stimuli conditions compared to baselines (see below).

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Analysis Summary for Central Delta - Placebo Condition

Means and standard deviations for percent central delta:

Baselines:	mean = 18.1997	s. d. = 4.0204	n = 18
Period 1:	mean = 18.5893	s. d. = 4.234	n = 18
Period 2:	mean = 20.298	s. d. = 3.9881	n = 18
Period 3:	mean = 21.0204	s. d. = 4.0122	n = 18
Period 4:	mean = 21.6606	s. d. = 5.1337	n = 18
Period 5:	mean = 21.8038	s. d. = 4.334	n = 18
Period 6:	mean = 19.5615	s. d. = 4.449	n = 18

Analysis of Variance Table

Source	-S.S.-	-DF-	-MS-	-F-	Approx. p
Total	2450.28	125			
Treatment	222.86	6	37.14	1.98	0.0732
Error	2227.42	119	18.72		

Error term used for comparisons = 18.72 with 119 d. f.

Dunnett's Comp. (two-tailed)	Difference	P	Q	Critical q (.05)
Mean Baselines - Mean Period 1	0.3895	2	.27	1.98
Mean Baselines - Mean Period 2	2.0982	4	1.455	2.381
Mean Baselines - Mean Period 3	2.8207	5	1.956	2.471
Mean Baselines - Mean Period 4	3.4609	6	2.4	2.55
Mean Baselines - Mean Period 5	3.604	7	2.499	2.601
Mean Baselines - Mean Period 6	1.3618	3	.944	2.241

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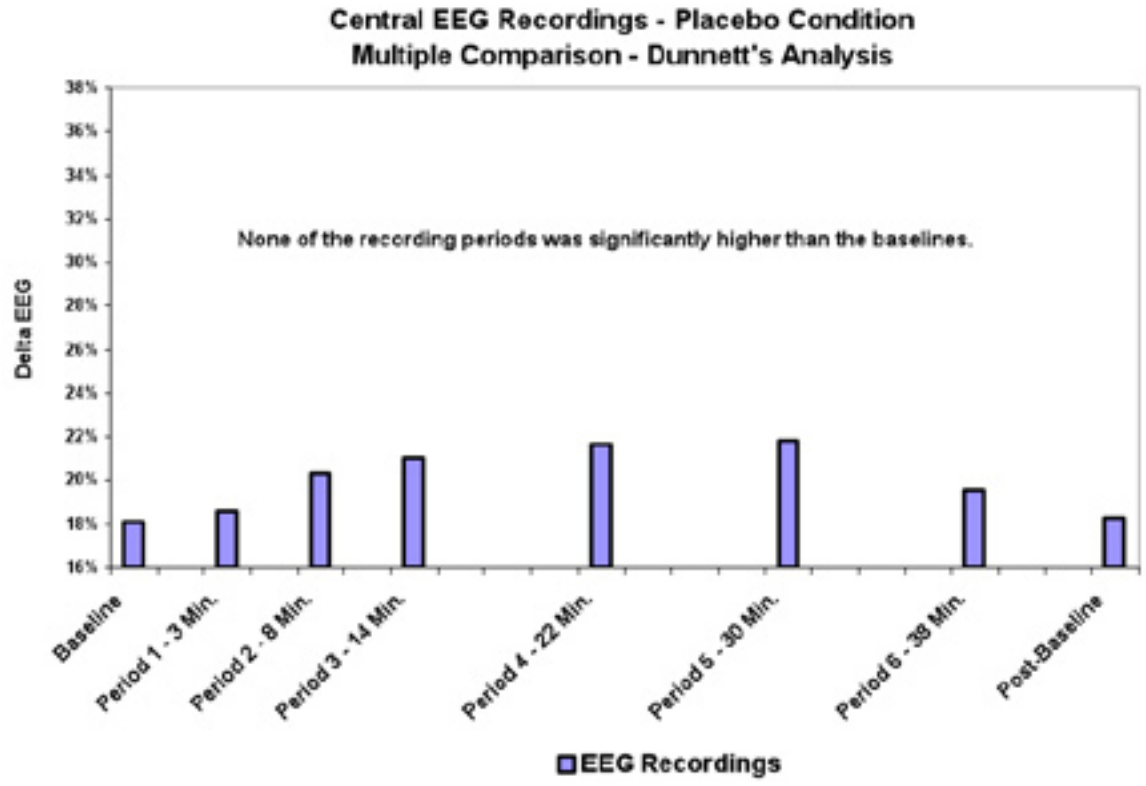

Figure 6. Central-delta EEG

The results of this second study did not significantly distinguish occipital-alpha and central-delta brain-wave activity during the placebo stimulus periods from the baselines. As set forth in the hypothesis of this placebo study, the observed decreases in alpha amplitudes coupled with increasing delta activity were expected as a reaction to listening to monotonous tones. These changes, however, were not statistically significant—meaning that they could be expected to have happened by chance alone.

