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Joel F. Lubar, Major Professor

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Associate Vice Chancellor and
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AN ASSESSMENT OF THE EFFECTS OF MULTI-SESSION AUDIO-VISUAL STIMULATION ON COGNITIVE MEASURES AND THE CORTICAL EEG

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

DeAnna Lee Timmermann

August 1998

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ACKNOWLEDGMENTS

I would like to acknowledge and thank my husband, David Lee Coleman, for all of his emotional and financial encouragement over the last eight years. This dissertation would not have been possible without David. I would also like to thank my parents, Sylvia Timmermann and A. LeRoy Timmermann, for providing me a lifelong love of learning, as well as David's parents, Jack and Jean Coleman, for their support over the last eight years.

Additionally, I would like to thank my committee members Dr. Joel Lubar, Dr. William Calhoun, Dr. John Malone, and Dr. Schuyler Huck for their guidance, comments, and assistance in developing this dissertation. A special thank you must go to Bob Muenchen, who spent seemingly endless hours assisting me during the statistical analysis of the data. Appreciation is also extended to Lucas Tremont, for his many hours of data processing.

Finally, I would like to acknowledge Dr. Harold Russell and Synetic Systems for providing me with the Polysync Pro devices used in this investigation.

ABSTRACT

The effects of multi-session (20 sessions) audio-visual stimulation (AVS) at the dominant alpha frequency and twice dominant alpha frequency on the EEG were investigated using thirty subjects. A pilot study provided priliminary data to predict the outcomes of multi-session AVS. An eyes-closed baseline EEG determined each subject's dominant alpha frequency. Ten subjects were stimulated for twenty minutes at their dominant alpha frequency, ten at twice their dominant alpha frequency, and ten subjects served as controls, receiving no stimulation. A post-session EEG was recorded two weeks after the AVS sessions ended. Power data were analyzed for 19 locations in six bandpasses using repeated-measures ANOVAs and appropriate post-hoc tests. Results indicate neither AVS condition affected the alpha bandpass. Alpha AVS showed within-session effects on the beta 1 and beta 2 bandpasses, but no long-term effects. Beta AVS increased within-session power within the theta, beta 1, and beta 2 bandpasses, showing long-term effects at frontal locations within the beta 1 bandpass. Exploratory analyses of eyes-open EEG data indicate that changes in power seen in the eyes-closed data do not persist when the eyes are open. Neither AVS condition showed effects on the cognitive tests employed in this study. These results are discussed in the context of neurofeedback.

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CHAPTER I

AUDIO-VISUAL STIMULATION AND THE ELECTROENCEPHALOGRAM: AN OVERVIEW

The EEG.

The electroencephalogram, or the EEG, is a measurement of the physical processes that underlie the neural systems of all living organisms. It is a measure of the electrical activity of cortical neurons (Pilgreen, 1995). More precisely, the EEG reflects the ionic flow across the membranes of mainly pyramidal cells which lie in the gyri of the cerebral cortex (Martin, 1991). The EEG is "based on the theory of volume conduction which describes the flow of ionic current generated by nerve cells through the extracellular space" (Martin, 1991, p 781). A recording electrode placed on the scalp summates the postsynaptic potentials of large numbers of cell assemblies located beneath the electrode. Postsynaptic potentials directly under the electrode contribute the most to the recorded signal; neural activity further from the recording site contributes less. Since pyramidal cells orient perpendicularly to the surface of the cerebral cortex, forming macro columns through the distinctive layers of the cerebral cortex, it is mainly the postsynaptic activity of these cells that is summated to produce EEG output (Pilgreen, 1995).

To record the EEG, electrodes are arranged in a standardized position on the scalp according to what is referred to as the 10-20 International System developed by Herbert Jasper in 1958 (Duffy, Iyer, & Surwillo, 1989). This system ensured the same electrode placement in the majority of EEG laboratories world-wide and is based on percent

differences (either 10% or 20%) from major skull landmarks. The brain is divided into frontal, central, parietal, temporal, and occipital regions. These regions reflect the underlying cortical areas and are represented by the initials F, C, P, T, and O, respectively. The left side of the head is denoted by odd numbers, and the right side of the head is denoted by even numbers. The locations of the 10-20 International System are illustrated in Figure 1[1].

Two properties of the EEG are frequency (cycles per second), which is measured in Hertz (Hz), and amplitude, measured in microvolts (mV). Researchers in the EEG field have traditionally divided EEG output into ranges of frequencies, called bandpasses, possessing unique spatial properties. Slow-wave activity, referred to as delta activity, has a frequency between 0.5 and 4 Hz, and the waveform of this bandpass tends toward a high amplitude, synchronized sinusoidal shape. The theta bandpass encompasses frequencies between 4 and 8 Hz, often has a square or saw-toothed shape, and is usually of moderate voltage. The alpha bandpass is approximately 8 to 13 Hz activity and is the most distinctive waveform in most people, consisting of large sinusoidal waves. Finally, the beta bandpass is made up of those frequencies between 13 and 32 Hz, and is generally represented by low amplitude, quickly oscillating, synchronized or desynchronized waves.

The distinctive waveforms of the EEG are generated from cortico-cortical and corticothalamic connections (Silberstein, 1995) and reflect local, regional, and global resonances between macro columns of pyramidal cells. Local resonances (between very slightly separated macro columns) and regional resonances (macro columns separated by

[1] All figures may be found in Appendix A.

several centimeters) are thought to produce alpha and beta activity, while global resonances from widely separate areas of the cortex produce delta and theta activity (Silberstein, 1995; Lubar, 1997). These resonances feed back to their respective cortico-cortical and corticothalamic connections, serving to enhance, modulate, or suppress subsequent activity.

With technological advances over the last several decades, EEG recording and interpretation has become increasingly complex. Early EEG research relied upon visual inspection of EEG output, usually from only a few electrodes, and depended upon the pattern recognition skill of the EEG technologist in detecting the unique bandpass characteristics. Currently, the EEG can be recorded from 19, 64, 128, or even more locations simultaneously, and computerized analysis of the EEG signal has allowed for more accurate and objective interpretation. Spectral analysis breaks down the complex wave form of the EEG into its different frequency components, and provides the amplitudes of those frequencies. This is done by using a series of mathematical transformations named after the 18th century mathematician Jean Baptiste Fourier (Duffy, et al., 1989). Fast-Fourier transformation can be performed on EEG segments of any length by averaging together the components of the waveform. This analysis provides a measure of power, which reflects the mean squared value of each bandpass' amplitude. Power is measured in picowatts.

The EEG has been a very effective tool in several applied medical areas. According to Duffy, et al. (1989, p 245), "the conditions in which the EEG provides somewhat

specific diagnostic information include seizure disorders, sleep disorders, and certain forms of encephalitis. It is similarly useful in the documentation of brain death". In the area of seizure disorders, the EEG is a particularly useful diagnostic tool, with 90% of patients with absences seizures (staring spells and lapses of consciousness that last a few seconds) showing epileptiform abnormalities in the EEG recording (Duffy et. al, 1989). The non-REM sleep stages themselves are defined by the waveforms and bandpass activity present in EEG recordings during sleep. Sleep disorders such as apnea and narcolepsy are diagnosed with EEG recordings in a sleep laboratory. The very definition of "brain dead" is the absence of any detectable EEG activity. Thus, qualities ascribed to the EEG recording can and do predict certain abnormalities in cortical and behavioral activity pertinent to the field of medicine.

Additionally, the frequency bandpasses of EEG activity have been associated with behavioral (states of arousal) and cognitive states over several decades of research (Martin, 1991; Pilgreen, 1995). Delta activity is associated with deep sleep and loss of consciousness, while theta is associated with drowsiness, daydreaming, and reduction of attention. Relaxed attention is the behavioral state usually ascribed to alpha activity, and the beta bandpass is correlated with alert attentiveness and intense mental concentration (solving mathematical equations, problem solving, etc.). Alpha activity is most obvious in posterior regions while the eyes are closed; alpha is attenuated or blocked by visual and mental attention (Duffy, et al., 1989). The attenuation or blocking effect brought about by opening the eyes is not limited to the alpha bandpass, although alpha blocking is much

more obvious than the blocking seen within the theta and beta bandpasses (Noguchi & Iwahare, 1971). Generally, high-amplitude sinusoidal activity across the entire cortex is associated with a lack of cognitive processing, while low-amplitude, broad spectrum EEG activity is usually associated with being alert or actively processing information (Nunez, 1995). It is important to keep in mind that "the human EEG indicates much less about brain function than researchers need or want to know. It is a cliché that the normal EEG is a global indicator only for large-scale activity of the human cerebral cortex" (Mulholland, 1995, p 264). However, the EEG, as a global indicator of cortical activity, has provided a research instrument for non-invasively exploring cognitive activity.

Altering the EEG.

Researchers have used the EEG to associate unique EEG patterns with particular clinical populations. For example, Lubar and others have reported several studies that indicate people with attention-deficit disorder (ADD) and attention-deficit with hyperactivity (ADHD) show a slowing of the EEG, with a higher ratio of theta to beta power than seen in matched controls (Shouse & Lubar, 1978; Lubar & Lubar, 1984; Lubar, 1991; Lubar, Swartwood, Swartwood, & O'Donnell, 1995). Children suffering from learning disorders (LD) show a similar pattern. Tansey (1991) reports LD children have over two times the amount of 7 Hz theta activity as compared to 14 Hz sensorimotor activity. Chronic Fatigue Syndrome (CFS) sufferers show a pattern of high delta activity and low amplitude beta activity (Tansey, 1993; Garloch, 1994; James & Folen, 1996).

Alcoholics tend to exhibit decreased alpha levels when compared to controls (Peniston & Kulkosky, 1989). These researchers have hypothesized that changing the EEG patterns of clinical populations to more closely resemble those of normal populations may alleviate some or all of the symptoms associated with the disorder. Two possible techniques for altering the EEG are neurofeedback (or EEG biofeedback) and audio-visual stimulation (AVS), also referred to as entrainment.

Neurofeedback. During the 1970's, researchers began to apply biofeedback techniques to modulate EEG bandpasses in an attempt to relieve symptoms of certain clinical populations, particularly those people suffering from seizure disorders and attention-deficit disorders (Lubar, 1991). Neurofeedback is a recently coined term that describes the use of biofeedback instrumentation for the purpose of helping persons increase or decrease the production of various frequencies of EEG activity. For example, in the case of ADHD, neurofeedback is provided to increase the production of sensorimotor rhythm (12 - 15 Hz) and/or beta activity, while at the same time decreasing the production of excessive theta activity (Lubar, 1995). Other applications of neurofeedback are in the areas of treating alcohol abuse and accompanying depression (Saxby & Peniston, 1995), chronic fatigue syndrome (James & Folen, 1996), cognitive deficits associated with learning disabilities (Tansey, 1991), stroke rehabilitation (Rozelle & Budzynski, 1995), and even improving sports performance and concentration (Landers et. al, 1991). An exciting area in the field of neurofeedback is in the use of the EEG to control cursor activity on a computer monitor (Wolpaw, McFarland, Neat, & Forneris,

1991; Wolpaw & McFarland, 1994). After training, participants can literally move a cursor purposefully across a screen to intercept moving targets by modulating their EEG at specific locations and within specific bandpasses. The intended purpose of this application of neurofeedback is to provide individuals with paralysis or severe motor handicaps a medium to communicate with others. For all these applications, the most effective neurotherapies are those that show a change in the subject's EEG. A change in the EEG is associated with a change in behavior.

There are several explanations regarding the efficacy of neurofeedback. Major theoretical rationales for the use of neurofeedback include operant conditioning, the learning of self-regulatory behaviors, and a concept referred to as behavioral stillness. Traditionally, operant conditioning has been used to explain how biofeedback works (Rosenfeld & Hetlzer, 1978). This view emphasizes the reinforcing properties of the neurofeedback signal and its effects on evoked potentials. More recently, Shellenberger and Green (1987) argue that what is learned during clinical applications of biofeedback (and thus neurofeedback) is the self-regulation of behavior. That is, the biofeedback signal allows for an awareness of previously undifferentiated physiological states, and this awareness is coupled with the acquisition of "self-regulation skills gained through practice of a variety of techniques ranging from the more physiological, such as breathing exercises, to the more mental, such as imagery" (p 205). For example, children diagnosed with ADHD may learn, via neurofeedback, to distinguish when they are attending to stimuli (producing beta bandpass activity) and when they are performing off-task

(producing excessive theta activity). Finally, Mulholland (1995) presents evidence that the EEG is an indicator of movements of behavior, and is only indirectly an indicator of cognitive processes. He suggests that "learned EEG changes are mediated by learned control of motor processes" (p 272), and it is only when cortical activity is not involved with the production of motor processes (i.e., when a person is behaviorally still) that cortical processes can be involved in cognitive activities. According to this rationale, neurofeedback effects arise not only from the regulation of EEG frequencies, but also (and perhaps mainly) from the regulation of muscular activity. Neurofeedback is effective because it reduces motor activity, "freeing" the cortex for more cognitively applied activities.

Audio-visual Stimulation (AVS). Another way to attempt to modify a person's EEG is through the use of entrainment or AVS devices. Entrainment devices use either light, sound, or both light and sound together, presented at specified frequencies, with the objective of "driving" the EEG towards those frequencies. For example, a light flashing at 10 Hz should produce a photic driving response of 10 Hz activity in the recorded EEG. There are several terms employed to describe the use of external stimulation in order to affect the EEG. Audio-visual stimulation (AVS) is the use of both a series of tones and a series of flashing lights in concert to stimulate the brain. Entrainment may be used interchangeably with the term AVS, although some researchers use only light stimulation in entrainment studies (i.e., Rosenfeld, Reinhart, & Srivastava, 1997). In general, the light

stimulation used in this research area is sinusoidally modulated light (SML). Sinusoidally modulated stimulation is preferred because a sine wave modulation eliminates possible stimulation effects due to harmonic frequencies. A sine wave only produces the designated fundamental frequency (Sears, 1950). Intermittent photic stimulation (IPS) is a phrase most commonly used for the procedure using strobe light flashes at rates of 1-50/second to stimulate the brain (Duffy, et al., 1989). IPS has clinical applications in that it can provoke paroxysmal discharges in persons with seizure disorders (Walter, Dovey, & Shipton, 1946). Photic driving is a term applied to the rhymthic time-locked physiological cortical activity in response to SML or AVS.

EEG Correlates of AVS.

That external stimulation (ie, flashing lights) can effect the EEG has been known since the early 1930's, when Adrian & Matthews (1934) spun cardboard cutouts in front of a light source to create sinusoidal photic stimulation. From the 1960's through the 1980's, researchers became interested in exploring the effect of sinusoidally modulated light (SML) on naturally occurring alpha activity (8 to 13 Hz) of the occipital cortex (Van der Twill & Verduyn Lunel, 1965; Iwahara, Noguchi, Yang, & Oishi, 1974; Townsend, Lubin & Naitoh, 1975; Aranibar & Pfurtscheller, 1978). These studies indicate SML between frequencies of 8 -13 Hz generally leads to a corresponding activation of the alpha bandpass, measured from occipital loci. This is particularly evident when SML approximates the subject's dominant alpha frequency (Van der Twill & Verduyn Lunel,

1965; Townsend, et al., 1975). However, confounding these studies is the attenuation or a blocking response to visual stimulation in the spontaneous EEG, in addition to the evoked photic driving response to specific frequencies of SML (Iwahara, et al., 1974; Aranibar & Pfurtscheller, 1978). Also, not all individuals produce a photic driving response. Garoutte, Aird, and Correnti reported in 1958 there is "considerable variation from subject to subject in the binding of cortical rhythm to photic flash rhythm" (p. 770). Some of their subjects showed no photic driving response, some followed the photic flashes at "exactly the same frequency and with essentially constant flash-to-wave latency delays" (p. 770), and most fell somewhere between the two extremes. This variability in photic driving response is confirmed by Kawaguchi, et al. (1993), who found one-half of their subjects did not produce a photic driving response within the alpha bandpass to fixed-frequency, repetitive stroboscopic flashes ranging from 5 to 16 Hz.

Studies in the 1970's and 1980's mainly were concerned with the occipital alpha bandpass effects of IPS. More recent studies of AVS and the photic driving response have examined the effects of stimulation on the beta, theta, and even delta bandpasses, in addition to the alpha bandpass. Also, more cortical regions have been included in analyses. Using low-frequency theta AVS, Dieter & Weinstein (1995) described significant reduction in mean activity (an increase of delta and theta activity) in frontal, central, and parietal regions, in addition to occipital regions. Brauchli, Michel, & Zeier (1995) found a reduction in alpha and theta spectral power during AVS utilizing variable and fixed frequency programs. In a study examining effects of both 10 Hz and 22 Hz

stimulation, Rosenfeld, et al., (1997) reported no significant group effects of 10 Hz stimulation on the alpha bandpass with 9 subjects, although 22 Hz stimulation nonsignificantly increased beta bandpass activity. These studies indicate that photic stimulation affects more than the alpha bandpass, if there even is a driving response in the alpha bandpass, and that more than the occipital cortex is involved during stimulation.

Clinical Uses of AVS.

The clinical applications of IPS and/or AVS have had nearly as long a history as that of the research in the area. As previously mentioned, IPS has been used as a method to activate paroxysmal EEG discharges in suspected seizure patients and to help localize cortical epileptic foci since Walter, et al. first reported the phenomenon in 1946. During the 1950's and 1960's, researchers became interested in using both visual and auditory rhythmic stimulation as a means of inducing relaxation and hypnosis (see Morse, 1993 for a review). Applications of audio or visual stimulation have been particularly embraced by members of the medical community in an attempt to alleviate patient pain and encourage relaxation. Shealy, et al., (1990) have reported successes from the early 1960's up to 1990 in using photic stimulation to ease labor pains, aid in anesthesiology, and relieve chronic pain symptoms. More recently, the use of audio-visual stimulation (AVS) has been reported as an effective method to relieve dental pain and anxiety. Morse (1993) found that subjects using AVS were more relaxed, less anxious, and had lower GSR readings that control subjects during a root canal procedure. The particular benefit of AVS in this

setting is the elimination of the necessity to provide drug sedation for patients prior to the procedure. Morse has used AVS with no reported side-effects in a wide variety of patients, including two with epileptic seizures.

The relaxation and reduction of anxiety effects associated with the use of AVS, particularly when used in dental and medical settings, may be attributed to the decreased ability of the patient to see and hear the instruments and procedures. AVS may serve as a form of sensory deprivation, in the sense that sensory information other than the flashing lights provided in goggles and the pulsing tones from headphones is limited. Additionally, AVS has been associated with a reduction in autonomic arousal, especially when low levels of stimulation and variability are programmed (Brauchli, et al., 1995). It has been suggested that photic stimulation and AVS applications may alter states of consciousness through enhancing specific bandpasses of EEG activity. In this manner, AVS is thought to induce visual imagery (Glicksohn, 1986) and hypnagogic states (Dieter & Weinstein, 1995) which may serve to distort subjective feelings of pain and anxiety.

Photic stimulation at low frequencies (3 Hz and below) has been indicated as a way to relieve muscle-tension headaches (Solomon, 1985). Low frequency photic stimulation was not effective in alleviating migraine headaches in Solomon's study. However, Anderson (1989) found excellent clinical results using variable frequency photic stimulation (VFP) at high frequencies (up to 50 Hz) and intensities for patients with long-standing migraine headaches. In seven subjects, all experiencing migraines for at least five years, 49 out of 50 migraine headaches were reported to be relieved by photic stimulation;

36 out of 50 were reported to be stopped by using photic stimulation. Additionally, the duration of migraines decreased on average of 5 ½ hours with the use of photic stimulation (median duration of migraine with VFP = 35 minutes; median duration of migraine without VFP = 6 hours).

Although the efficacy of AVS in modulating and enhancing brain activity has yet to be fully explored experimentally, the success of photic stimulation and AVS in the areas of pain management, headache relief, and relaxation has resulted in a broader application of the techniques. However, it is often difficult to understand the rationale for using photic or AVS in certain clinical cases. For example, Kumano, et al., (1996), reported a case study using photic stimulation to alleviate a depressive disorder in a 37 year old man. The researchers had photic stimulation follow the naturally produced alpha frequency of the subject. After two different treatments separated by two months, one involving 16 sessions and the other involving 18 sessions of photic stimulation, the patient reported an improvement in his overall mood. However, the patient had continued to take anti-depressant medications during the treatment sessions, hence it is rather difficult to understand why the researchers would believe that any improvement in the subject's affect should be attributable to photic stimulation and not to medication.

Fortunately, some cognitive applications of photic and AVS have firmer theoretical foundations. Rosenfeld, et al. (1997) have identified three rationales for using entrainment to improve cognition. The strongest in terms of theoretical underpinnings is that entrainment works much in the same way as neurofeedback, in the sense that it increases

EEG activity in certain bandpasses. Entrainment may be a useful adjunct with neurofeedback to decrease the number of sessions necessary to learn how to produce certain EEG frequencies. For example, Patrick (1996) used photic stimulation in combination with neurofeedback to increase production of 12 - 14 Hz activity while decreasing production of 4 - 8 Hz activity in 8 - 14 year old children diagnosed with ADHD. He had each subject learn to recognize the light stimulation pattern associated with flashing lights at a frequency range of 12 - 14 Hz. Once subjects could recognize the light pattern associated with the increase in 12 - 14 Hz activity, they were asked to reproduce the light patterns silently. Patrick then "pair[ed] the light patterns with a tone that came on when the subject exceeded a pre-set threshold of 12 - 14 Hz activity" (p 30). After the subjects could reliably produce the tones, Patrick gradually withdrew the photic stimulation while asking the subjects to continue to produce the tone. Subjects learned to create 12 - 14 Hz activity without the presence of the photic stimulation over 15 training sessions, much less than the normal 30 - 40 sessions used in traditional neurofeedback therapies. Additionally, the subjects showed significant gains in controlling impulsivity and significant gains in attention over the training sessions as measured by WISC-3 processing speed scale and freedom from distractibility scores, errors of comission on the T.O.V.A., and the Achenbach Child Behavior Checklist and Profiles scores.

Another rationale for using entrainment is that in clinical populations the dominant EEG frequency within some bandpass reflects a pathological state, and entrainment or AVS serves to drive the dominant frequency away from pathology towards a more normal

dominant frequency. The theoretical basis for this application comes from research that indicates sensory experiences stimulate brain growth. Repeated stimulation of a neuron or a neural pathway can change the structure of a neuron, making it easier to form new connections with other neurons (Lynch, 1986), and cause long-term changes in the potentiation of neural pathways (Alkon et. al, 1991). Enriched sensory experiences enhance cognitive functioning (Diamond, 1988). Applying this line of reasoning to brain dysfunctions, Carter & Russell (1993) have reported significant improvement in cognitive and behavioral functioning, related to the number of AVS sessions, in learning disabled boys. Currently Russell (1997) is engaged in a long-term project determining the effectiveness of AVS in maintaining cognitive improvements with this population. AVS may improve or alleviate the cognitive dysfunctions associated with brain damage, particularly closed head injury (Montgomery, Ashley, Burns, & Russell, 1994), and damage from aneurysms and strokes (Russell, 1997). As Rosenfeld, et. al (1997) point out, however, there is no empirical evidence that indicate the driven EEG arises from the same pathways as spontaneous EEG. Although the EEG may change as an evoked response to stimulation, that does not necessarily mean that there will be lasting effects on spontaneous cortical activity after the stimulation has ceased.

The final rationale reported by Rosenfeld, et. al, for the use of AVS is that a random presentation of various frequencies of stimulation somehow has functional effects on the EEG. There is little to no theoretical or empirical evidence for this assertion, but commercial manufacturers of entrainment devices continue to create idiosyncratic

programs for the machines they sell. Unfortunately, even the names given to these idiosyncratic programs can be misleading -- Dieter & Weinstein (1995) found that a preprogrammed session of AVS labeled as "theta" actually produced stimulation in the delta range.

A caveat regarding the use of photic and audio-visual stimulation needs to be mentioned. Although there are theoretical bases for using AVS, there have been few empirical studies determining the actual effects AVS has on the brain's activity, particularly cognitive functioning. Although Carter & Russell (1993), Russell (1997), and Montgomery, et al. (1994) have shown cognitive improvement in specific subject populations, a limitation of all these studies has been the lack of a control group. It is quite possible that the improvements noted in these populations may be attributable to the passage of time, rather than the use of AVS. Additionally, there has been very little study regarding the effects of AVS on "normal" populations. In one of the few studies reported using a normal subject, Gontkovsky, Burns, & Montgomery (1997) found no systematic effects of 11 Hz stimulation over 50 AVS sessions in any bandpass of the EEG. In particular, there was no carryover of the effects of stimulation between sessions. However, the AVS provided in the Gontkovsky, et al. (1997) study was provided with the subject's eyes open, an untraditional application of AVS, and only to a single subject. There has been no reported research indicating the effects of traditional eyes-closed AVS on normal populations. Thus, it is clear that more research is necessary to delineate the effects and uses of AVS, particularly with normal participants.

CHAPTER II

PILOT STUDY: SINGLE SESSION AVS

In light of the recent clinical and commercial applications of AVS, it is important to develop a more thorough understanding of AVS effects on cortical activity. A limitation of most EEG studies to date using photic or audio-visual stimulation has been the examination of a restricted number of scalp locations and/or frequencies. A pilot study was designed to address specifically the effect of AVS at an individual's dominant alpha frequency and twice the dominant alpha frequency across 19 locations and over the range of EEG frequencies from less than one Hz to 32 Hz, and included a post-session measure one half hour after the stimulation session had ended.

This pilot study was an exploratory study to determine if there were any effects of AVS as measured by EEG recordings both during and after stimulation. It was hypothesized that AVS at an individual's dominant alpha frequency, the alpha stimulation condition, would increase power within the alpha bandpass. This hypothesis was based on previously reported results (Van der Twill & Verduyn Lunel, 1965; Townsend, et al., 1975) that alpha bandpass effects are strongest when the visual stimulation used approximated the subject's peak frequency of activity within the alpha bandpass. Since earlier research of AVS has rarely included alpha AVS effects on bandpasses other than the alpha bandpass, no attempt was made to hypothesize the effects of alpha AVS on the delta, theta, or beta bandpasses.

Rosenfeld, et al. (1997) found that AVS at 22 Hz came close to significantly increasing power within the beta bandpass. A beta stimulation condition was added to the pilot study to further explore this finding. It was decided to define the beta stimulation condition by doubling the individual subject's dominant alpha frequency (i.e., if a subject had a dominant alpha frequency of 10 Hz, the beta stimulation would be provided at 20 Hz.) Providing beta stimulation at twice the dominant alpha frequency seemed a more logical way of defining beta stimulation than to randomly pick a frequency between 13 and 32 Hz. It was hypothesized that beta stimulation would increase power within the beta bandpasses, as in the Rosenfeld, et al. (1997) study. Once again, no attempt was made to hypothesize what would occur in the bandpasses (delta, theta, and alpha) other than the beta bandpasses.

Materials and Methods.

Participants. Thirteen participants (7 male and 6 female) were recruited from the undergraduate and graduate populations of the University of Tennessee, Knoxville. Participants ranged in age from 20 - 30 years, with a mean of 25.5 years. All participants reported no previous history of epilepsy, learning disabilities, attention deficit disorder, or mental illnesses during personal screening interviews. Participants self-reported that they were free of medication use during the study.

Apparatus. Audio-visual stimulation was provided by a Polysync Pro (Synetic Systems) device. This unit consisted of headphones and a pair of "photoscopic" glasses that were connected to a small, portable unit that was programmed to provide specified levels of visual and auditory stimulation. The physical characteristics of the visual and audio stimulation will be described in depth in the apparatus section of Chapter 3, p. 34.

Since the Polysync Pro is a piece of electrical equipment, it is possible that it may create localized electrical fields that might interfere with EEG recording. To ensure that the EEG recordings would not be contaminated with electrical fields generated by the Polysync Pro, the device was tested in two ways. First, the goggles and, separately, the headset were held within 1.5 cm of the recording electrical input, and no corresponding electrical activity on the EEG recording was detectable. Secondly, localized electrical fields were tested for during an actual recording session. An eyes-closed baseline EEG recording was compared with an eyes-closed recording of the same subject receiving blocked AVS, looking at all 19 channels of the standard 10-20 system. This was done by having the eyes masked and the ears plugged so the subject did not see or hear the AVS, although the equipment was turned on. The subject reported that he did not detect the stimulation. There was no difference between the baseline and blocked AVS recordings, which indicate the Polysync Pro equipment did not produce electrical interference in the EEG recordings.

A quantitative referential EEG (QEEG) was recorded from 19 electrodes following the International 10-20 system for electrode placement, with linked earlobe

references. All electrode impedances were below 5 KOhm. Recordings were made using an electrode cap (Electro Cap Inc.). Rhythm software (Stellate Systems) was employed to record and analyze the raw EEG. A detailed description of the EEG recording equipment and analysis procedures will be described in depth in Chapter 3, pp. 34 - 35.

Another possible contaminant of the EEG is signal aliasing. This occurs when high frequency activity "folds back" into the lower frequencies, creating peaks at frequencies that are 1/4 and 1/2 of the original signal's frequency. Rhythm software eliminates signal aliasing by the use of a 16 point FIR (finite impulse response) filter that has a sharp low-pass cutoff set at 64 Hz and higher. The possibility that signal aliasing was not prevented by the software was double-checked by inputting 100 Hz sinewaves with amplitudes of 50 and 100 microvolts peak-to-peak through the system. According to spectral analysis of the signal, there were no peaks at either 25 Hz or 50 Hz, which would be expected if aliasing did indeed occur. Furthermore, there were no indications of aliasing anywhere within the bandpass of 0.5 - 32 Hz, upon examination of 0.25 Hz bandwidths.

Procedure. The thirteen participants came to the laboratory on two different occasions for AVS sessions. These sessions were at least two weeks apart to minimize carry-over effects. The procedure was the same for both stimulation sessions. Participants were seated upright in a plastic chair located in a sound-attenuated, dimly lit room for the EEG recordings. The headphones and glasses were placed over the electrode cap. All participants had an eyes-closed baseline EEG recorded for four minutes

at the beginning of the session. This baseline recording was analyzed to determine each subject's dominant alpha frequency, defined as the peak power between 8 and 12 Hz at locations Pz and P4 as measured by power spectral analysis, rounded to the nearest 0.5 Hz. Participants were then provided AVS for 20 minutes, with EEG recording occurring simultaneously. Participants were instructed to close their eyes and relax during the 20-minute AVS. Thirty minutes after the stimulation session, a post-session eyes-closed EEG was recorded for four minutes to determine if AVS had any lasting effects on the EEG after the stimulation had ceased. For the alpha stimulation condition, each participant was stimulated at their dominant alpha frequency. During the beta stimulation condition each participant received AVS at twice their dominant alpha frequency. The presentation of the AVS condition was counter-balanced; during the first AVS session six of the participants experienced alpha stimulation and seven experienced beta stimulation. For the second session, those who experienced alpha stimulation during the first session received beta stimulation, and those who experienced beta stimulation first received alpha stimulation.

EEG Data Management. EEG data were analyzed via Fast-Fourier transformation to provide power data for the 19 recording locations in each of six bandpasses (Delta 1 = 0.75 - 2 Hz, Delta 2 = 2 - 4 Hz, Theta = 4 - 8 Hz, Alpha = 8 - 12 Hz, Beta 1 = 13 - 21 Hz, and Beta 2 = 21 - 31 Hz). Each 20-minute AVS condition was analyzed in 4 five-minute blocks (0 - 5 min, 5 - 10 min, 10 - 15 min, and 15 - 20 min) to examine changes over the course of stimulation. The post measure was a 5 minute EEG recording taken one half

hour after the AVS session. Thus, there were six power measures per frequency bandpass in this pilot study: baseline, 5 min, 10 min, 15 min, 20 min, and post. All EEG data were log-transformed [log(x)] to correct for skewed distributions. Histograms of log-transformed data were normally distributed.

Due to the exploratory nature of the study, there were a large number of variables of interest. In order to reduce the data to a more manageable size, one-way repeated-measure ANOVAs were conducted with time (baseline, 5 min., 10 min., 15 min., 20 min., and post) as the within subject factor using SPSS (version 8) software. These ANOVAs were conducted for each location within a bandpass; thus 114 ANOVAs were used in examining the alpha condition and another 114 were utilized in examining the beta condition. These analyses indicated which locations within a particular bandpass had significant changes in power over time. Mauchly's test was utilized to check for sphericity of the data. If sphericity was not violated, the more powerful univariate repeated measures using the split plot approach was used to test significance (degrees of freedom = 5,60). For violation of sphericity, the multivariate approach to repeated measures was used (degrees of freedom = 5,8).

Five paired difference t-tests were done for each significant location when an ANOVA yielded a significant result. These t-tests compared the baseline mean to each of the stimulation and post means to determine if any significant changes from baseline power levels occurred. A Bonferroni adjusted probability level of $p<.05$ (0.05/5 = 0.01) was used to define significance for each of these pairwise post hoc comparisons.

Results.

There were no order effects of stimulation session, as would be expected with the AVS sessions conducted at least two weeks apart. All alpha stimulation data were grouped for analysis, as were all beta stimulation data.

Dominant Alpha AVS. For the alpha stimulation condition, the ANOVAs indicated a total of 23 significant locations. The locations, by bandpass, were as follows: delta 1 - T3, C3, Cz, C4; delta 2 - F3, C3, Fz, Cz; theta - F4, O2, T6; alpha - No significant ANOVA results; beta 1 - F7, Fp1, F3, Fz, F4, F8; beta 2 - T5, F3, P3, Fz, Cz. See Table 1[2] for F values and probabilities for the alpha stimulation condition.

Post-hoc paired difference t-tests were conducted for each of these twenty-three locations. Twelve of the twenty-three locations had significant changes (with a Bonferroni-corrected alpha level of 0.05 or lower) from the baseline measure either during the AVS session or one-half hour after the session. Means and standard errors of the means of those locations resulting in a significant difference in power from baseline as indicated by t-tests for the alpha AVS condition are presented in Table 2.

It is often easier to understand an illustration of results than it is to interpret numbers in a table. Figures 2 and 3 show graphically the locations by bandpass that significantly changed from baseline power levels either during the alpha AVS condition (Figure 2) or one-half hour after the alpha AVS had ceased (Figure 3).

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[2] All tables may be found in Appendix B.

As can be seen in Figures 2 and 3, alpha stimulation did not have a significant effect on the alpha bandpass over baseline levels, even during the stimulation condition itself. However, alpha stimulation did significantly increase power at location C3 within the delta 1 bandpass, as well as locations C3 and Cz in the delta 2 bandpass. The theta bandpass showed significant increases of power at locations F4 and O2. Several frontal locations were significantly increased in the beta 1 bandpass (Fp1, F3, Fz, and F4), and central locations were increased in the beta 2 bandpass (Fz, Cz, and P3). All of these increases occurred during the alpha AVS session. The Beta 1 bandpass was the only bandpass that showed lasting effects of alpha stimulation, with three locations (FP1, F3, and Fz) still significantly higher in power compared with baseline levels one half-hour after the alpha AVS session was completed.

Twice Dominant Alpha AVS. For the beta stimulation condition, the analyses indicated a total of 36 significant locations. The locations, by bandpass, were as follows: delta 1 - F7, F3, Fp2, F4, T4; delta 2 - No Significant ANOVA results; theta - T3, T5, Fp1, F4, C4, P4, F8, T4, T6; alpha - C3, C4, F8; beta 1 - F7, T5, Fp1, F3, C3, O1, Fz, Cz, Pz, Fp2, F4, C4; beta 2 - T3, C3 , P3, O1, Fz, Cz, Pz. See Table 3 for F values and probabilities for the beta stimulation condition.

Post-hoc paired difference t-tests were conducted for each of these thirty-six locations. All but one of these thirty-six locations had significant Bonferroni-corrected changes in power from the baseline measure either during the beta AVS session or one-

half hour after the session ended. Means and standard errors of the means of those locations resulting in a significant difference in power from baseline as indicated by t-tests for the alpha AVS condition are presented in Table 4. Figure 4 shows the locations that had within-session changes in power, and Figure 5 illustrates the locations that were significantly higher in power one-half hour after the beta AVS had ended.

Beta stimulation significantly affected power over baseline levels at several locations during the beta AVS session, as can be seen in Figure 4. Several significant decreases in power at frontal locations occurred in the delta 1 bandpass, with locations Fp2, F4, F3, F7, and T4 all decreasing during the first 5 minutes of beta AVS. These decreases in power continued throughout the AVS session and persisted to the post measures, but the decreases were not significant (see Table 4). The delta 2 bandpass did not show any significant changes in power during the AVS session. However, there were several locations showing significant increases in power during beta AVS in the theta bandpass (locations T3, F4, C4, P4, F8, and T4), the beta 1 bandpass (F7, T5, Fp1, F3, C3, O1, Fz, Cz, Pz, Fp2, F4, and C4), and in the beta 2 bandpass (T3, P3, O1, Fz, Cz, and Pz).

The theta, alpha, beta 1, and beta 2 bandpasses had several locations showing lasting AVS effects, with significant increases in power remaining one half-hour after beta AVS was completed (see Figure 5). By bandpass, the theta bandpass showed lasting AVS increases at locations T5 and T6; the alpha bandpass at locations C3, C4, and F8; the beta

1 bandpass at locations F7, T5, Fp1, F3, C3, O1, Fz, Pz, and C4; and the beta 2 bandpass at locations C3, P3, Fz, and Cz.

Discussion.

The results found in this pilot study indicate that AVS at the dominant alpha frequency and twice the dominant alpha frequency has significant effects on EEG power both during and one-half hour after the AVS sessions. Stimulation in the frequency ranges of 8 - 12 Hz did not have a significant effect on the corresponding alpha activity of the cortex. However, stimulation at the dominant alpha frequency did affect other bandpasses, with the most lasting effect on the beta 1 (13 - 21 Hz) bandpass. There were also within-session increases of low frequency activity (0.5 - 4 Hz) at central locations, increases of theta activity (4 - 8 Hz), and increases of beta 2 activity (21 - 32 Hz) with alpha AVS. Beta AVS (stimulation at twice the dominant alpha frequency) did have effects on the beta 1 bandpass (13 - 21 Hz) as expected; additionally, within session results indicated an increase of theta activity (4 - 7 Hz) and beta 2 activity (21 - 32 Hz), and a decrease of delta 1 activity (0.5 - 2 Hz).

It is surprising that alpha stimulation did not have a significant effect on the alpha bandpass over baseline levels, even during the stimulation condition itself. The presentation of alpha AVS was customized to each subject's dominant alpha frequency in hope of maximizing the effects of the stimulation. Earlier studies had indicated individual differences in the photic driving response (Garoutte, et al., 1958; Kawaguchi et al., 1993;

Rosenfeld, et al., 1997), and it had been suggested that these differences may be due to a suppression of the natural alpha rhythm when exposed to stimulation at a frequency other than an individual's spontaneous alpha (Townsend, et al., 1975; Rosenfeld, et al., 1997). Another factor may be responsible for individual responses to alpha AVS besides the specific dominant alpha frequency. This lack of significant effects within the alpha bandpass during AVS supports Brauchli et al. (1995) findings that AVS does not increase alpha power.

Alpha stimulation did significantly affect the delta 1 and 2 bandpasses, the theta bandpass, and the beta 1 and 2 bandpasses. The significant within-session increases of power in the delta bandpasses occurred in central locations (location C3 in delta 1; C3 and Cz in delta 2) and not at the frontal poles, which makes it unlikely that these increases were due to eye blinks or large eye movement artifact. In the same manner, it is unlikely that in increases over baseline power at frontal and central locations in the beta 1 and beta 2 bandpasses during alpha AVS could be attributed to muscle tension. This paradoxical increase of central activity within low frequency (0.5 - 4 Hz) bandpasses along with an increase of frontal beta activity during extended sessions of AVS has also been reported by Dieter & Weinstein (1995), although these researchers used low-frequency preprogrammed stimulation designed to increase theta activity.

Results from beta stimulation were in agreement with the original prediction that beta AVS would have a significant effect on the beta 1 bandpass. Twelve of the nineteen locations within the beta 1 bandpass had significant increases in power during the beta

AVS session. Ten of these locations showed significant lasting effects, with increases of power ranging from 6 to 11% remaining one half hour after beta AVS had ceased. To a lesser degree, beta AVS had significant within-session and post-session effects on the beta 2 bandpass, with seven locations showing significant within-session increases and four locations (C3, P3, Fz, and Cz) showing significant post-session increases. Beta AVS also significantly increased within-session theta power in mainly right hemisphere locations and showed post-session increases at T5 and T6. Additionally, there were significant decreases in power at frontal locations within the delta 1 bandpass.

It may be suggested that these results are simply due to alpha desynchronization or blocking by visual stimulation. It would be expected to see a blocking of the alpha rhythm and an increase in beta activity due to the arousing effects of visual stimulation. However, there are several reasons why this possibility is not supported by the data presented in this study. First, there were no significant effects of any kind, neither decreases nor increases, within the alpha bandpass during either AVS session. Secondly, if alpha blocking did occur, with a corresponding increase in activity in the higher frequency bandpasses, the effect would be expected to habituate over time, particularly in light of the fact that the AVS sessions lasted twenty minutes. However, as can be deduced from Tables 2 and 4, beta 1 power continued to <u>increase</u> over the 20-minute AVS sessions in frontal locations. It is possible that EEG changes at location T5, O1, and PZ, which do decrease in power over the beta stimulation session, are due to alpha desynchronization, but alpha desynchronization can not account for the significantly increased power over baseline

levels one half-hour after the stimulation had ceased at these locations. In fact, none of the significant post session increases in power from baseline levels can be explained as alpha blocking by a visual stimulus. Finally, the findings in this study indicate different patterns of significant increases and decreases in response to alpha and beta stimulation, respectively, using the same participants for both conditions. If these results were due to the arousing effects of sensory stimulation alone, and not specific to the AVS frequency presented, similar patterns of increases and decreases would be expected for both conditions.

A possible explanation for these results lies in the subjective experiences the participants in this study described in interviews after the AVS sessions. Most participants reported feeling highly relaxed and very sleepy during the AVS sessions, although all participants stated that they did not actually fall asleep. More participants reported feeling very sleepy during the alpha AVS session as compared to the beta AVS session. During beta AVS, in particular, participants described visual imagery as being a dominant aspect of the experience. One participant experienced "quickly flashing memory clips", another had thoughts of childhood memories, while yet another reported that she seemed to be racing through thoughts, unable to complete one thought before another arose. One participant reported auditory hallucinations during both alpha and beta AVS, and two participants had proprioceptive hallucinations (feeling as if his/her body was moving although it was not) during beta AVS.

Dieter & Weinstein (1995) report similar subjective states in their study using low-frequency AVS. They state that "as photo-stimulation progresses, the individual experiences a free-flowing chain of thoughts...which is followed by dynamic visual patterns" (p 87). They suggest that participants enter a hypnagogic state similar to Stage 1 of the NREM sleep stages. In the current study, the increases in power in the delta and theta bandpasses within the AVS sessions may be attributed to the increased visual imagery and relaxation experienced during AVS. Increases in the beta bandpasses may be associated with the active flow of thought most participants said occurred during AVS. It remains to be explained why participants would continue to have significantly more power in the beta 1 bandpass after alpha AVS, and significantly more power in the theta, alpha, beta 1 and beta 2 bandpasses after beta AVS, one half-hour after the AVS sessions had ended.

CHAPTER III

PURPOSE OF PROPOSED RESEARCH

The pilot study indicated that audio-visual stimulation affects EEG power within several bandpasses and at several locations both during and after stimulation. These results are very intriguing, and further exploration of AVS effects is indicated. One question to be addressed is the effect of AVS over a number of stimulation sessions. With repeated stimulation over many sessions, perhaps the increased beta activity seen in the pilot study would become more prevalent. The pilot study indicated that the beta 1 bandpass effects lasted at least one half hour after the stimulation ceased; perhaps with repeated sessions a cumulative effect would occur, with increases in power lasting days or even weeks. If AVS is to be used as an adjunct to neurofeedback (Patrick, 1996), it is also important to determine if the increase in activity in the slow-wave bandpasses, particularly the theta bandpass, continues to remain over several AVS sessions or if it instead disappears over time. Additionally, further studies of AVS need to incorporate a control measure. Although unlikely, it is possible the persistent increase in power seen in the pilot study within the Beta 1 bandpass for both alpha and beta stimulation was due to merely sitting quietly with eyes closed for twenty minutes.

The purpose of this study was to investigate the effects of dominant alpha AVS and twice dominant AVS over 20 stimulation sessions on both the eyes-closed and eyes-open cortical EEG. A control group was included in the study to rule out the possibility that the AVS findings in the pilot study were due to simply sitting quietly with eyes closed.

Because claims of increased reading speed, reading comprehension, and intelligence test scores have been attributed to the use of AVS devices (Adams, 1995; Adams, 1996), this investigation also examined possible cognitive changes as correlates of multi-session AVS.