Discussion

These studies appear to demonstrate that the binaural beat has a direct effect on brain-wave activity. Such a direct effect would involve the interaction of binaural-beat stimulation with the basic rest-activity cycle, with other sensory stimulation, and with "higher order" memory or attentional processes under the scrutiny of the reticular formation. All of these systems cooperate to maintain homeostasis and optimal performance. Natural state changing mechanisms (Steriade, McCormick, and Sejnowski 1993), ultradian rhythms, individual differences, prior experience, and beliefs may all contribute to the effects of and response to binaural-beat stimulation as they do with nearly all other behaviors.

Newman (1997a,b) and references therein describe the extended reticular-thalamic activating system and convincingly argue that this "conscious system" is responsible for modifying generalized levels of arousal as well as individual explicit patterns of arousal. Newman (1997a) writes, "This extended reticular-thalamic activating system (ERTAS) has been increasingly implicated in a variety of functions associated with consciousness, including: orienting to salient events in the outer world; dream (REM) sleep; the polymodal integration of sensory processes in the cortex (binding); selective attention and volition." It may be that rhythmic sound patterns affect overall cortical levels of arousal by providing frequency information from the olivary nuclei, the first site of contralateral integration in the auditory system (Oster 1973), to the ERTAS (Swann et al. 1982). Perhaps the reticular *sees* the intervening rhythmic stimuli (including binaural beating) as phantom cortical activity and, in an attempt to maintain homeostasis, alters arousal levels accordingly.

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Data on an assortment of subject variables were also studied. There were no significant performance differences in either the experimental or placebo groups based on sex, experience with binaural beats, or temperament type (Myers-Briggs Type Indicator). In the placebo group delta levels were significantly ($p < .05$) higher during afternoon sessions than during morning sessions. Interestingly, in the experimental group delta levels were significantly higher during the morning sessions.

Although this paper is concerned primarily with the voluntary regulation of arousal levels through the use of persistent rhythmic sound stimuli, the incidental regulation of brainwave states by means of prevailing sounds in the workplace or home environment cannot be overlooked. The rhythmic mechanical sounds of machinery or electronic devices may enhance or impair task vigilance or work performance (see Lane et al. 1998). Background sounds may affect mood and sense of wellness.

Conclusion

The two studies reported provide statistical observations in support of the notion that rhythmic sound patterns (binaural beats, in this case) appear to engender changes in cortical arousal, which can be objectively monitored with the free-running EEG. As the reticular is responsible for regulating cortical arousal (Swann et al. 1982; Empson 1986; Newman and Baars 1993; Newman 1997a,b; Petty 1998), it is possible that the reticular formation serves as the mechanism of change in arousal levels engendered by externally initiated (e.g., music, rhythmic drumming, or binaural beats) coherent oscillations within the superior olivary nuclei and the cholinergic neurons within the nucleus reticularis.

Additionally, four decades of investigation have shown that exposure to such stimuli under appropriate circumstances can provide access to expanded states of consciousness (Atwater 1997). Several free-running EEG studies (Foster 1990; Sadigh 1990; Hiew 1995, Brady and Stevens 2000, among others) suggest that binaural beats induce alterations in cortical arousal states. These cited studies also document measurable changes in the ERTAS during exposure to binaural beats because the reticular formation is responsible for the regulation of cortical arousal (see Swann et al. 1982; Empson 1986; Newman and Baars 1993; Newman (1997a,b); and Petty 1998).

It would appear that the rhythmic frequencies of an auditory stimulus (when objectively demonstrated by an EEG frequency-following response) affect cholinergic neurons within the nucleus reticularis. Such an intercourse modifies the membrane transport and production of acetylcholine and consequently results in changes in arousal states. These suppositions are compatible with current knowledge of the reticular formation and suggest a neural mechanism, an instrument for the voluntary regulation of cortical levels of arousal using audio stimuli.

The implications in the enhancement of human performance as it relates to the control of generalized arousal levels such as the basic rest/activity cycle, sleep cycles, mood and motivational states, orienting and vigilance, etc., are intriguing. This paper encourages further research and the responsible application of existing technologies providing access to propitious states of consciousness.