Based on the results from the pilot study, it is hypothesized that AVS at the dominant alpha frequency will increase the eyes-closed EEG power as compared to a control group in central locations within the delta 1 and delta 2 bandpasses, right frontal and occipital locations within the theta bandpass, frontal locations within the beta 1 bandpass, as well as central and parietal locations within the beta 2 bandpass during alpha AVS. Alpha AVS should have no effects on the alpha bandpass. Lasting changes in power (over days or weeks) should occur at frontal locations in the beta 1 bandpass with alpha AVS.

Additionally, it is hypothesized that AVS at twice the dominant alpha frequency will decrease the eyes-closed EEG power in frontal locations within the delta 1 bandpass, and will increase the eyes-closed EEG power over right hemispheric locations within the theta bandpass, as well as most locations within the beta 1 bandpass and left hemisphere and central locations within the beta 2 bandpass during beta AVS as compared to controls. Beta AVS should have no effects on the delta 2 or alpha bandpasses during the stimulation sessions. Lasting changes in power should occur in temporal locations within the theta bandpass, central and frontal locations within the alpha bandpass, nearly all locations within the beta 1 bandpass, and at left central and parietal locations within the beta 2 bandpass.

If there are significant and lasting changes in the beta bandpasses with either alpha or beta stimulation, it is hypothesized that the group (or groups) that indicate increased beta power levels will have better post scores on cognitive tests than their pre scores.

In addition to the hypothesized outcomes, this study will explore the affects of AVS on the eyes-open EEG. There have been no studies to date reporting on the effects of AVS on the eyes-open EEG, so all locations and bandpasses will be examined. Also, the affects of AVS on locations other than those predicted above will be explored to determine if multi-session AVS changes the eyes-closed EEG in ways which were not detected after one session of AVS.

Materials and Methods.

Participants. Thirty participants (8 male and 22 female) were recruited from the undergraduate and graduate populations of the University of Tennessee, Knoxville. Participants ranged in age from 20 - 45 years, with a mean of 23.7 years. All participants reported no previous history of epilepsy, learning disabilities, attention deficit disorder, or mental illnesses during personal screening interviews. Participants self-reported that they were free of medication use during the study.

Apparatus. Audio-visual stimulation was provided by a Polysync Pro (Synetic Systems) device. This unit consisted of headphones and a pair of "photoscopic" glasses

that were connected to a small, portable unit that was programmed to provide specified levels of visual and auditory stimulation. The glasses had eight light emitting diodes (LEDs), four per side, arranged in a cross pattern. The LEDs were situated approximately 1.5 cm from the eyes, and emitted red light at .166 candle power at the frequencies employed. Audio stimulation consisted of a cycled tone with a pitch of 185 Hz, presented to both ears simultaneously, with a duty cycle of 50% and a loudness level of approximately 77 dB(A scale) for the alpha condition and 81 dB(A scale) for the beta condition. Decibel measures were provided by a Type 1565-B sound-level meter (General Radio). The relatively minor difference in decibel levels is due to the weightings of the A scale, which takes into account subjective estimates of loudness, annoyance, and speech interference (General Radio Instruction Manual, 1972). Both auditory and visual stimulation were sinusoidally modulated.

A quantitative referential EEG (QEEG) was recorded from 19 electrodes following the International 10-20 system for electrode placement, with linked earlobe references. All electrode impedances were below 5 KOhm. Recordings were made using an electrode cap (Electro Cap Inc.). Raw EEG was fed through 19 matched 7P511 pre-amplifiers (Grass Instrument Co.), with bandpass filters set to 0.5 - 100 Hz. A BMSI 12-bit A to D converter digitized the outputs of the amplifiers. Rhythm software (Stellate Systems) was employed to record the raw EEG. The sampling rate was set at 128 samples per second. Under Rhythm, when a sampling rate of 128 Hz is specified, the actual rate employed is oversampled at 256 Hz and each digitized point is replaced by a

weighted sum of its neighbors; every other point of this filtered data is written to disk as a 16 bit value (G. Lapierre, personal communication, March 11, 1998). This sampling rate allows for analysis from 1 - 32 Hz according to the base Nyquist frequency which states the highest frequency of analysis is less than or equal to 1/4 of the sampling rate (Kellaway & Petersen, 1976). Signal aliasing was eliminated by the use of a 16 point FIR (finite impulse response) filter, with a sharp low pass cutoff set at 64 Hz and higher.

Several psychometric measures were used in this study to determine if the claims of increased cognitive abilities following the use of AVS were accurate. Since the participants took the pre- and post-tests only 2 months apart, an effort was made to use tests that either had multiple forms or that were less likely to show test-retest effects. The main claims regarding cognitive improvement are in the reading and intelligence testing domains. As such, the Peabody Picture Vocabulary Test - Revised (PPVT-R), forms L and M, and the Digit Span and Coding subscales from the Wechsler Adult Intelligence Scale - Revised (WAIS-R) were used. Additionally, the Raven Progressive Matrices for adults and the Halstead Category Test (adult form) subtest of the Halstead - Reitan Battery were given to the participants before and after the study.

Finally, the participants were given a self-report form created to assess their subjective experiences during and after the AVS sessions.

Procedure. Participants were randomly assigned into one of three groups (control, alpha stimulation, or beta stimulation) based on a coin toss. All participants came into the

lab for a three-hour session to complete the psychometric tests. After the psychometric tests were completed, all participants arranged to come into the lab on another day for EEG recording. During the EEG session, an eyes-closed baseline EEG was recorded for five minutes. This eyes-closed baseline recording was analyzed to determine each subject's dominant alpha frequency, defined as the peak power between 8 and 12 Hz at locations Pz and P4 as measured by power spectral analysis and Fast Fourier transformation, rounded to the nearest 0.5 Hz. After the eyes-closed baseline recording, all participants also had a five minute eyes-open EEG recorded.

Participants received a twenty minute AVS session five days a week for four weeks. All participants wore the photoscopic glasses and the headphones, and were seated in the same room using the same AVS device for every session. The control participants were informed they would be receiving subliminal stimulation during the course of the study. This ruse was facilitated by creating a AVS program for which the volume and intensity of the stimulation were both set at zero. All control participants reported they were unable to detect the stimulation once the program began. The alpha stimulation group received AVS at their dominant alpha frequency, and the beta stimulation group received AVS at twice their dominant alpha frequency. Participants were told to sit quietly in the darkened room with their eyes closed during the twenty minute session. Participants were also asked to try to refrain from falling asleep during the sessions.

Eyes-closed EEGs were recorded for all participants during the fifth, the tenth, the fifteenth, and the twentieth AVS session. Before the AVS session started, a five minute eyes-closed baseline EEG was recorded. On the tenth and twentieth session, a five minute eyes-open baseline was also recorded. The eyes-open baseline EEG was recorded every other EEG session because of time restraints and participant comfort. Most participants experienced additional muscle tension during the eyes-open EEG recording due to the effort of remaining still and trying not to blink during the recording session. This muscle tension tended to corrupt the first several minutes of the AVS EEG until the muscle tension dissipated. All EEG recordings were conducted in the same room, and each participant had the recording done on the same day of each week and at the same time of the day. Participants were seated upright in a plastic chair located in a sound-attenuated, dimly lit room for the EEG recordings. The headphones and glasses were placed over the electrode cap to provide AVS. The headphones and glasses do not produce localized electrical fields that might have interfered with the EEG recordings; see page 19 to see how the presence of localized electrical fields was tested.

Two weeks after the last AVS session, a five minute eyes-closed EEG recording and a five minute eyes-open EEG recording were conducted. These EEG recordings were scheduled to occur on the same day of the week and at the same time of the day as the previous EEG recordings. Participants then arranged to return to the lab for a three hour session to retake the psychometric measures and to fill out the subjective experience questionnaire.

EEG Data Management. The EEG was analyzed off-line on a Pentium 133 processor using Rhythm software to provide power data. Rhythm analysis employs Hanning windowing and cosine tapering of each selected four-second epoch. The Rhythm software is unique in that it allows for the selection of any length of EEG recording, as long as it has a minimum length of 4 seconds. Additionally, the Rhythm software allows for artifact rejection within an individual four-second epoch, as long as the total selected artifact-free section of the EEG record is at least four seconds in duration. Thus, short duration and very small artifact events can be selected out of the EEG record, leaving only artifact-free EEG for analysis. Eye-blinks, large eye movements, and all observable muscle artifacts were removed prior to analysis by a visual review of the EEG records.

Rhythm analysis provided power data via Fast-Fourier transformations for the 19 recording locations in each of six bandpasses (Delta 1 = 0.75 - 2 Hz, Delta 2 = 2 - 4 Hz, Theta = 4 - 8 Hz, Alpha = 8 - 12 Hz, Beta 1 = 13 - 21 Hz, and Beta 2 = 21 - 31 Hz). There were a large number of power variables. First there were the original baseline eyes-open and eyes-closed EEG recordings. For each EEG recording of the AVS session, a five minute eyes-closed baseline was recorded, as well as the twenty minute AVS session. Every other AVS EEG recording session, an eyes-open baseline EEG was also recorded. Finally, both a five minute eyes-closed and a five minute eyes-open EEG were recorded as post measures two weeks after the last AVS session. Each EEG recording of the 20-minute AVS condition was analyzed in 4 five-minute blocks (0 - 5 min, 5 - 10 min, 10 - 15

min, and 15 - 20 min). Thus, for each participant the dependent EEG measures were as follows:

1. an eyes-closed baseline power measure.
2. an eyes-open baseline power measure.
3. an eyes-closed baseline power measure after four AVS sessions.
4. four power measures from the 5 minute blocks of the fifth AVS session.
5. an eyes-closed baseline power measure after 9 AVS sessions.
6. and an eyes-open baseline power measure after 9 AVS sessions.
7. four power measures from the 5 minute blocks of the tenth AVS session.
8. an eyes-closed baseline power measure after 14 AVS sessions.
9. four power measures from the 5 minute blocks of the fifteenth AVS session.
10. an eyes-closed baseline power measure after 19 AVS sessions.
11. an eyes-open baseline power measure after 19 AVS sessions.
12. four power measures from the 5 minute blocks of the twentieth AVS session.
13. an eyes-closed baseline power measure two weeks after the 20th AVS session.
14. an eyes-open baseline power measure two weeks after the 20th AVS session.

Thus, there were 26 power measures per frequency bandpass for each of the thirty participants. All EEG data were log-transformed [log(x)] to correct for skewed distributions. Histograms of the log-transformed data were normally distributed.

Results

Psychometric Measures. None of the psychometric measures indicated significant differences between groups on any of the psychometric measures (PPVT-R - $F(1,2) = 0.933, p < 0.406$; digit span - $F(1,2) = 0.297, p < 0.746$; coding - $F(1,2) = 0.018, p < 0.982$; Raven's - $F(1,2) = 2.523, p < 0.099$; Categories - $F(1,2) = 0.663, p < 0.523$).

EEG Measures. The statistical analyses of this large data set were conducted in several sets. Eyes-closed and eyes-open EEG data were treated as separate conditions. All statistical analyses were conducted using SPSS (version 8) software. Both predicted and exploratory analyses were conducted.

Eyes-closed Condition -- Comparing Original Baseline to the Last Five Minutes of the 5th, 10th, 15th, and 20th AVS Session. The first set of analysis compared the last five minutes of each of the eyes-closed EEG recorded AVS sessions with the original baseline power levels. The last five minutes of each session was chosen because the pilot study indicated this time period of the twenty minute AVS sessions showed the greatest changes from baseline power levels for most locations. The locations used in these analyses were those locations that showed significant within-session changes in power from baseline levels during the pilot study. For the alpha AVS group, these locations by bandpass were as follows: delta 1 - C3; delta 2 - C3 and Cz; theta - F4 and O2, beta 1 -

Fp1, F3, Fz, and F4; beta 2 - P3, Fz, and Cz. For the beta AVS group, these locations by bandpass were as follows: delta 1- F7, F3, Fp2, F4, and T4; theta - T3, F4, C4, P4, F8, and T4; beta 1 - F7, T5, Fp1, F3, C3, O1, Fz, Pz, Cz, Fp2, F4, and C4; beta 2 - T3, P3, O1, Fz, Cz, and Pz. The locations compared in this analysis are shown in Figure 2 for the alpha AVS group and Figure 4 for the beta AVS group.

These locations were examined by one-tailed paired difference t-tests comparing the original baseline power level to the power levels of each of the AVS variables. The same locations from the control group's data set were also compared with one-tailed paired difference t-tests to ensure any significant changes indicated by the multi-session AVS data weren't due to simply sitting quietly with the eyes closed for twenty minutes. Because these one-tailed t-tests were confirming predicted outcomes, the 0.05 probability level did not need to be adjusted for multiple comparisons. The means and t-scores of these analyses are presented in Table 5 for the alpha AVS and control groups and in Table 6 for the beta AVS and control groups.

For the alpha AVS group, eleven of the twelve locations tested confirmed the predicted outcomes during at least one of the four AVS measures (5th session, 10th session, 15th session, and 20th session). See Table 5 to compare the alpha AVS and control groups over the last 5 minutes of the EEG recorded sessions. During the 5th session, nine of the twelve predicted locations showed significant changes in power for the alpha AVS group (see Figure 6). These locations by bandpass were location C3 within the delta 1 bandpass, locations C3 and Cz within the delta 2 bandpass, locations F4 and

O2 within the theta bandpass, locations F3, Fz, and F4 within the beta 1 bandpass, and finally location Cz within the beta 2 bandpass. Location Fp1 within the beta 1 bandpass and locations Fz and P3 within the beta 2 bandpass were the three locations that did not show the predicted changes in power. However, the control group also showed significant changes in power at eight of the twelve predicted locations (see Figure 7). Location Cz within the delta 2 bandpass, location F4 within the theta bandpass, and locations Cz and P3 within the beta 2 bandpass were the locations that did not show significant changes in power over baseline levels for the control group. During the 10th AVS session, the alpha AVS group only showed the predicted changes in power at three locations, all within the beta 1 bandpass (see Figure 8). These were locations F3, Fz, and F4. The control group showed no significant changes in power at any of the predicted locations during the 10th session (see Figure 9). The same three locations within the beta 1 bandpass (F3, Fz, and F4) were significantly higher in power during the 15th session for the alpha AVS group, as well as locations Cz and P3 within the beta 2 bandpass (see Figure 10). The control group also showed increases in power at locations F3, Fz, and F4 within the beta 1 bandpass during the 15th session, but did not show significant increases within the beta 2 bandpass (see Figure 11). During the 20th AVS session, the alpha group showed the predicted increases at ten of the twelve locations, with only location Fp1 within the beta 1 bandpass and location P3 within the beta 2 bandpass not exhibiting the expected increases (see Figure 12). The control group showed significant changes in power at only two of the twelve predicted locations; location O2 within the theta bandpass

and location Fp1 within the beta 1 bandpass significantly increased in power during the 20th session (see Figure 13).

For the beta AVS group, nineteen of the predicted thirty-one locations tested confirmed the predicted outcomes during at least one of the four AVS measures. These locations were within the theta, beta 1 and beta 2 bandpasses. None of the predicted decreases within the delta 1 bandpass were significant for either the beta AVS group or the control group at any of the four time variables. See Table 6 to compare the beta AVS and control groups over the last 5 minutes of the EEG recorded sessions.

As seen in Figure 14, during the 5th session the beta AVS group showed the predicted increases of power at five of the eight locations within the theta bandpass (T3, T5, C4, P4, and T4), at six of the 12 locations within the beta 1 bandpass (F3, Fz, F4, C3, Cz, and Pz), and at two of the six locations within the beta 2 bandpass (Cz and Pz). Although the control group did not show any of the predicted increases within the theta bandpass, eleven of the twelve locations within the beta 1 bandpass significantly increased in power (only location Pz did not significantly increase from baseline), and two of the six locations within the beta 2 bandpass (Fz and O1) significantly increased during the 5th session (see Figure 15). During the 10th session, the beta AVS group showed significant increases in power at three locations within the theta bandpass (F4, C4, and T4), at nine locations within the beta 1 bandpass (Fp1, Fp2, F3, Fz, F4, C3, Cz, C4, and Pz), and at locations Cz and Pz within the beta 2 bandpass (see Figure 16). The control group showed a significant increase in power at only location F7 within the beta 1 bandpass

during the 10th session (see Figure 17). During the 15th session, the beta group showed one location (C4) within the theta bandpass as being significantly higher in power from baseline levels. The same nine locations within the beta 1 bandpass (Fp1, Fp2, F3, Fz, F4, C3, Cz, C4, and Pz) as during the 10th AVS session showed significant increases in power during the 15th session for the beta AVS group, as well as locations Cz and Pz within the beta 2 bandpass (see Figure 18). The control group showed significant increases in power at locations Fp2, F3, Fz, and F4 within the beta 1 bandpass during the 15th session (see Figure 19). During the 20th session, the beta group showed only one location (T5) within the theta bandpass as being significantly higher in power from baseline levels. Eleven of the twelve locations within the beta 1 bandpass significantly increased in power, with location O1 being the only location that did not show a significant change. Once again, locations Cz and Pz within the beta 2 bandpass significantly increased during the AVS session for the beta AVS group (see Figure 20). The control group showed significant increases in power only at locations Fp1 and Fp2 within the beta 1 bandpass during the 20th session (see Figure 21).

After the above predicted analyses were conducted, a set of exploratory analyses was conducted with the same five eyes-closed power measures (original baseline, last five minutes of the 5th session, last five minutes of the 10th session, last five minutes of the 15th session, and the last five minutes of the 20th session) to determine if bandpass locations had AVS effects during the EEG-recorded sessions other than those predicted by the pilot study. One hundred and fourteen one-way repeated-measure ANOVAs

comparing all three groups (control, alpha AVS, and beta AVS) were used to indicate which locations within a particular bandpass had significant changes in power during AVS sessions. Mauchly's test was utilized to check for sphericity of the data. If sphericity was not violated, the more powerful univariate repeated measures using the split plot approach was used to test significance (degrees of freedom = 4,8). For violation of sphericity, the multivariate approach to repeated measures was used (degrees of freedom = 4,4). See Table 7 for F values and probabilities for these analyses.

Four two-tailed paired difference t-tests were done for those significant locations indicated by ANOVAs if t-tests had not already been conducted for that particular location in the previous analyses. Data from a total of twenty-four locations were analyzed. These t-tests compared the baseline mean to the last five minutes of each of the EEG recorded AVS sessions. A Bonferroni adjusted probability level of $p<.05$ (0.05/4 = 0.013) was used to define significance for each of these pairwise post hoc comparisons. Most of these comparisons were not significant at such a stringent probability level. However, six additional locations for the alpha AVS group were indicated as having significant increases in power during the last five minutes of AVS across the time measures. During the 5th session, locations T3 and T5 within the delta 2 bandpass, and location O2 within the theta bandpass, showed significant increases from baseline power levels for the alpha AVS group (see Figure 6). Location T5 within the delta 2 bandpass was also significantly increased during the 15th session (see Figure 10). Additionally, location T5 within the delta 2 bandpass and locations F7 and Cz within the beta 1 bandpass were significantly

increased for the alpha AVS group during the 20th session (see Figure 12). Only one additional location was indicated by the exploratory analysis for the beta AVS group; location T3 showed increased power within the beta 1 bandpass during the last five minutes of the 20th beta AVS session (see Figure 20). The control group showed two additional locations (T3 and T5) within the beta 1 bandpass as having a significant increase in power during the 5th session (see Figures 7 and 15).

Eyes-closed Condition -- Comparing Original Baseline to 20th Session Baseline and Post Measures. As well as within-session effects, the pilot study indicated that several locations by bandpasses continued to exhibit significant changes in power one half hour after the AVS sessions ceased. The second set of analyses utilized those locations within a bandpass indicated by the pilot study that had significant lasting changes from baseline one half hour after either alpha AVS or beta AVS (see Figures 3 and 5). It was predicted that these locations would continue to show significant changes from baseline power levels after multiple sessions of AVS. To test these predictions, one-tailed paired difference t-tests were conducted for each location within a bandpass that had significant changes in power one half hour after an AVS session as indicated by the pilot study data. The same bandpass locations from the control group's data set were also compared via one-tailed paired difference t-tests to ensure any significant changes weren't due to sitting quietly with the eyes closed for twenty minutes. To keep as many degrees of freedom as possible, three power measures were used in these predicted analyses -- the original

baseline power measure, the baseline power measure of the 20th session (approximately 15 to 24 hours after the 19th AVS session), and the two weeks post power measure. The baseline power measure of the 20th AVS session was chosen because if there was a cumulative effect of the AVS sessions, this power measure should be most likely to be indicative of significant changes from baseline power levels.

For the alpha stimulation condition, the pilot study indicated only three locations that continued to show significant changes from baseline power levels one half hour after the AVS session ended (see Figure 3). These were locations Fp1, F3, and Fz, all within the beta 1 bandpass. None of these locations showed significant increases in power from baseline levels at either the baseline measure of the 20th alpha AVS session or at the post measure two weeks later. Means, t-scores and probabilities for these analyses are presented in the upper portion of Table 9.

For the beta stimulation condition, the pilot study indicated several locations as showing significant lasting effects over baseline power levels (see Figure 5). These locations, by bandpass, were: theta - T5 and T6; alpha - C3, C4, and F8; beta 1 - F7, T5, Fp1, F3, C3, O1, Fz, Pz, F4, and C4; beta 2 - C3, P3, and Fz. None of the locations within the alpha bandpass showed significant increases in power from baseline levels at either the 20th session baseline (see Figure 22) or at the post measure (see Figures 23 and 24) after beta AVS. However, location T6 within the theta bandpass showed a significant increase in power from the original baseline power level to the post measure (see Figure 23). Additionally, five locations (Fp1, F3, Fz, F4, and C4) within the beta 1 bandpass

showed significant increases in power levels between the last beta AVS session and the post measure two weeks after the last beta AVS session (see Figure 24). Three of these locations (F3, Fz, and F4) were significantly higher than the original baseline power at the post measure (see Figure 23). Finally, two of the three predicated locations within the beta 2 bandpass (C3 and Fz) had significantly higher power levels two weeks after the last AVS sessions when compared to the 20th session measure (see Figure 24). The control group results indicated there were no significant increases in power data at these locations. See the lower portion of Table 9 for means and t-score values and probabilities from this set of analyses.

It is possible that the locations indicated by the pilot study as showing significant within sessions changes in power could demonstrate a cumulative change in power over the multiple sessions of AVS. Thus, the locations showing within session changes in power in the pilot study could have lasting changes in power after multiple sessions of AVS. The next set of analyses explored this possibility. The locations that were indicated by the pilot study as having within-session significant changes from baseline were examined by one-tailed paired difference t-tests for the same three power measures (original baseline, baseline of the 20th session, and two weeks post) utilized in the previous analyses. These locations are illustrated in Figure 2 for the alpha AVS group and Figure 4 for the beta AVS group. The locations by bandpass for the alpha AVS group were as follows: delta 1 - C3; delta 2 - C3 and Cz; theta - F4 and O2, beta 1 - Fp1, F3, Fz, and F4; beta 2 - P3, Fz, and Cz. For the beta AVS group, these locations by bandpass

were as follows: delta 1- F7, F3, Fp2, F4, and T4; theta - T3, F4, C4, P4, F8, and T4; beta 1 - F7, T5, Fp1, F3, C3, O1, Fz, Pz, Cz, Fp2, F4, and C4; beta 2 - T3, P3, O1, Fz, Cz, and Pz. The same locations from the control group's data set were also compared with paired difference t-tests to ensure any significant changes weren't due to sitting quietly with the eyes closed. The means and t-scores of these analyses are presented in Table 10 for the alpha AVS and control groups and in Table 11 for the beta AVS and control groups. Notice that three locations within the beta 1 bandpass (Fp1, F3, and Fz) for the alpha AVS group are represented on both Tables 9 and 10. Also, several locations (beta 1 - F7, T5, Fp1, F3, C3, O1, Fz, Pz, F4, and C4; beta 2 - P3 and Fz) are represented on both Tables 9 and 11 for the beta AVS group. This is because these locations showed both significant within-session and post-session changes in power in the pilot study.

For the alpha AVS group (Table 10), only location F4 within the theta bandpass showed a significant increase from the original baseline to the post measure of the twelve locations analyzed. This increase occurred between the 20th session baseline measure and the post measure (see Figures 25 through 27).

From the twenty-nine locations indicated from the single-session beta AVS pilot study, twelve locations showed significant differences in power levels over the course of the study. Location T4 within the delta 1 bandpass significantly decreased from original baseline levels at both the baseline of the 20th session and at the post measure (see Figures 28 and 29). Location F4 within the theta bandpass significantly increased in power from the 20th session baseline to the post measure two weeks later (see Figure 30). Seven

locations within the beta 1 bandpass (Fp1, F3, Fz, Cz, Fp2, F4, and C4) significantly increased in power over the two weeks between the 20th session and the post measure (Figure 30), with five of these locations (F3, Fz, Cz, Fp2, and F4) showing a significant increase from the original baseline to the post measure (see Figure 29). Finally, locations Fz and Cz in the beta 2 bandpass also significantly increased from the 20th session baseline to the post measure (Figure 30), with location Cz showing a significant increase from the original baseline to the post measure (see Figure 29).

After the above predicted analyses were conducted, an exploratory analysis was done with the same three eyes-closed power measures (original baseline, baseline after 19 AVS sessions, and post) to determine if other bandpass locations had lasting AVS effects after multiple sessions of AVS. One hundred and fourteen one-way repeated-measure ANOVAs comparing all three groups (control, alpha AVS, and beta AVS) were conducted to indicate which locations within a particular bandpass had significant lasting changes in power over time. Once again, Mauchly's test was utilized to check for sphericity of the data. If sphericity was not violated, the more powerful univariate repeated measures using the split plot approach was used to test significance (degrees of freedom = 2,4). For violation of sphericity, the multivariate approach to repeated measures was used (degrees of freedom = 2,2). See Table 12 for F values and probabilities for these analyses.

Three two-way paired difference t-tests were conducted for those significant locations indicated by the ANOVAs, if t-tests had not already been conducted for that

particular location. Data from a total of eleven locations were analyzed. These t-tests compared the baseline mean to the 20th session baseline and post means. A Bonferroni adjusted probability level of $p<.05$ (0.05/3 = 0.017) was used to define significance for each of these pairwise post hoc comparisons. As can be seen in Table 13, several locations were significant at $p < 0.05$, but only three locations remained significant after the Bonferroni correction. Two of the significant locations involved the control group, with location Fp1 within the delta 2 bandpass significantly increasing in power and location Fz within the beta 1 significantly decreasing in power between the original baseline and the 20th session baseline. The beta AVS group showed a significant increase in power at location F4 within the beta 2 bandpass between the 20th session and the post measure, with the post power level significantly higher than either the original baseline or the 20th session baseline (see Figures 29 and 30).

It was thought perhaps the changes in power attributable to AVS habituated over time, causing the peak changes in power to be after the first few AVS sessions, rather than accumulating over the 20 sessions. If this was true, more locations would show significant changes at the 5th AVS session than at the 20th AVS session. This possibility was tested by conducting another 114 ANOVAs comparing the original eyes-closed baseline power levels with the eyes-closed baseline of the 5th AVS session. None of these 114 tests indicated a significant interaction between groups, suggesting that the effect of AVS accumulated over time instead of habituating over time.

Eyes-open Condition. The final set of analyses was conducted with the eyes-open EEG data. There was not an eyes-open condition in the pilot study; as such, all the analyses using the eyes-open data were exploratory. These results are preliminary and must be confirmed by further research.

The same three power measures (original baseline, baseline after 19 AVS sessions, and post) from the second set of analyses were used in this analysis of the eyes-open EEG data to examine if multi-session AVS also showed effects on the eyes-open EEG. One of the difficulties with eyes-open EEG recordings is the presence of muscle tension in the recording. Of course, muscle tension can occur during eyes-closed EEG recordings; however, people tend to show much less muscle tension without the eyes open. Several locations were not analyzed in the eyes-open data set because the muscle tension artifact was difficult, if not impossible, to remove from the record. These locations were Fp1, Fp2, T5, T6, O1, and O2. Seventy-eight one-way repeated-measure ANOVAs comparing all three groups (control, alpha AVS, and beta AVS) were utilized to indicate which locations within a particular bandpass, if any, had significant lasting changes in power over time. Once again, Mauchly's test was utilized to check for sphericity of the data. If sphericity was not violated, the more powerful univariate repeated measures using the split plot approach was used to test significance (degrees of freedom = 2,4). For violation of sphericity, the multivariate approach to repeated measures was used (degrees of freedom = 2,2). Only seven locations out of the 78 were indicated by the ANOVAs as having significance. Location F8 was indicated in the delta 1, delta 2, and theta bandpasses.

Within the alpha bandpass, location C4 was significant. Location P3 was significant in the beta 1 bandpass, and both locations C4 and F8 were significant within the beta 2 bandpass. See Table 14 for F values and probabilities for these analyses.

Three two-tailed paired difference t-tests were done for each of these seven significant locations. These t-tests compared the eyes-open baseline mean to the eyes-open 20th session baseline and post means. A Bonferroni adjusted probability level of $p<.05$ (0.05/3 = 0.017) was used to define significance for the pairwise post hoc comparisons. Only location F8 within bandpass delta 1 for the beta AVS group was significant after the Bonferroni correction. This location showed a significant reduction in power from the original baseline to the post measure. Table 15 presents the t-scores and probabilities for this set of analyses.

CHAPTER IV

DISCUSSION

Psychometric Measures.

There were no significant differences between groups on the pre and post measures of the cognitive tests given to all participants, although some participants did show non-significant improvement in post-scores as compared to pre-scores. The obvious conclusion is that AVS, either at the dominant alpha frequency or at twice the dominant alpha frequency, does not significantly affect the cognitive abilities measured by the PPVT-R, the coding and digit span subscales of the WAIS-R, the Raven's, or the Categories subtest of the Halstead-Reitan Battery. However, there are at least two caveats to keep in mind while assessing these data. First of all, the participants in this study were either in their senior year of undergraduate education or in graduate school at a four-year research university. It is possible that some or most of these participants were part of a select group that reflected strong cognitive abilities, and as such did not or could not show much improvement in the areas as measured by these psychometric tests over a two month period. This is substantiated by the scores many participants received on the cognitive tests. For example, many participants did not receive a true ceiling score on the PPVT-R because they were able to correctly identify most, if not all, of the definitions of the words used in the test. Secondly, these psychometric tests were given only two months apart, and for those tests without multiple forms (the Raven's, the Categories, and the subtests of the WAIS-R), it is quite possible that the post measures were confounded by the remembered experiences of the pre measures by the participants. This possibility is

particularly true for the Categories subtest. For this test, participants attempt to discern the underlying pattern in the presentation of four stimuli. Nearly all participants stated they were able to remember the right pattern at the post measure from their previous experience with the test.

It is possible that groups having deficits in certain cognitive areas may show improvement in their abilities over time after experiencing multiple sessions of AVS. As mentioned in the literature review (pp. 15 - 16), Russell (1997) has reported success in improving cognitive abilities in learning disabled populations and those suffering from the after effects of strokes and aneurysms, while Montgomery, et al. (1994) found damage due to closed head injuries may be alleviated via AVS. The current study indicates people who are successful at the college level do not seem to show noticeable cognitive improvement after twenty sessions of AVS, as measured by the psychometric tests used in this study. More research is necessary to determine which, if any, populations can show cognitive gains after experiencing AVS. Similarly, other psychometric measures should be explored that may be more sensitive to subtle changes in cognitive processes in normal adults than those used in this study.

EEG Measures.

Dominant Alpha AVS. In terms of within-session changes in power levels, alpha AVS did affect cortical activity in many of the ways predicted by data from the pilot study. During the alpha AVS sessions, both the low frequency bandpasses and the higher frequency

bandpasses showed increased power over baseline levels (see Table 5 and Figures 6, 8, 10, and 12). The alpha bandpass showed no significant effect of alpha AVS. This confirms the pilot study results which indicated alpha AVS does not significantly affect the alpha bandpass but does affect the other bandpasses.

The low-frequency bandpasses (delta 1, delta 2, and theta) showed somewhat similar patterns of within-session activity for both the alpha AVS and control groups (see Figures 7, 9, 11, and 13 for control group data). Power was increased over original baseline levels at left central locations within the delta 1 bandpass (location C3) during the 5th and the 20th alpha AVS sessions. Power was also increased within the delta 2 bandpass at left central and temporal locations (locations C3, Cz, T3, and T5) during the 5th alpha AVS session, location T5 during the 15th alpha AVS session, and locations C3, Cz, and T5 during the 20th alpha AVS session. The control group also showed significant increases at location C3 within the delta 1 and delta 2 bandpasses during the 5th session, but did not show any significant activity at other predicated locations within the delta 1 and delta 2 bandpasses throughout the remainder of the sessions. Within the theta bandpass, power increased at right frontal (F4) and occipital (O2) locations during the 5th and 20th alpha AVS sessions. The control group also showed a similar pattern of significant increases within the theta bandpass, with power significantly increasing for this group at location O2 during the 5th and 20th session.

Thus, alpha AVS is associated with significant within-session changes of power in central and temporal locations within the delta 1 and delta 2 bandpasses, and in right

frontal and occipital locations within the theta bandpass. However, sitting quietly in the dark with the eyes closed for twenty minutes is also associated with increases in power at some of the same locations as those shown by the alpha AVS group, particularly within the theta bandpass. It may be that alpha AVS does increase power at central and temporal locations within the delta 1 and delta 2 bandpasses during the AVS session. However, these bandpasses do not show a systematic effect of alpha stimulation. Although several locations during the fifth session and the twentieth session show significant increases in power from baseline levels during alpha AVS, the tenth session does not. During the fifteenth session only one location shows a significant increase in power within the delta 2 bandpass. If these changes in low-frequency cortical activity were due directly to the alpha AVS, the data would be expected to show basically the same within-session effects of alpha AVS at each time measure. Therefore, it is difficult to argue that alpha AVS changes power levels within the lower frequency bandpasses above and beyond sitting quietly with the eyes closed.

Within the higher frequency bandpasses (beta 1 and beta 2), the alpha AVS group and the control group showed more diverse patterns of within-session activation over the four time measures. Frontal locations within the beta 1 bandpass increased in power at F3, Fz, and F4 during alpha AVS across all four of the time measures, with locations F7 and Cz also showing a significant increase in power over baseline levels during the 20th session. The control group showed more erratic effects within the beta 1 bandpass at these locations, with power increasing significantly during the fifth and fifteenth sessions,

actually decreasing below baseline levels during the tenth session, and non-significantly increasing during the twentieth session. The beta 2 bandpass results suggest an even clearer differentiation between the alpha AVS and the control groups. During alpha AVS, location Cz increased in power over all four time measures, with three of the time measures significantly increasing from baseline levels. The alpha AVS group also showed significant increases in power at location P3 during the 15th session and at location Fz during the 20th session. The control group did not show significant increases in power at Cz within the beta 2 bandpass during any of the time measures. Additionally, besides the significant increase in power at location Fz during the 5th session, the control group did not show significant increases in power within the beta 2 bandpass (power increasing at Fp1 may be attributable to muscle artifact).

The data regarding the within-session effects of alpha AVS on the higher frequency bandpasses suggests that alpha AVS has a real effect on power levels in the higher frequencies, particularly at frontal and central locations, during the stimulation session. The alpha group shows significantly increased power at frontal locations across all of the time measures. As a cautionary note, however, the control group does show significantly increased power at frontal locations within the higher frequency bandpasses *occasionally*. A possible explanation for the control group's data is that the initial increase in power seen during the 5th session was due to the novelty of the situation, which habituated over time, leading to the more sporadic changes seen in power measures of the control group as the study progressed.

Regardless of the within-session changes in the cortical EEG with alpha AVS, as can be seen in Tables 9, 10, and 13, the stimulation had minimal lasting effects on the cortical EEG. Only one location showed any significant changes from the original baseline power levels at the post measure for the alpha AVS group, location F4 within the theta bandpass. This lack of lasting cortical change when exposed to AVS at the dominant alpha frequency is in agreement with the findings from the pilot study for alpha AVS. While alpha AVS may lead to within-session changes in power, it has little or no effect beyond the AVS session itself.

Twice Dominant Alpha AVS. As in the pilot study, beta AVS appears to have a more dramatic and lasting affect on the cortical EEG than alpha AVS, particularly in the beta 1 and beta 2 bandpasses. The alpha bandpass showed no significant effects of the beta AVS sessions, confirming once again that AVS does not affect the alpha bandpass. None of the predicted decreases in power within the delta 1 bandpass seen in the single-session pilot study were confirmed by the multi-session study. However, beta AVS did show the predicted significant effects at several locations within the theta, beta 1, and beta 2 bandpasses during the last five minutes of the EEG-recorded beta AVS sessions (see Table 6 and Figures 14, 16, 18, and 20).

Within the theta bandpass, six of eight predicted locations (T3, T5, F4, C4, P4, and T4) showed significant increases in power from baseline levels during the beta AVS sessions. These increases were sporadic, with some occurring during the fifth session, some during the tenth session, and so on; none of these locations showed increases across all four of the time

measures. The control group showed no significant changes at any of these locations at any of the within-session time measures, indicating that the increases in power within the theta bandpass seen in the beta AVS group can be attributed to the beta AVS itself and not merely sitting quietly with the eyes closed.

The beta 1 bandpass showed dramatic within-session effects for the beta AVS group. Locations F3, C3, Fz, Cz, Pz, and F4 showed significant increases in power across all four of the time measures during the last five minutes of the AVS sessions. Locations Fp1, Fp2, and C4 showed significant increases in power during the last three time measures. Additionally, locations F7, and T5 showed significantly increased power during the twentieth beta AVS session. Only location O1 did not show the predicted results during beta AVS. Exploratory within-session results (Table 8) indicate that location T3 within the beta 1 bandpass also showed significant increases in power during beta AVS. Thus, by the 20th beta AVS session, 12 of 19 locations were showing significant increases in power over baseline levels within the beta 1 bandpass during the AVS session. All twelve locations clustered together . According to the findings of this study, AVS at twice the dominant alpha frequency activates frontal, central, and midline areas of the cortex during the stimulation condition. These results confirm those of the pilot study which suggested AVS at twice the dominant alpha frequency has extensive effects on the beta bandpass during the AVS session.

Once again, a cautionary note regarding these within-session effects on the beta 1 bandpass must be expressed. The control group also showed significant increases in power at several of the same frontal locations within the beta 1 bandpass, although the control data are

much more variable (see Table 6 and Figures 15, 17, 19, and 21). Thus, while beta AVS does directly effect the beta 1 bandpass at frontal, central, and midline locations, this is tempered by the fact that merely sitting quietly with the eyes closed can also occasionally significantly increase beta 1 power levels over original baseline levels at frontal locations. As in the discussion of the alpha AVS effects, the initial increases in power seen in the control group in the higher frequency bandpasses during the 5th session may be due to the novelty of the situation. The significant increases in power disappear by the 10th session, reappear in limited locations during the 15th session, and are gone again by the 20th session for the control group. The beta AVS group, on the other hand, showed systematic within-session increases in power in the beta 1 bandpass at virtually the same locations over all four of the time measures, indicating these effects are truly tied to the presentation of AVS at twice the dominant alpha frequency.

The beta 2 bandpass results more clearly indicate the effects of beta AVS. The two locations showing significant increases in power (Cz and Pz) within the beta 2 bandpass showed this effect across all four of the time measures for the beta AVS group; the control group did not indicate any significant increases in power for these two locations. These results suggest that beta AVS significantly affects midline locations within the beta 2 bandpass during the AVS session.

In terms of lasting effects of beta AVS, data are shown in Tables 9, 11, and 13 and in Figures 22-24 and Figures 28-30 that indicate several locations by bandpasses show significant effects at the post measure two weeks after the last beta AVS session occurred. Within the

delta 1 bandpass, location T4 showed significant decreases in power from the original baseline at both the 20th session baseline and the post measure (see Table 11). The theta bandpass showed a significant increase in power from original baseline to the post measure at location T6 (Table 9) and from the 20th session baseline to the post measure at location F4 (Table 11). Once again, the beta 1 bandpass showed the greatest number of significant changes from original baseline power. Several frontal (Fp1, Fp2, F3, Fz, and F4) and central (Cz and C4,) locations significantly increased in power during the two week interval between the last beta AVS session and the post measure. Five of these locations (Fp2, F3, Fz, F4, and Cz) were significantly higher in power at the post session when compared to original baseline power levels. Three locations within the beta 2 bandpass also showed this pattern of power increases, with locations F4, Fz, C3 and Cz significantly increasing in power from the 20th session baseline to the post measure and location Cz showing significant increases in power at the post measure when compared to the original baseline power levels.

What is especially intriguing about these results is that the 20th session baseline was not significantly different from the original eyes-closed baseline for either of the beta bandpasses, but somehow over the two week interval between the last beta AVS session and the post EEG recording beta 1 and beta 2 power levels significantly increased over original baseline levels. Neither the control group nor the alpha AVS group showed this pattern of power changes, indicating that these results were due to the exposure to beta AVS alone and not to some other factor.

Eyes-open Condition. The eyes-open EEG data were not consistent with the numerous significant outcomes indicated by the eyes-closed EEG data. Only one location, F8 within the delta 1 bandpass, showed a significant change over the course of the multiple session AVS study for the eyes-open EEG condition out of the large number of analyses conducted. This suggests that although a number of changes occur in the eyes-closed cortical EEG activity during and after AVS sessions, particularly when the stimulation is provided at twice the dominant alpha frequency, these changes do not generalize to the eyes-open EEG activity of a college population. It is possible that other populations, ie. learning disabled or ADD/HD, may show a generalized effect of AVS on the eyes-open EEG. More research is necessary in this area to determine if AVS can be useful in clinical settings with these populations.

General Discussion.

The results of the pilot study were confirmed to a large degree by the multiple session data. Audio-visual stimulation shows within-session effects on cortical activity as measured by the EEG. Both stimulation at the dominant frequency and stimulation at twice the dominant frequency affect power at several locations within the delta 1, delta 2, theta, beta 1, and beta 2 bandpasses during the respective AVS session. Neither type of AVS have any significant effects within the alpha bandpass.

Before AVS is embraced as an unique way to change cortical activity, however, it must be pointed out that power changes occurred at a number of the same locations and

bandpasses when participants simply sat quietly in dim light with their eyes closed. This is particularly true when providing AVS at the dominant alpha frequency. Alpha AVS does significantly increase power in frontal and central locations within the higher frequency bandpasses (13 - 32 Hz), but the multiple session data indicate that these cortical changes occur only during the stimulation session itself. It is possible that increases in frontal beta may last for an unspecified amount of time after the alpha AVS has ceased. The pilot study indicated that significant increases in power at locations Fp1, F3 and FZ within the beta 1 bandpass could be detected one-half hour after one twenty-minute alpha AVS session. However, there are no lasting cortical changes associated with alpha AVS presented over twenty sessions approximately 19 to 24 hours after the 19th session, as indicated by this study. Hence, incorporating AVS at the dominant alpha frequency for clinical purposes may not be particularly useful or desirable in terms of long-term changes in beta bandpass activity. However, alpha AVS may show clinical usefulness in terms of priming activity in higher frequency bandpasses; this possibility needs to be explored more intensively by further research.

Stimulation at twice the dominant frequency showed more extensive, lasting changes in the eyes-closed EEG. Beta stimulation particularly affected the theta, beta 1, and beta 2 bandpasses, both during the AVS sessions and at the post measure two weeks after the last AVS session. Although the control group showed sporadic significant changes within the beta 1 bandpass over the course of the study, they did not show any significant effects on the locations examined within the theta and beta 2 bandpasses.

Additionally, the control group did not show any lasting changes within these three bandpasses. Thus it appears that the increases in frontal, central, and midline activity seen in the eyes-closed EEG of the beta AVS group are attributable to the beta AVS itself and not to other factors.

Since beta bandpass activity is generally associated with mental processing (Duffy, et al., 1989), these results substantiate the Montgomery, et al. (1994) and Russell (1997) claims of cognitive improvement for certain types of brain injuries after several sessions of AVS. Although the college-attending subjects in this study did not show significant improvement in verbal skills or memory tasks after experiencing twenty sessions of beta AVS, it is possible that other populations, particularly those associated with brain injuries or learning disabilities, may show more noticeable effects. Additionally, other cognitive measures should be explored in future research in areas such as attention, efficiency of processing, efficiency of learning, speed of processing, and allocation of executive processes.

The beta AVS results presented in this study have implications for the use of beta AVS in the context of neurofeedback therapy, particularly for attentional disorders such as ADD/HD. Since one goal of neurofeedback therapy for ADD/HD is to increase beta production (Lubar, et al., 1995a; Lubar, et al., 1995b), it is possible that beta stimulation may be an useful adjunct to this particular neurofeedback application. Patrick (1996) has reported successfully shortening the number of neurofeedback sessions necessary to train beta production in boys via AVS priming. However, it is worrisome that this study also

indicates increases of theta activity during and after beta AVS. Since people with ADD/HD tend to show an excessive amount of theta production in comparison to matched controls, the use of beta AVS may not be warranted for this particular population. Further studies with ADD/HD populations are necessary to determine whether the beneficial effects of increased beta activity after exposure to beta AVS outweigh the detrimental effects of increased theta activity.