The Extended Reticular-Thalamic Activating System

The reticular formation of the brain stimulating the thalamus and cortex (the ERTAS) governs cortical brainwave patterns. In the ERTAS model, the reticular furnishes the neurotransmitter acetylcholine via the thalamus to the cortex. Lower portions of the reticular formation (the locus coeruleus and the raphe nuclei) provide the neurotransmitters noradrenaline and serotonin via "fountains" that largely bypass the thalamus on their way to the cortex (Newman 1997a). It is the balance of these neurotransmitters at the cortex that changes (or maintains) arousal levels, as measured by rhythmic EEG patterns, and the ERTAS plays an active role in regulating this balance. The reticulothalamic core mediates cortical activity through the action of the cholinergic neurons, which propagate the neurotransmitter acetylcholine. The "gating" ability of the nucleus reticularis appears to be the arousal control mechanism of the ERTAS. This "gating" activity regulates cortical interplay of inhibition and excitation between noradrenaline and serotonin from extrathalamic activation systems and acetylcholine via corticothalamic projections.

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CAMPBELL TO DELIVER KEYNOTE ADDRESS

We are delighted that Thomas W. Campbell has accepted our invitation to be the keynote speaker for **Consciousness: The Endless Frontier**, The Monroe Institute's Twenty-second Professional Seminar, which will be held March 20–24, 2010.

Tom holds a Bachelor of Science in physics and math from Bethany College and a Master of Science in physics from Purdue University, as well as having done doctoral-level work at the University of Virginia. He is the physicist described as "TC" in Bob Monroe's *Far Journeys*. Tom began researching altered states of consciousness with Bob in the early 1970s. He and a few others helped to design experiments and develop the technology for creating specific altered states, and they were also the main subjects of Bob's investigations at that time. For the past thirty years, Campbell has been focused on scientifically exploring the properties, boundaries, and abilities of consciousness. During that same time period, he excelled as a working scientist—a professional physicist dedicated to pushing back the frontiers of cutting-edge technology.

Using his mastery of the out-of-body experience as a springboard, he dedicated his research to discovering the outer boundaries, inner workings, and causal dynamics of the larger reality system. In February of 2003, Tom published the *My Big TOE* trilogy, which represents the results and conclusions of his scientific exploration of the nature of existence. This overarching model of reality, mind, and consciousness merges physics with metaphysics, explains the paranormal as well as the normal, places spirituality within a scientific context, and provides direction for those wishing to personally experience an expanded awareness of All That Is.

My Big TOE speaks to each individual reader about his or her innate capabilities. Readers will learn to appreciate that their human potential stretches far beyond the limitations of the physical universe. The acronym "TOE" is a standard term in the physics community that stands for "Theory Of Everything" and has been the Holy Grail of that community for fifty years. *My Big TOE* delivers the solution to that scientific quest at the layman's level with precision and clarity. Please join us in March to hear Tom share the knowledge and wisdom he has acquired since following his personal inclination to "find out for himself."

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RESEARCH UPDATE

"Brief Meditation Training Can Improve Perceived Stress and Negative Mood" by James D. Lane, PhD, et al., was published in *Alternative Therapies in Health and Medicine*, vol. 13, no. 1 (Jan./Feb. 2007), pp. 38–44. Dr. Lane has been a professional member of The Monroe Institute since 1999.

The study objectives were to test a brief, nonsectarian program of meditation training for effects on perceived stress and negative emotion, to determine the effects of practice frequency, and to test the possible moderating effects of neuroticism on treatment outcome. A single-group, open-label, pretest-posttest design was used, and the study was conducted at a university medical center. Two hundred healthy adults were enrolled. One hundred and thirty-three of them completed at least one follow-up visit. Participants learned a simple mantra-based meditation technique in four one-hour sessions and then practiced for 15–20 minutes twice daily. Outcome measures were evaluated with the Profile of Mood States, Perceived Stress Scale, State-Trait Anxiety Inventory (STAI), and Brief Symptom Inventory (BSI).

All four outcome measures improved significantly, with reductions from baseline that ranged from 14 percent (STAI) to 36 percent (BSI). More frequent practice resulted in a better outcome. Subjects with higher baseline neuroticism scores showed greater improvement. Preliminary evidence suggests that even brief instruction in a simple meditation technique can improve negative mood and perceived stress in healthy adults, which could yield long-term health benefits.

An abstract of the study "Hemispheric Synchronized Sounds and Perioperative Analgesic Requirements" by Susan M. Dabu-Bondoc, MD, et al., was presented at the annual meeting of the American Society of Anesthesiologists held October 18–22, 2008, in Orlando, Florida. Sixty patients were randomized into three groups: the treatment group (n=20) had Hemi-Sync® sounds; the music group (n=20) had music tapes of their choice; the control/placebo group (n=20) had blank cassette tapes.

The Hemi-Sync group had significantly reduced intraoperative analgesic consumption compared to the music and control groups. Pain scores in the Hemi-Sync group were significantly less one hour and 24 hours after surgery but analgesic requirements were similar among all three groups over the 24-hour postop period. Time to discharge trended lower in patients who had Hemi-Sync. The researchers concluded that Hemi-Sync sounds before and during general anesthesia decreased intraoperative but not postoperative analgesic requirements. [This paper has been submitted for publication.]

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