One last statement of caution regarding the use of AVS in the clinical setting must be addressed. Although the results from this multi-session AVS study indicate that AVS does affect the eyes-closed EEG, particularly when stimulation is provided at twice the dominant alpha frequency, the eyes-open EEG is minimally effected by either AVS condition after twenty AVS sessions. Whether the lack of effect of AVS on the eyes-open EEG is only seen in normal college students, or is also apparent in clinical populations is a concern that needs to be addressed in future research. Since neurofeedback typically is provided during an eyes-open situation, it may be difficult to incorporate beta AVS as a primer of cortical activity if there are not direct effects of AVS on eyes-open EEG activity. It would be interesting to determine if auditory stimulation alone (not in conjunction with visual stimulation) affects the cortical EEG. It would be easier to use auditory stimulation alone to prime EEG activity in an eyes-open, clinical context. This is an area that needs to be explored by additional research.

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APPENDICES

APPENDIX A

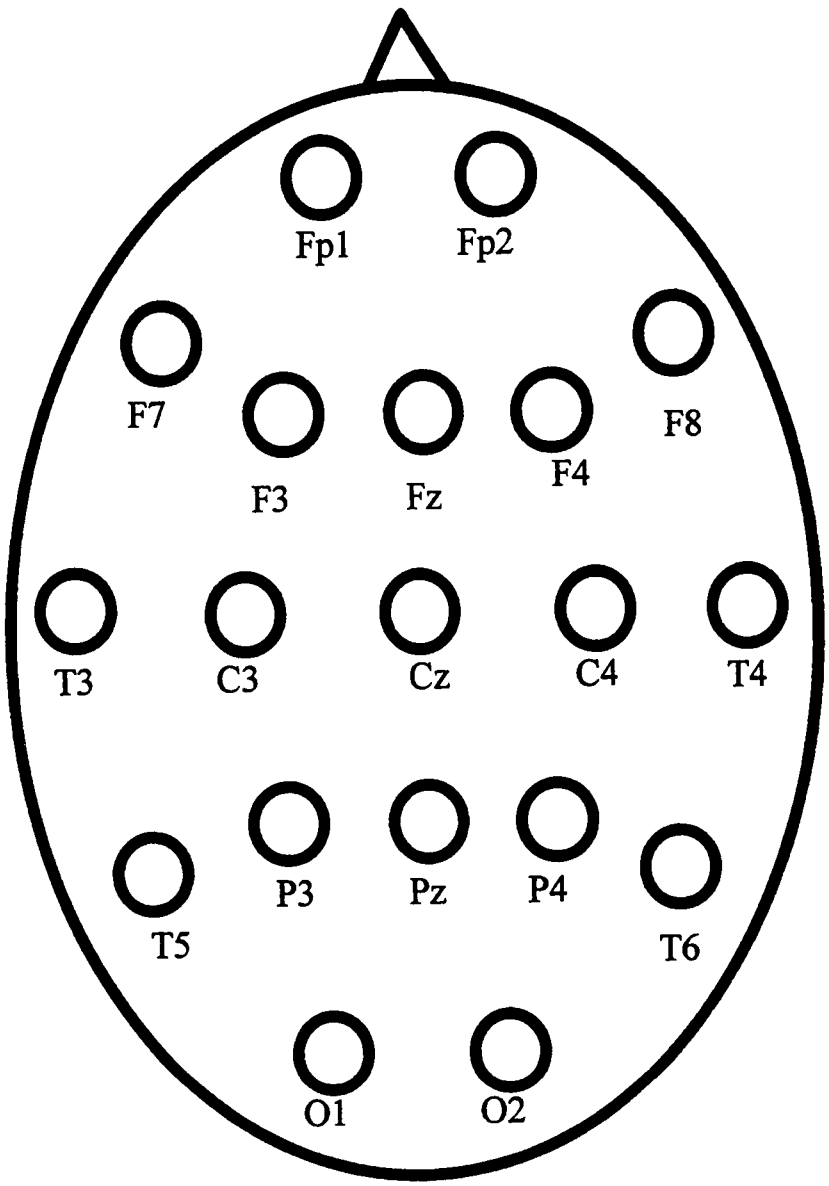


Figure 1. The 19 Locations of the International 10-20 System.

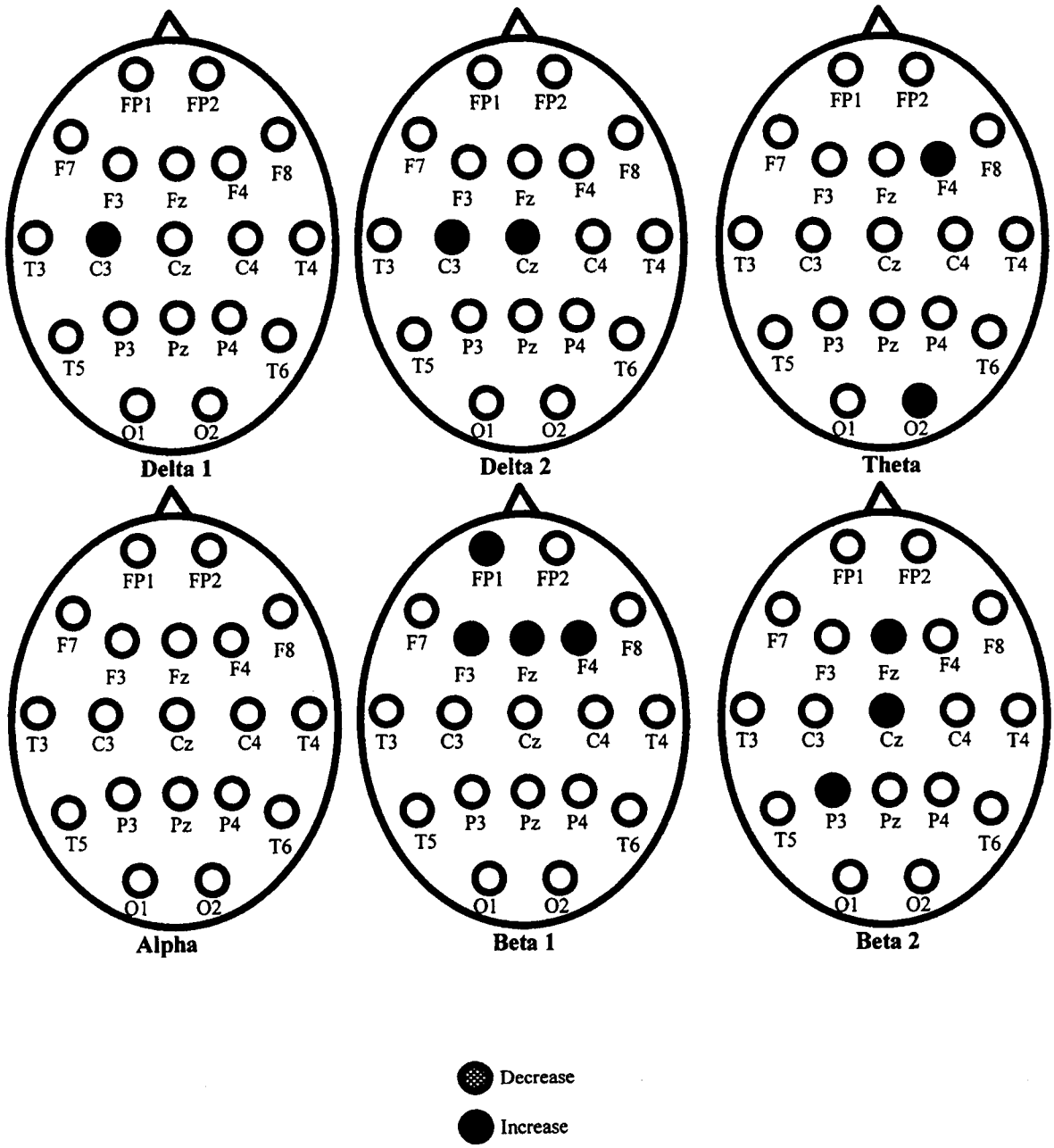


Figure 2. Significant Changes from Baseline EEG Activity during Alpha AVS Pilot Study Session.

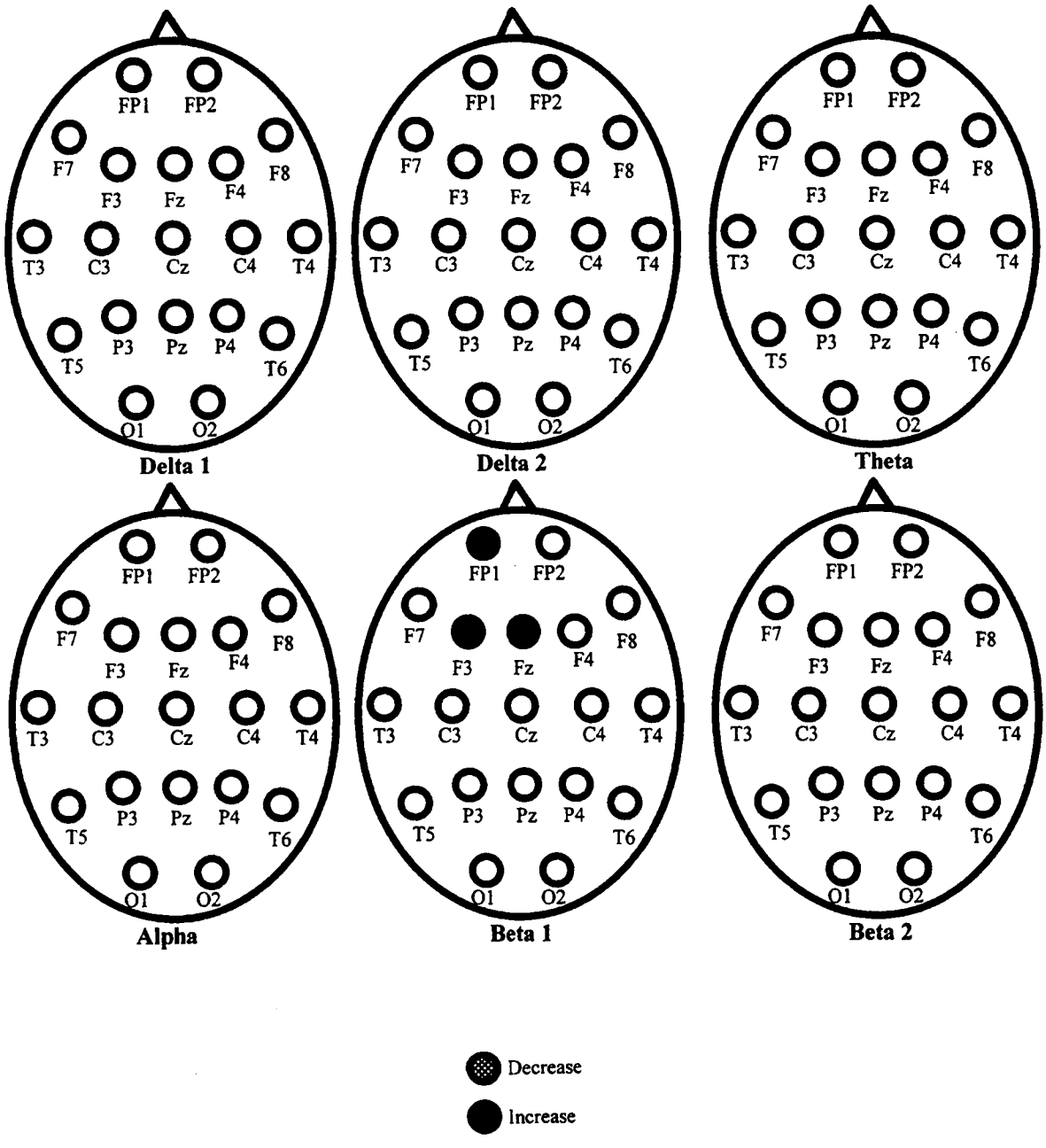


Figure 3. Significant Changes from Baseline EEG Activity 1/2 Hour After Alpha AVS Pilot Study Session.

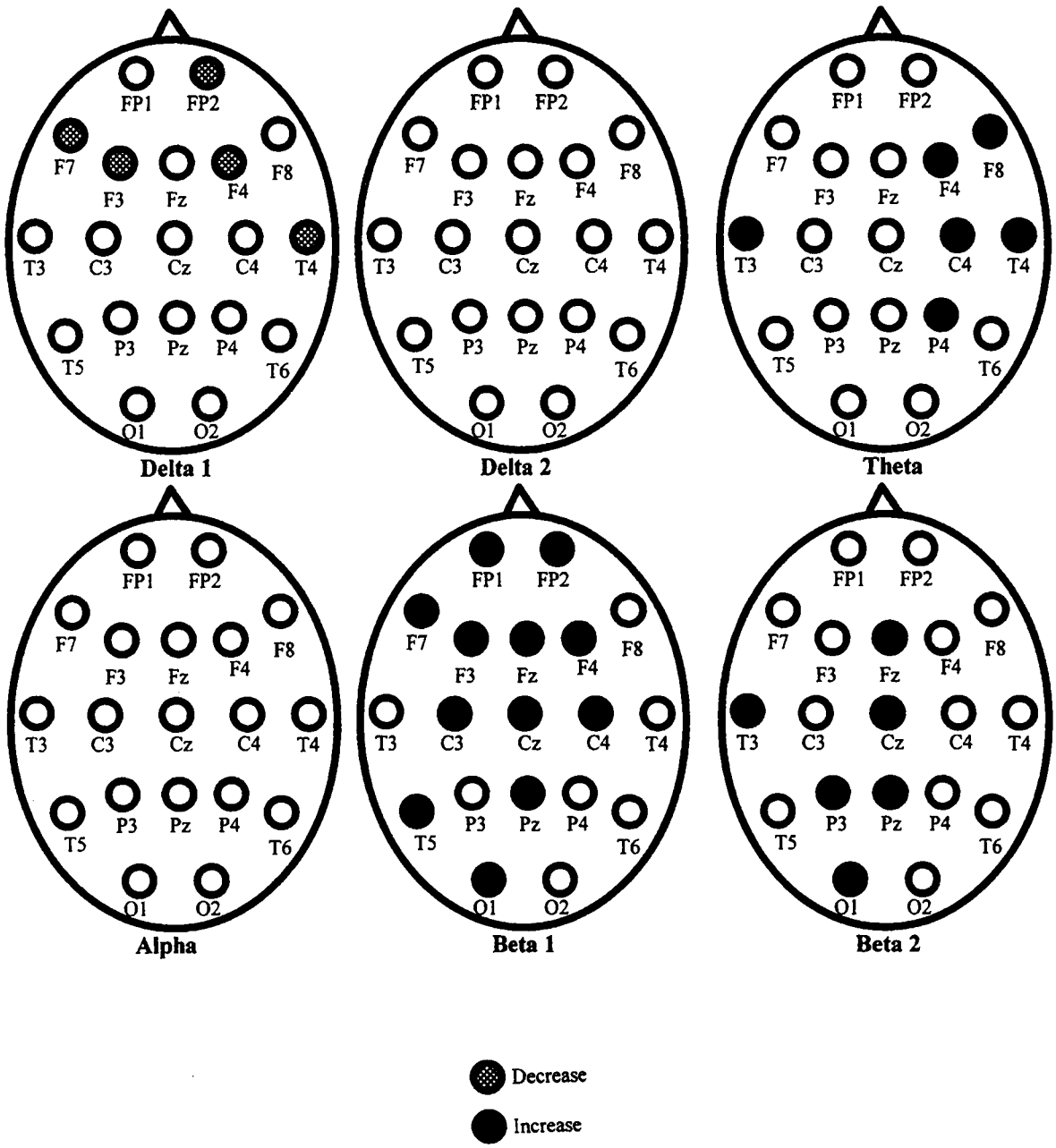


Figure 4. Significant Changes from Baseline EEG Activity during Beta AVS Pilot Study Session.

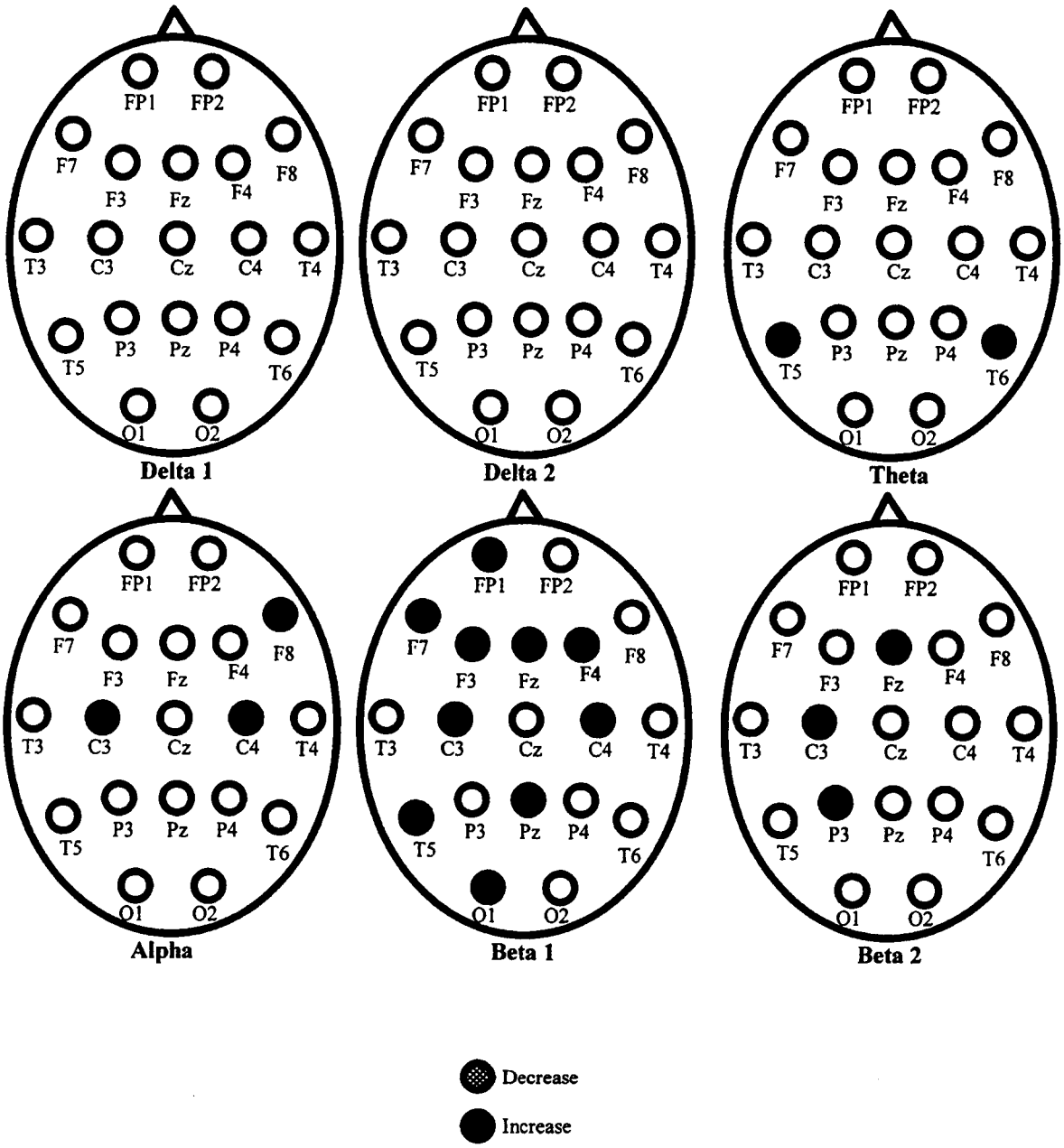


Figure 5. Significant Changes from Baseline EEG Activity 1/2 Hour After Beta AVS Pilot Study.

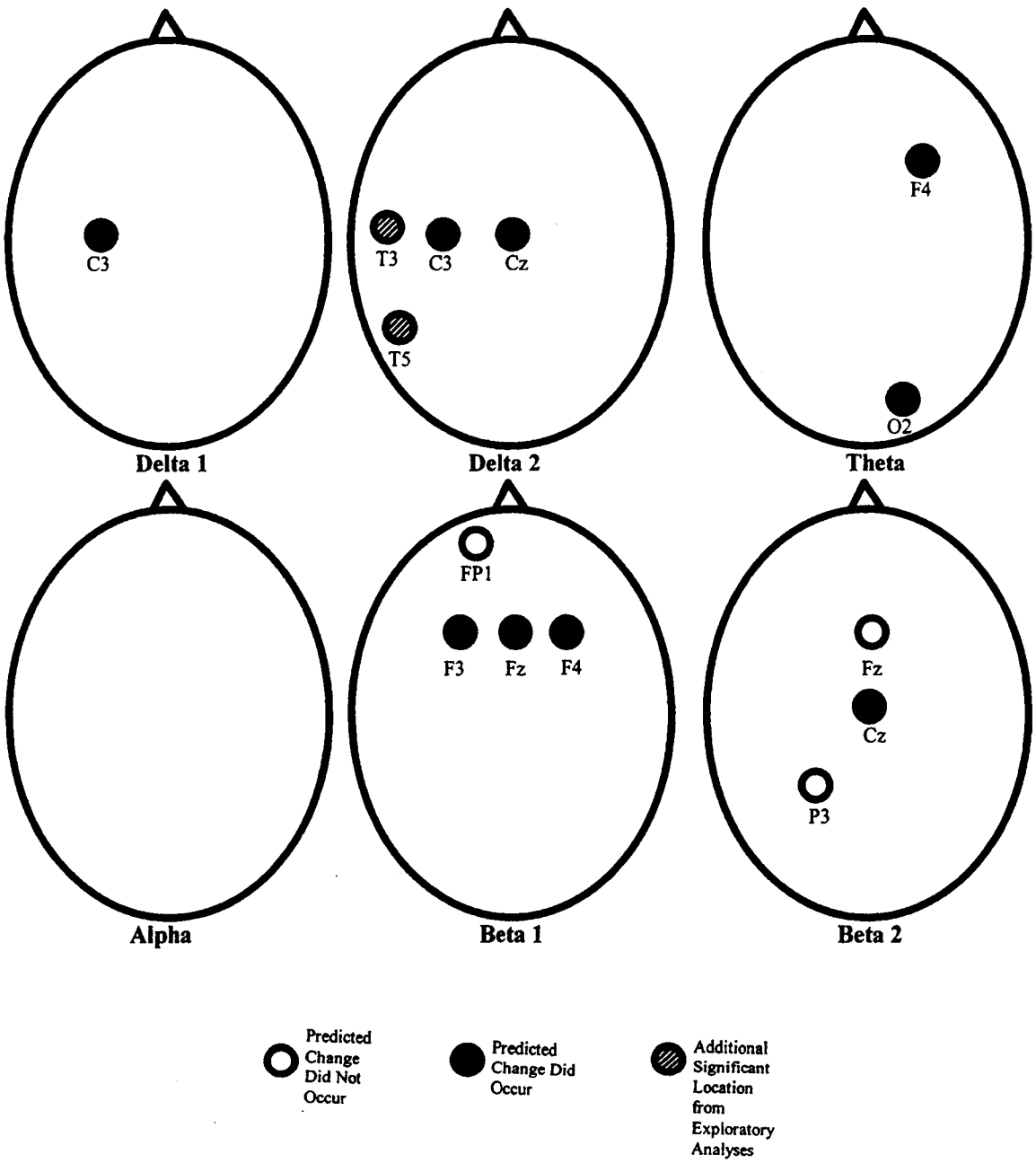


Figure 6. Significant Changes from Baseline for Locations Predicted by the Alpha AVS Pilot Study. This Figure Represents the Alpha AVS Group During the Last Five Minutes of the Fifth AVS Session.

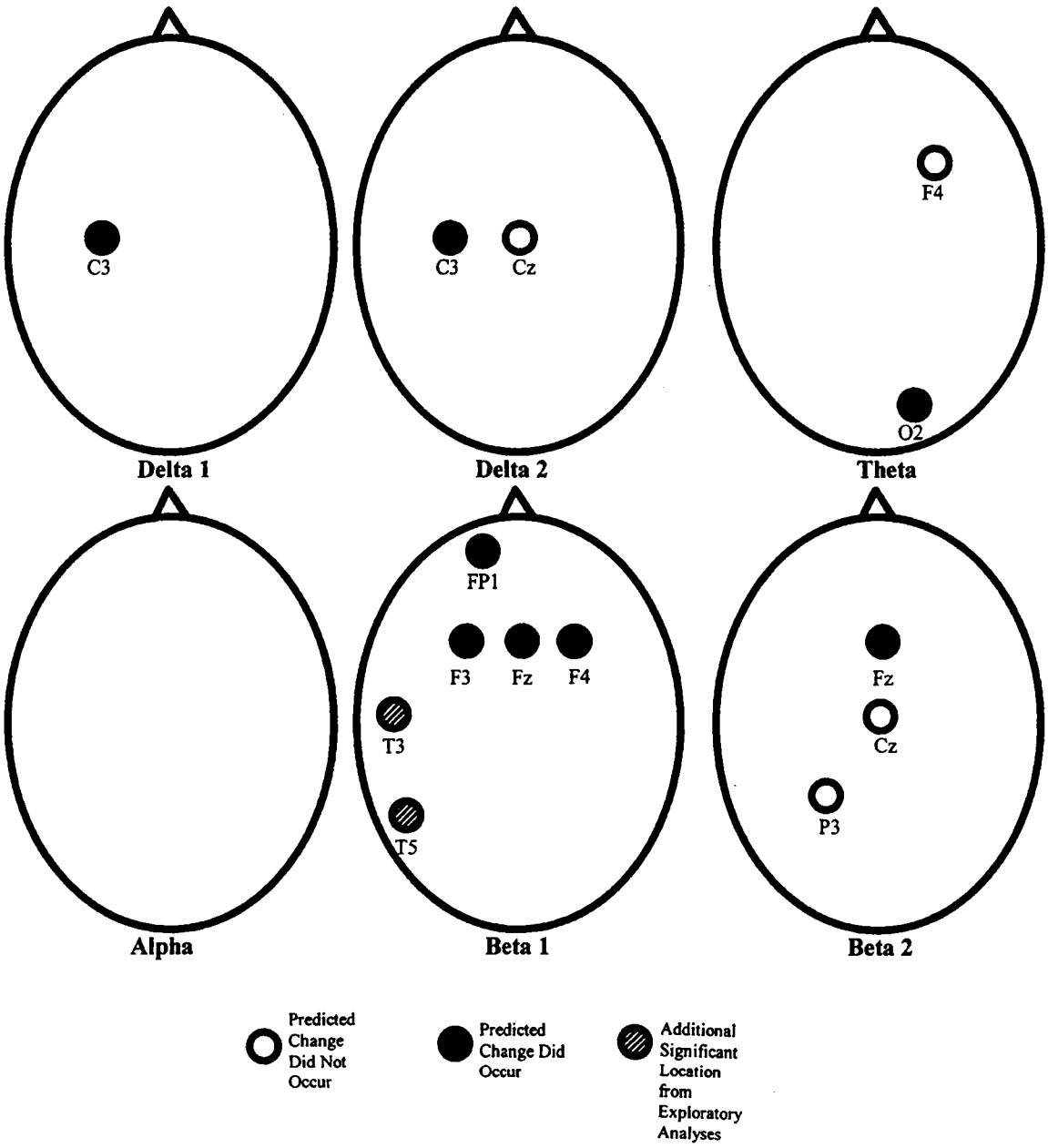


Figure 7. Significant Changes from Baseline for Locations Predicted by the Alpha AVS Pilot Study. This Figure Represents the Control Group During the Last Five Minutes of the Fifth AVS Session.

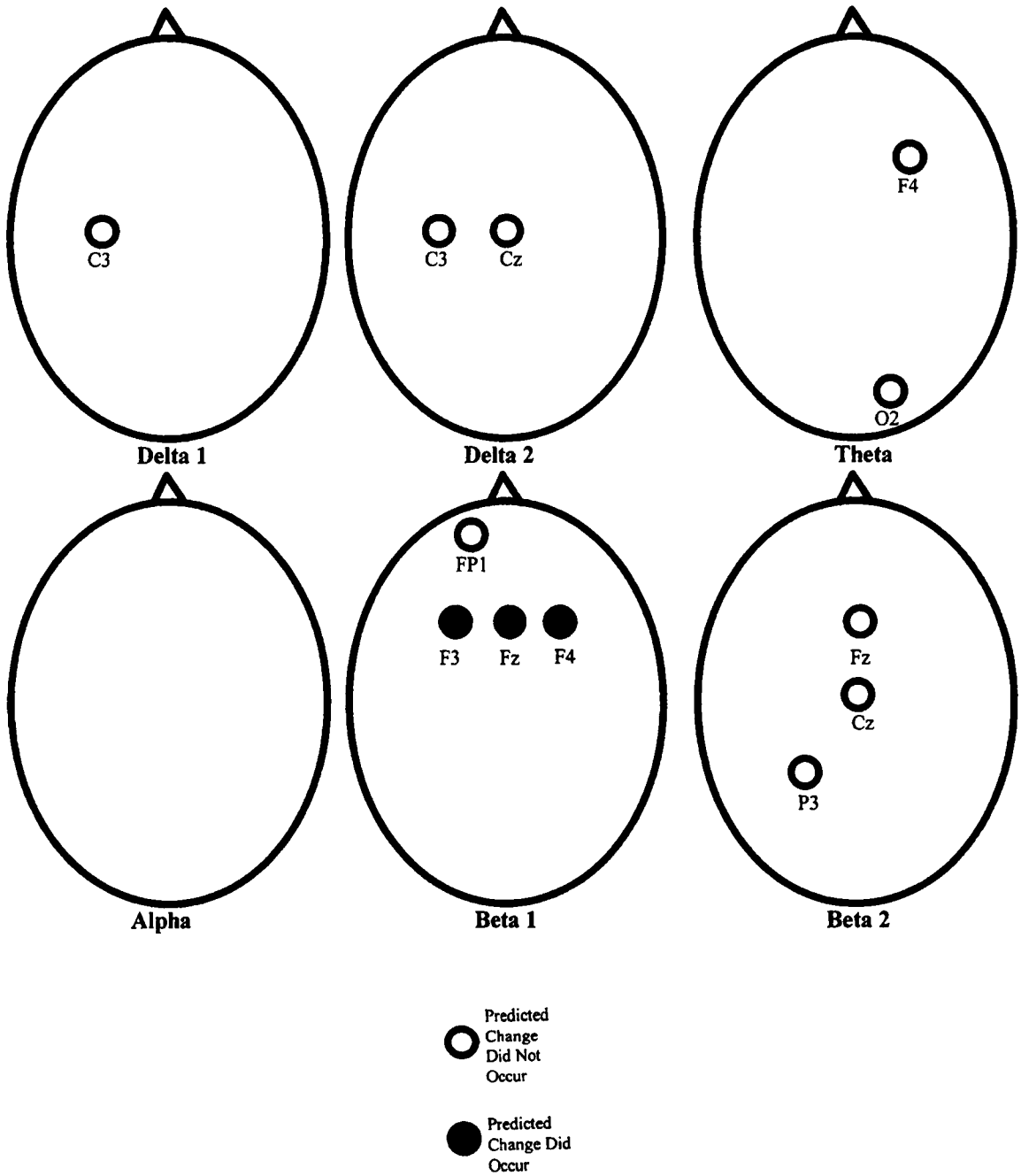
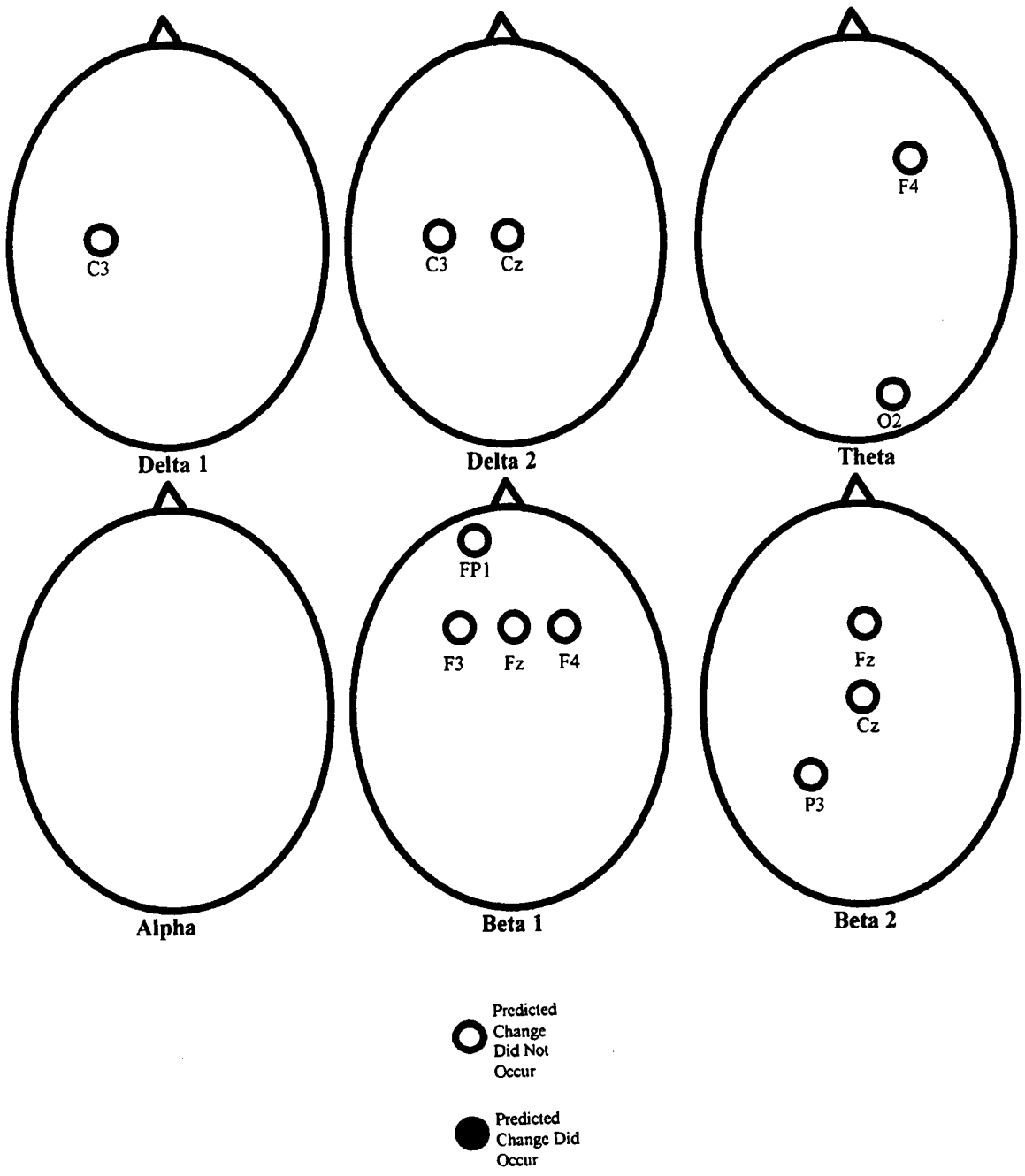


Figure 8. Significant Changes from Baseline for Locations Predicted by the Alpha AVS Pilot Study. This Figure Represents the Alpha Group During the Last Five Minutes of the Tenth AVS Session.



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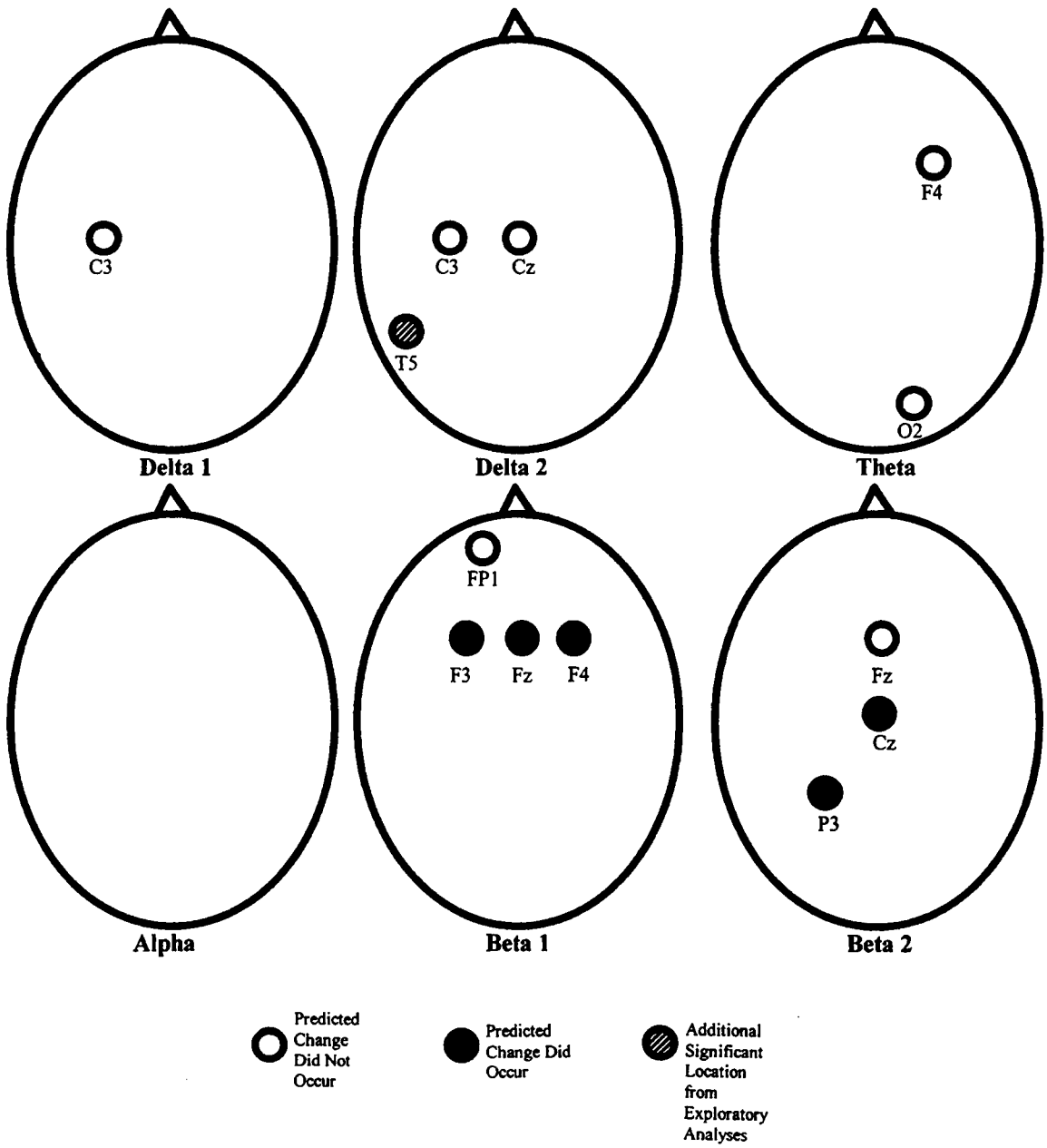


Figure 10. Significant Changes from Baseline for Locations Predicted by the Alpha AVS Pilot Study. This Figure Represents the Alpha Group During the Last Five Minutes of the Fifteenth AVS Session.

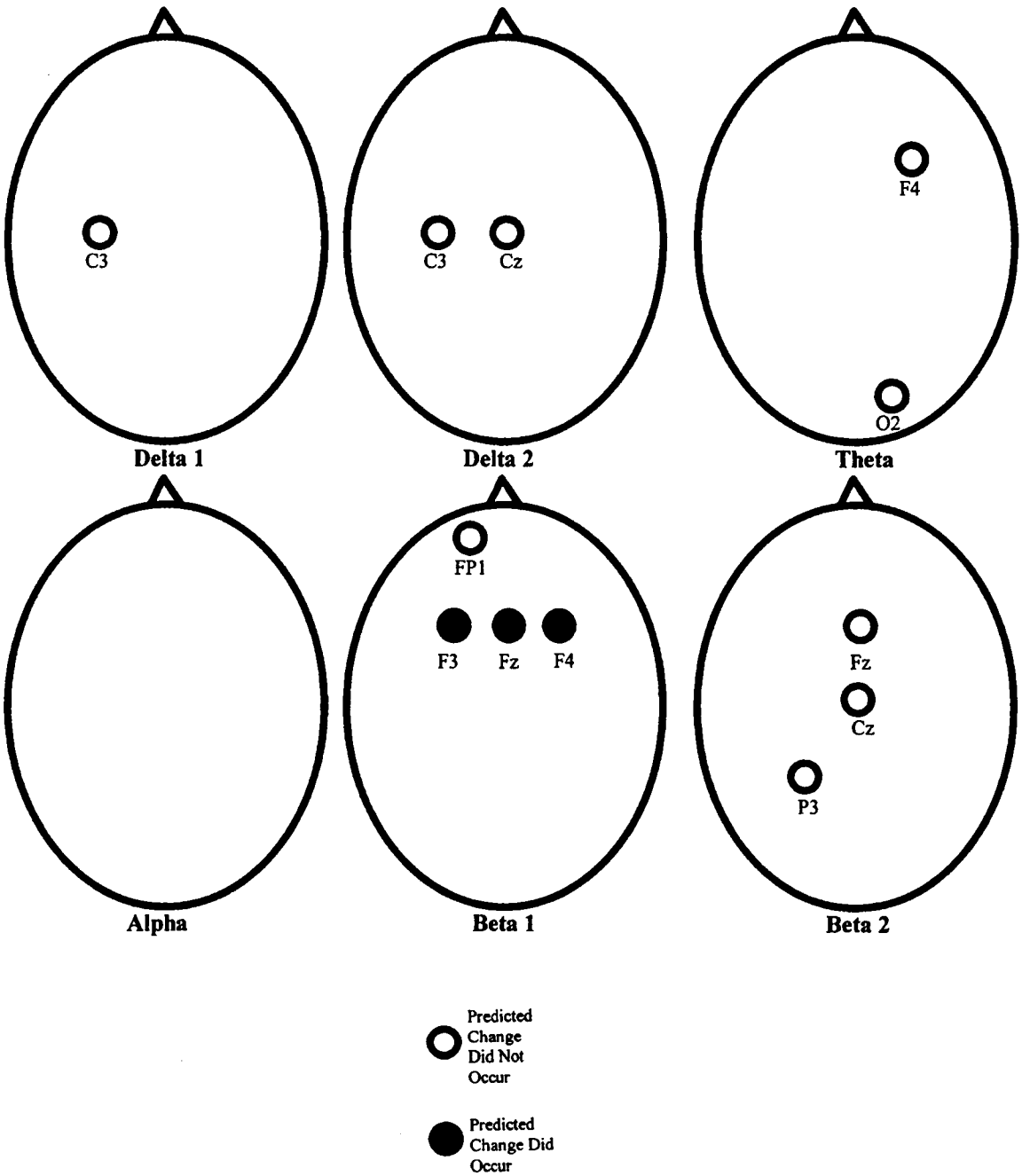


Figure 11. Significant Changes from Baseline for Locations Predicted by the Alpha AVS Pilot Study. This Figure Represents the Control Group During the Last Five Minutes of the Fifteenth AVS Session.

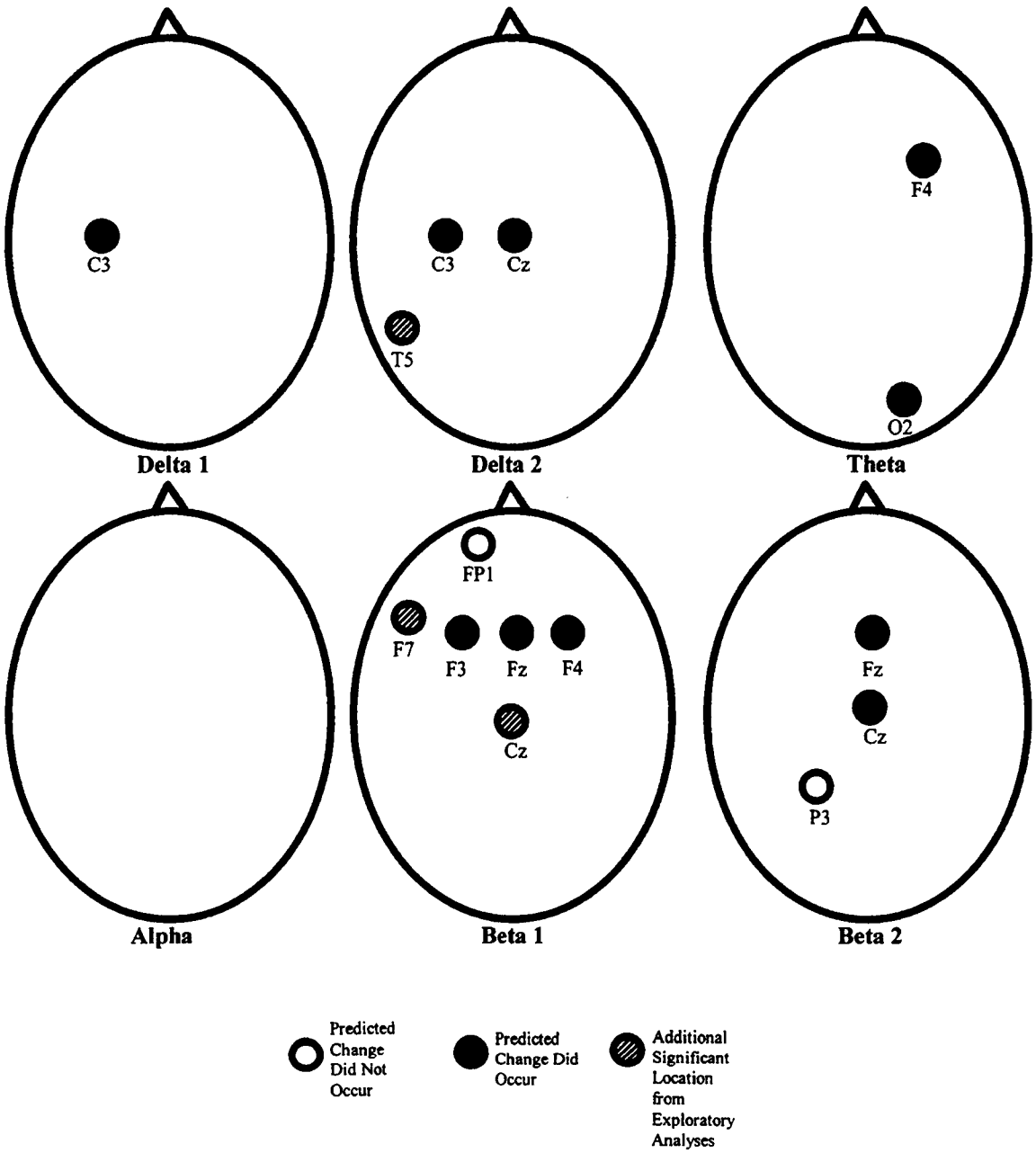


Figure 12. Significant Changes from Baseline for Locations Predicted by the Alpha AVS Pilot Study. This Figure Represents the Alpha Group During the Last Five Minutes of the Twentieth AVS Session.

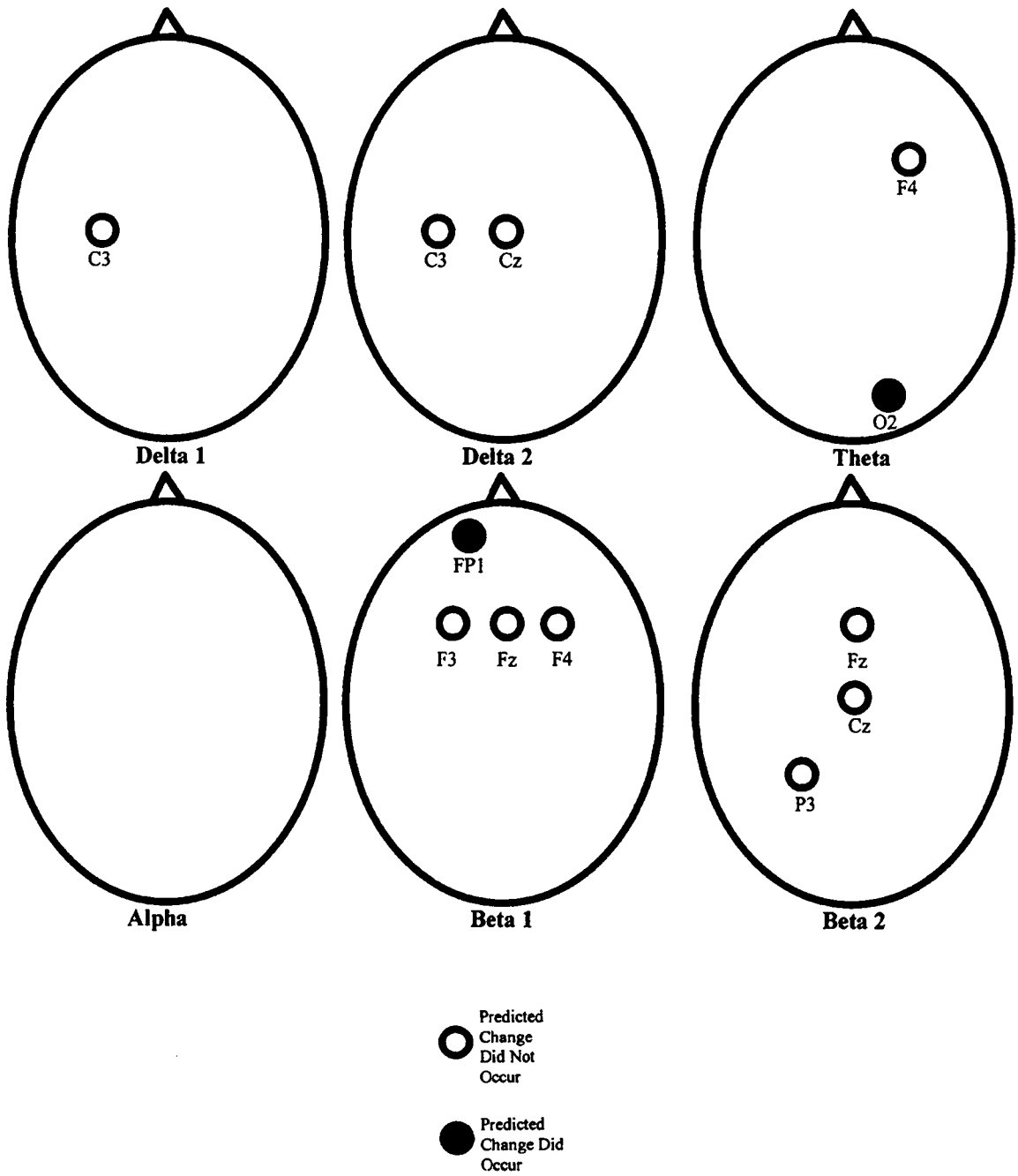


Figure 13. Significant Changes from Baseline for Locations Predicted by the Alpha AVS Pilot Study. This Figure Represents the Control Group During the Last Five Minutes of the Twentieth AVS Session.

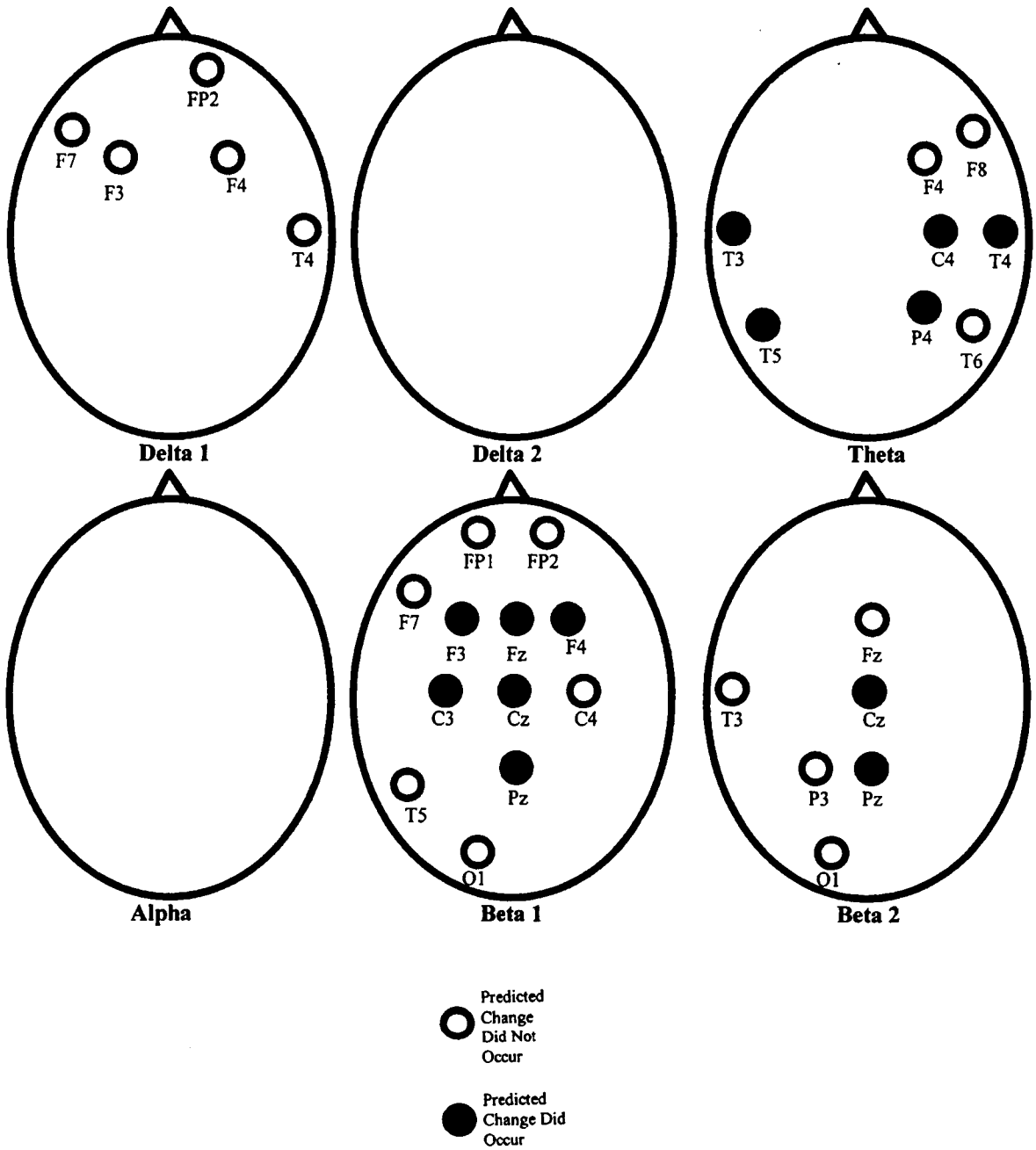
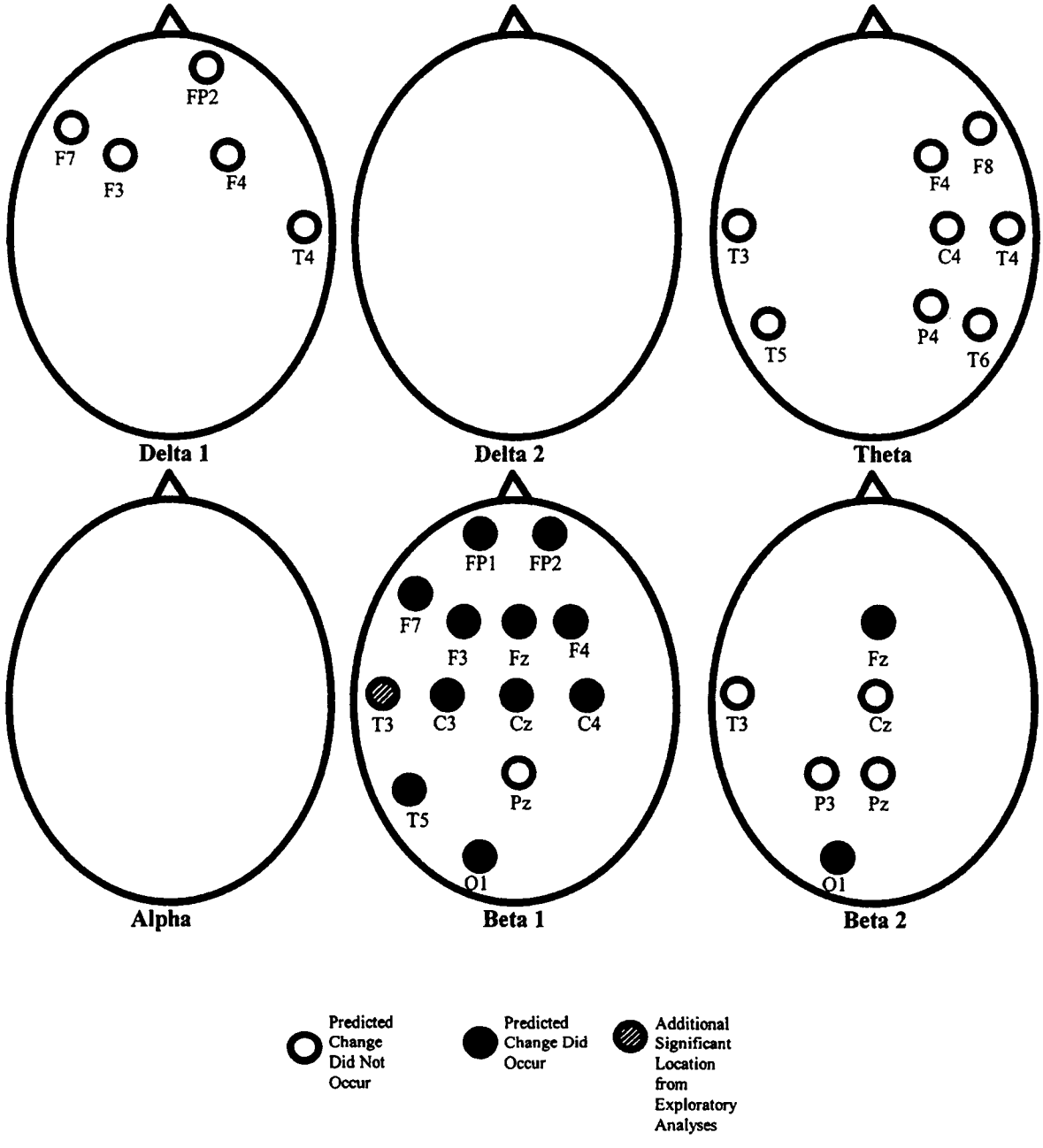


Figure 14. Significant Changes from Baseline for Locations Predicted by the Beta AVS Pilot Study. This Figure Represents the Beta Group During the Last Five Minutes of the Fifth AVS Session.



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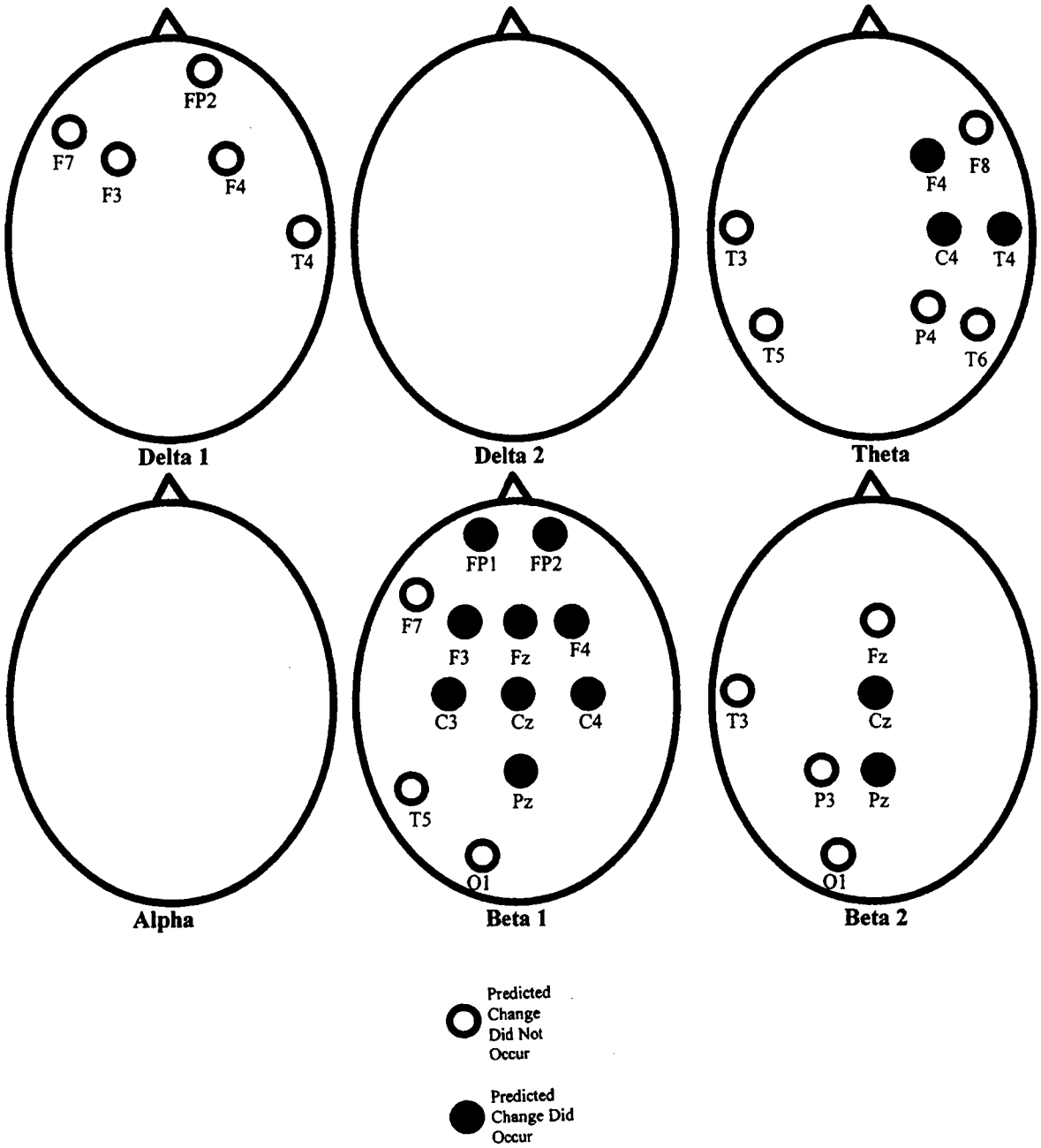

Figure 16. Significant Changes from Baseline for Locations Predicted by the Beta AVS Pilot Study. This Figure Represents the Beta Group During the Last Five Minutes of the Tenth AVS Session.

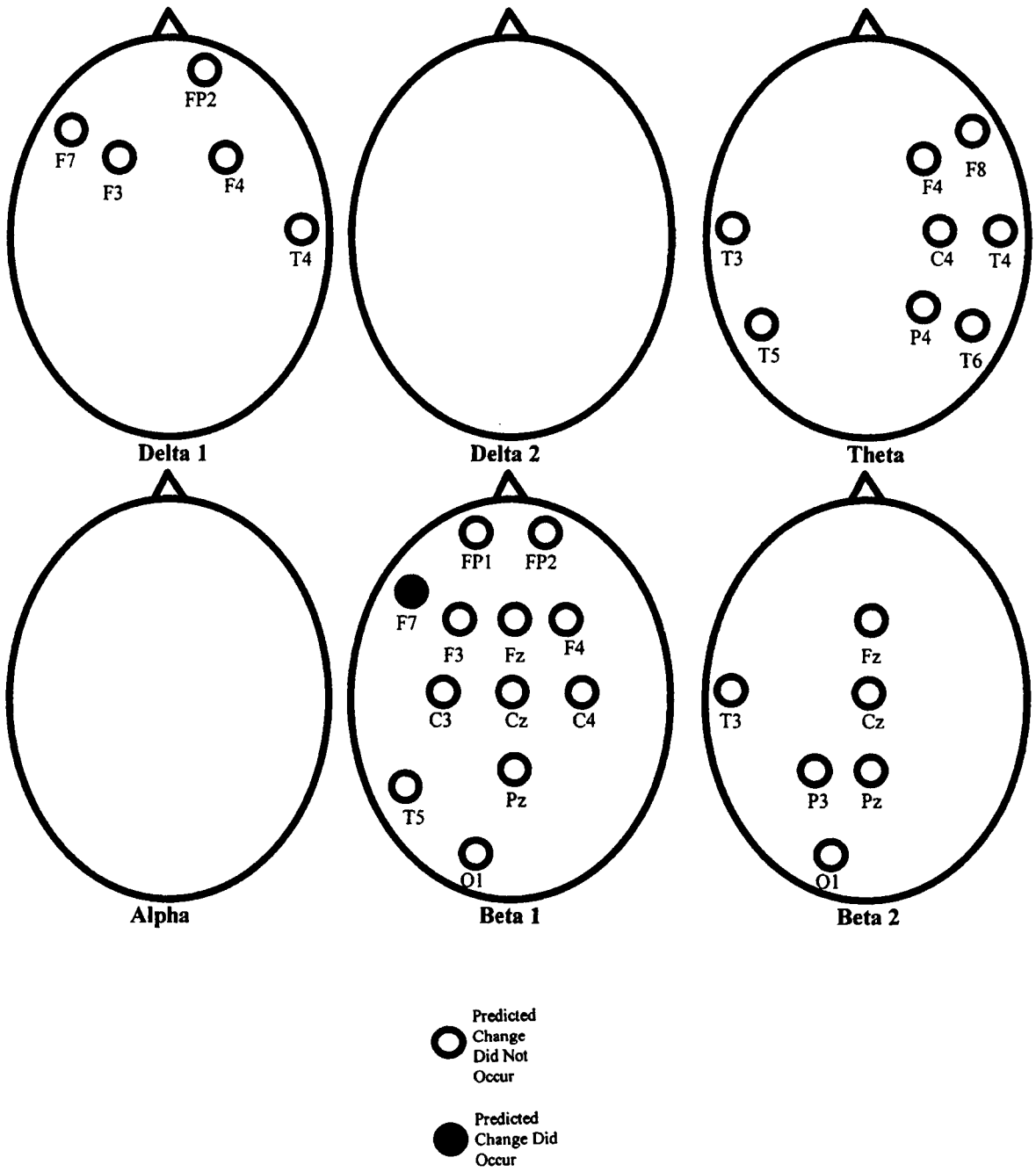

Figure 17. Significant Changes from Baseline for Locations Predicted by the Beta AVS Pilot Study. This Figure Represents the Control Group During the Last Five Minutes of the Tenth AVS Session.

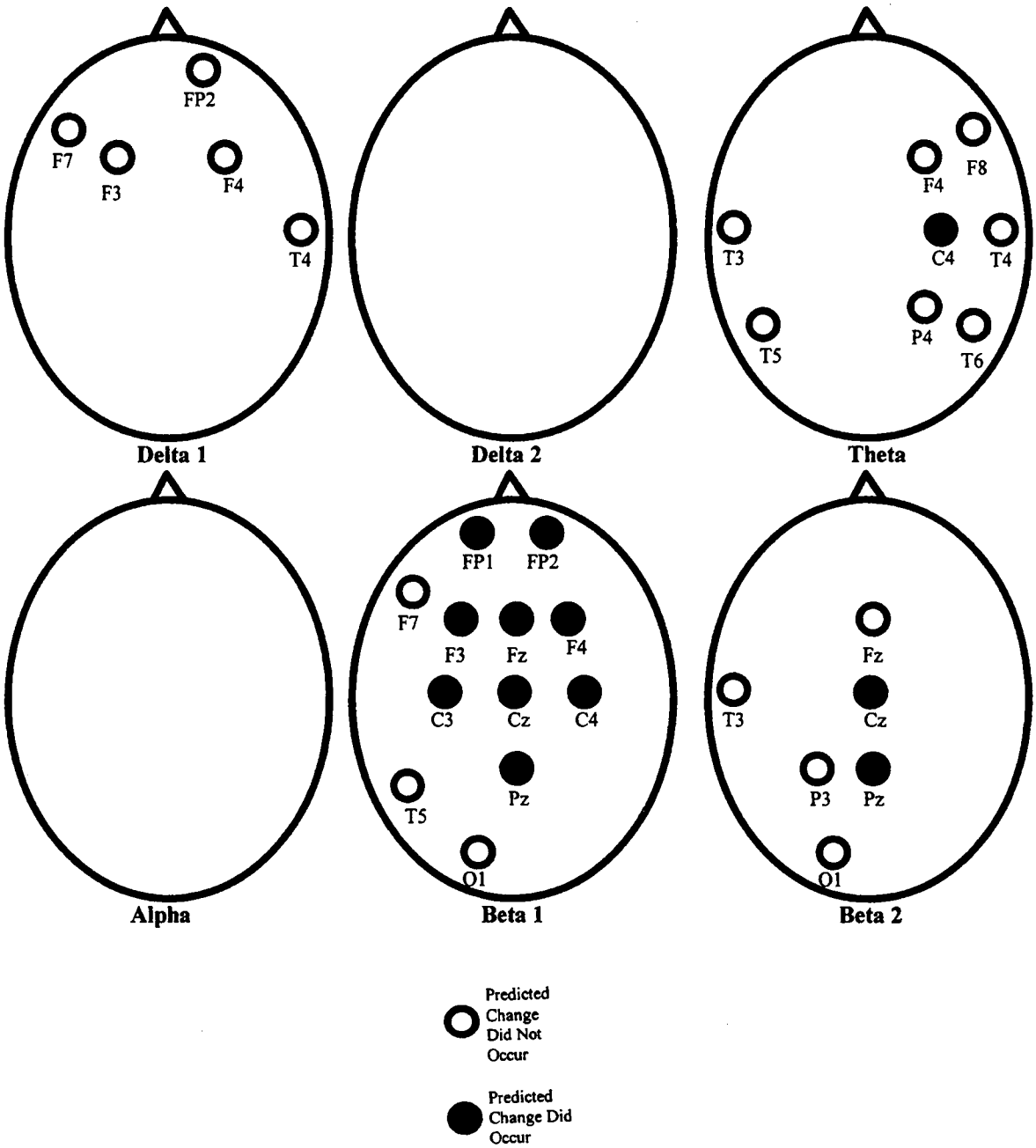

Figure 18. Significant Changes from Baseline for Locations Predicted by the Beta AVS Pilot Study. This Figure Represents the Beta Group During the Last Five Minutes of the Fifteenth AVS Session.

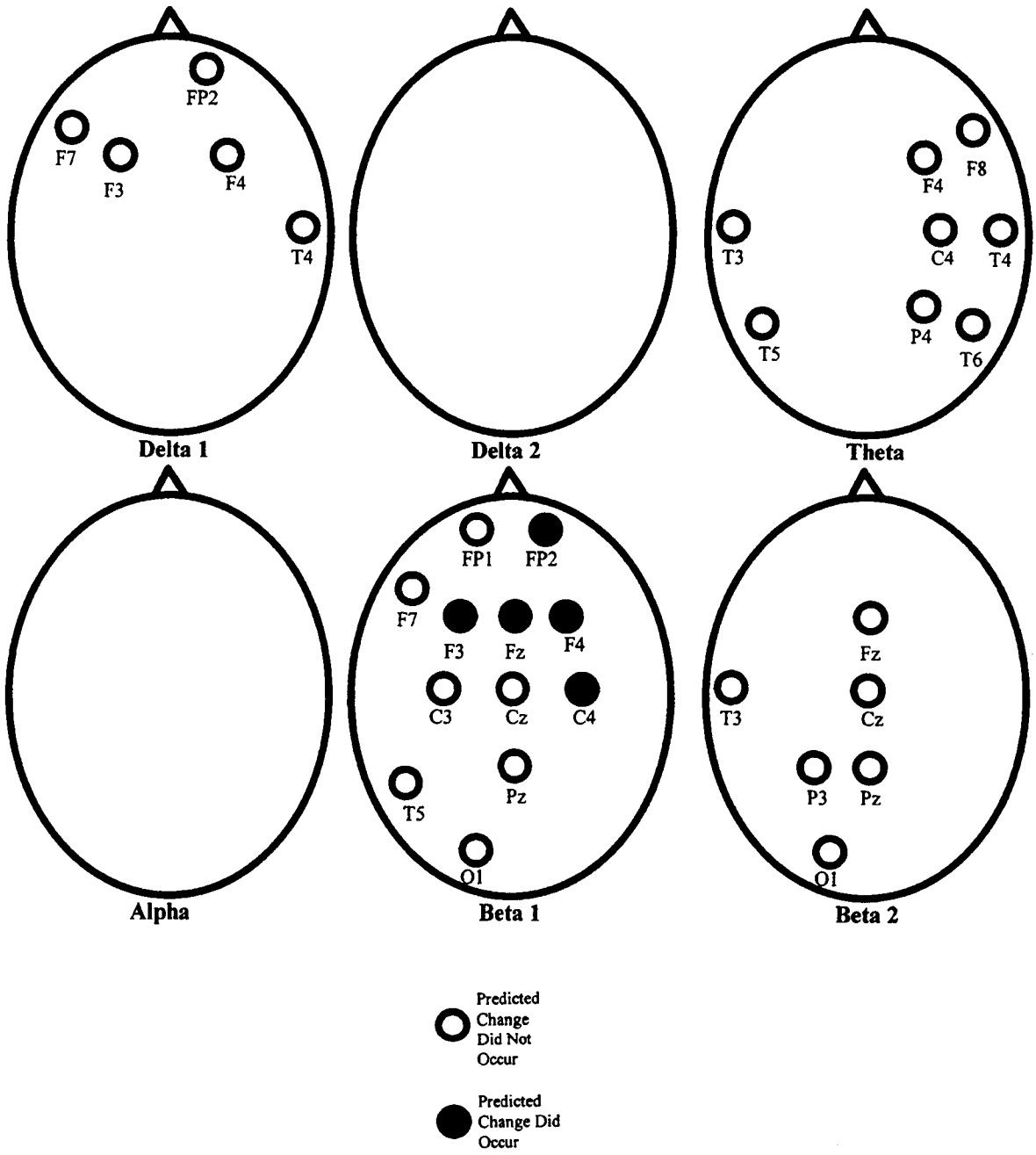

Figure 19. Significant Changes from Baseline for Locations Predicted by the Beta AVS Pilot Study. This Figure Represents the Control Group During the Last Five Minutes of the Fifteenth AVS Session.

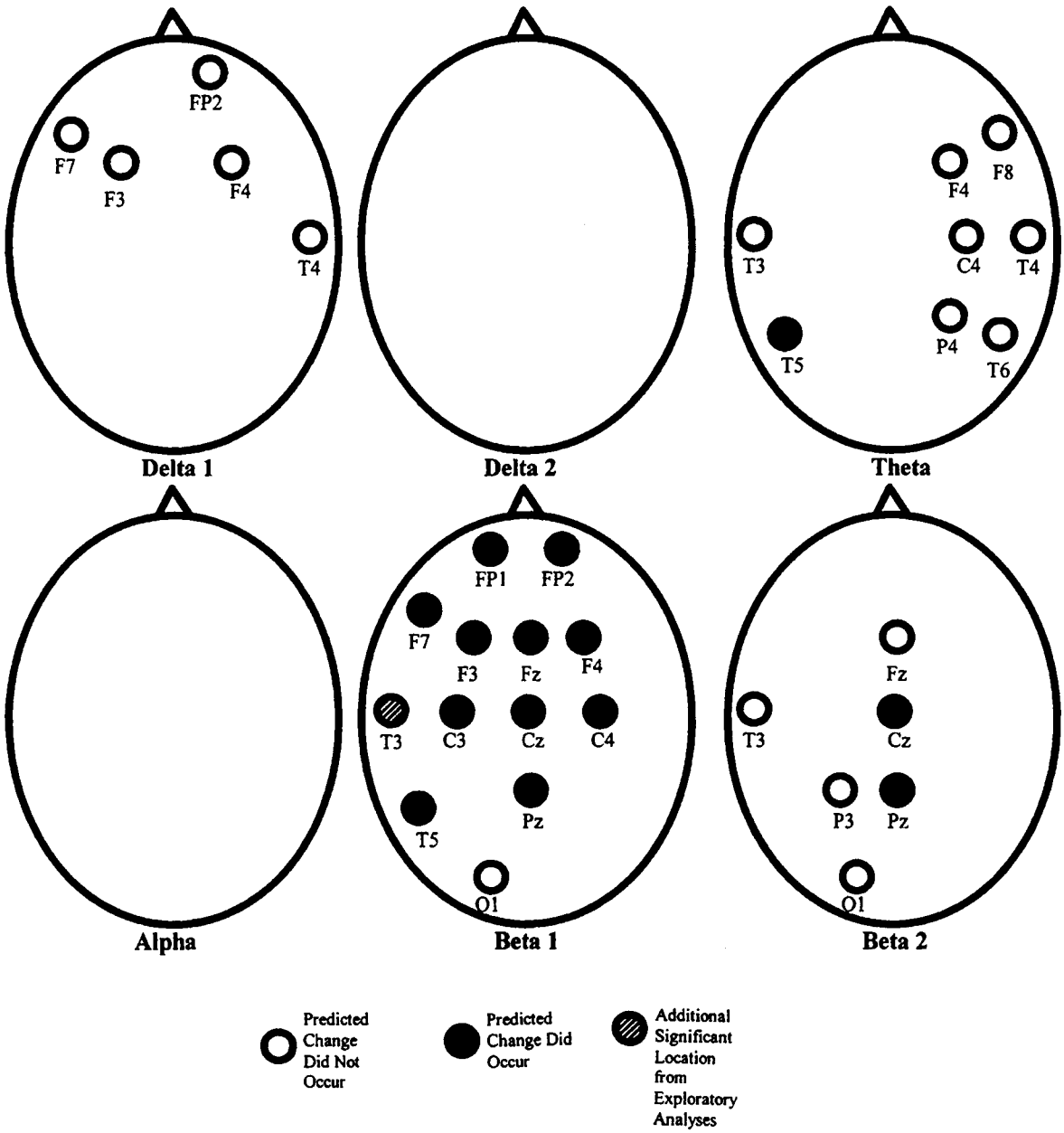

Figure 20. Significant Changes from Baseline for Locations Predicted by the Beta AVS Pilot Study. This Figure Represents the Beta Group During the Last Five Minutes of the Twentieth AVS Session.

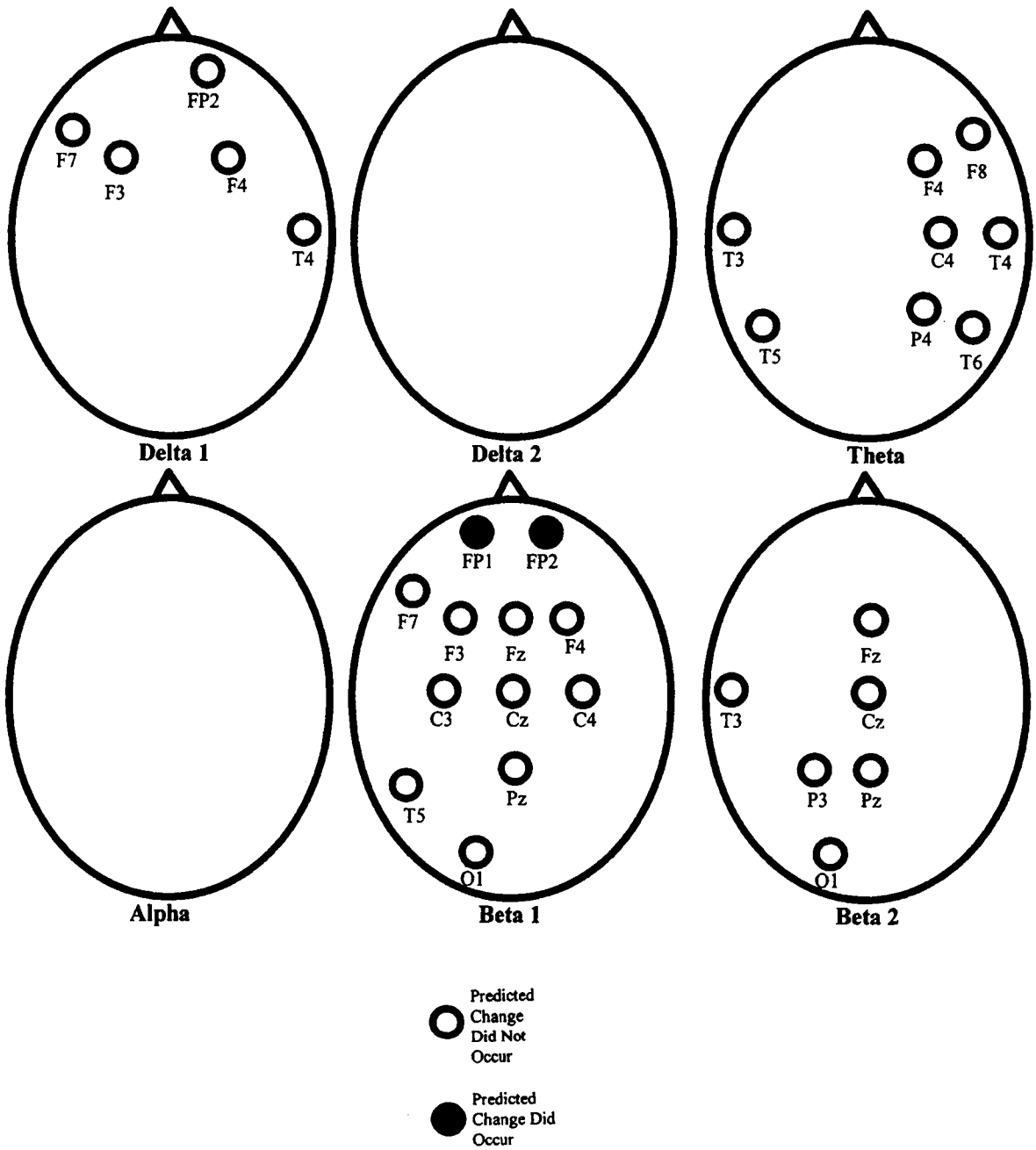

Figure 21. Significant Changes from Baseline for Locations Predicted by the Beta AVS Pilot Study. This Figure Represents the Control Group During the Last Five Minutes of the Twentieth AVS Session.

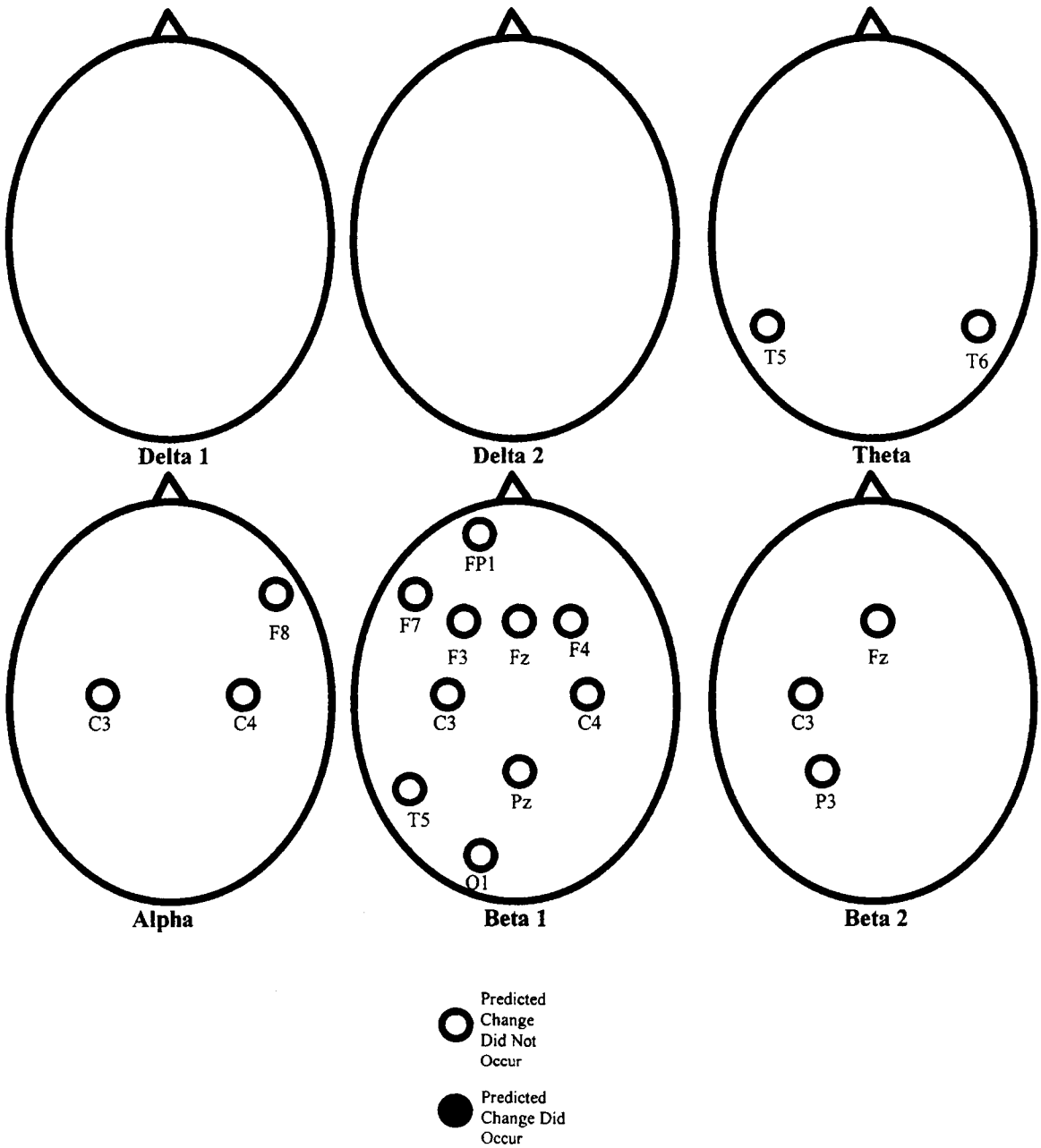

Figure 22. Predicted Significant Changes from Baseline to the 20th Session Baseline at Locations Showing Lasting Changes in Power for the Beta AVS Group as Indicated by the Pilot Study.

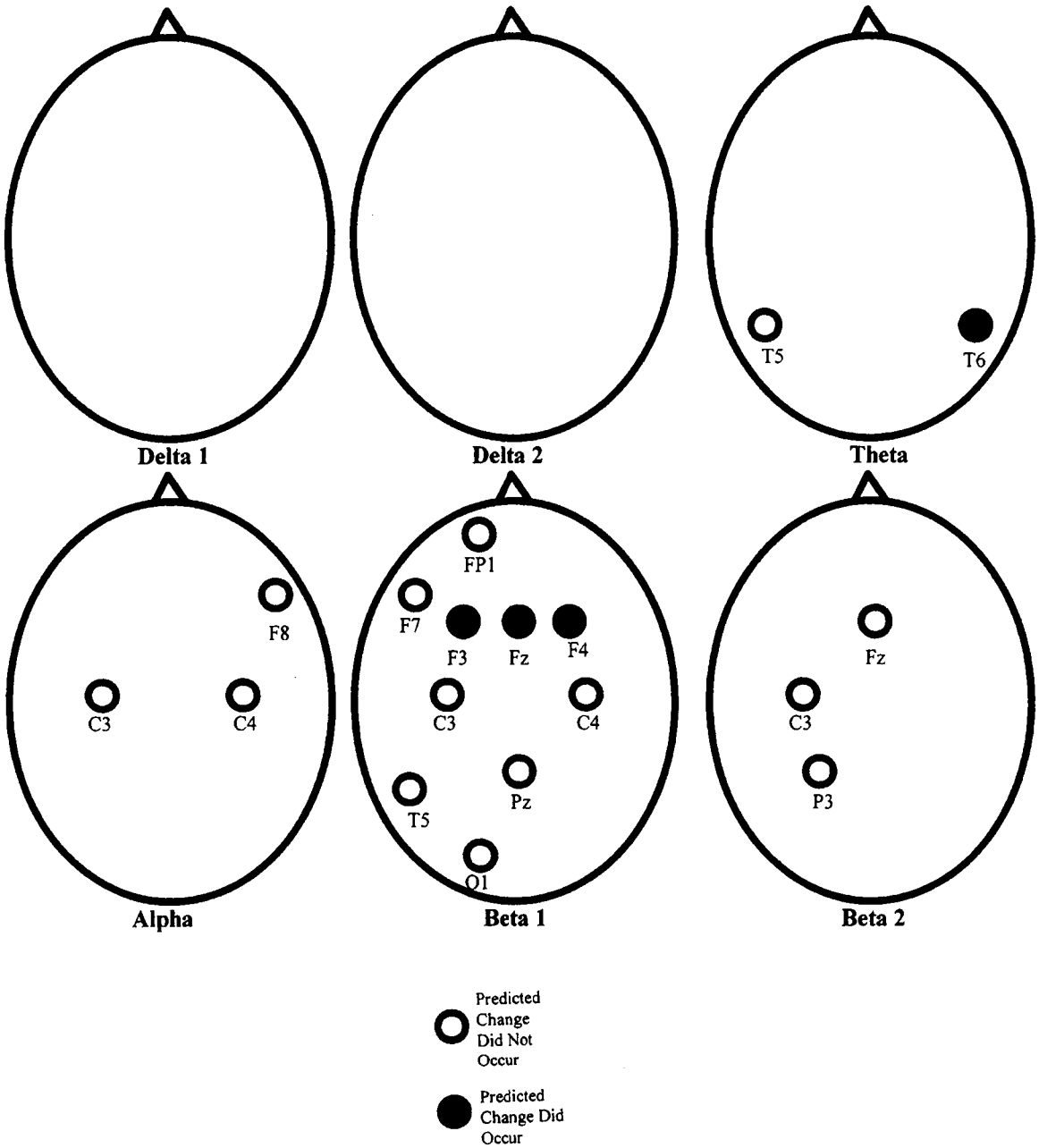

Figure 23. Predicted Significant Changes from Baseline to the Post Measure at Locations Showing Lasting Changes in Power for the Beta AVS Group as Indicated by the Pilot Study.

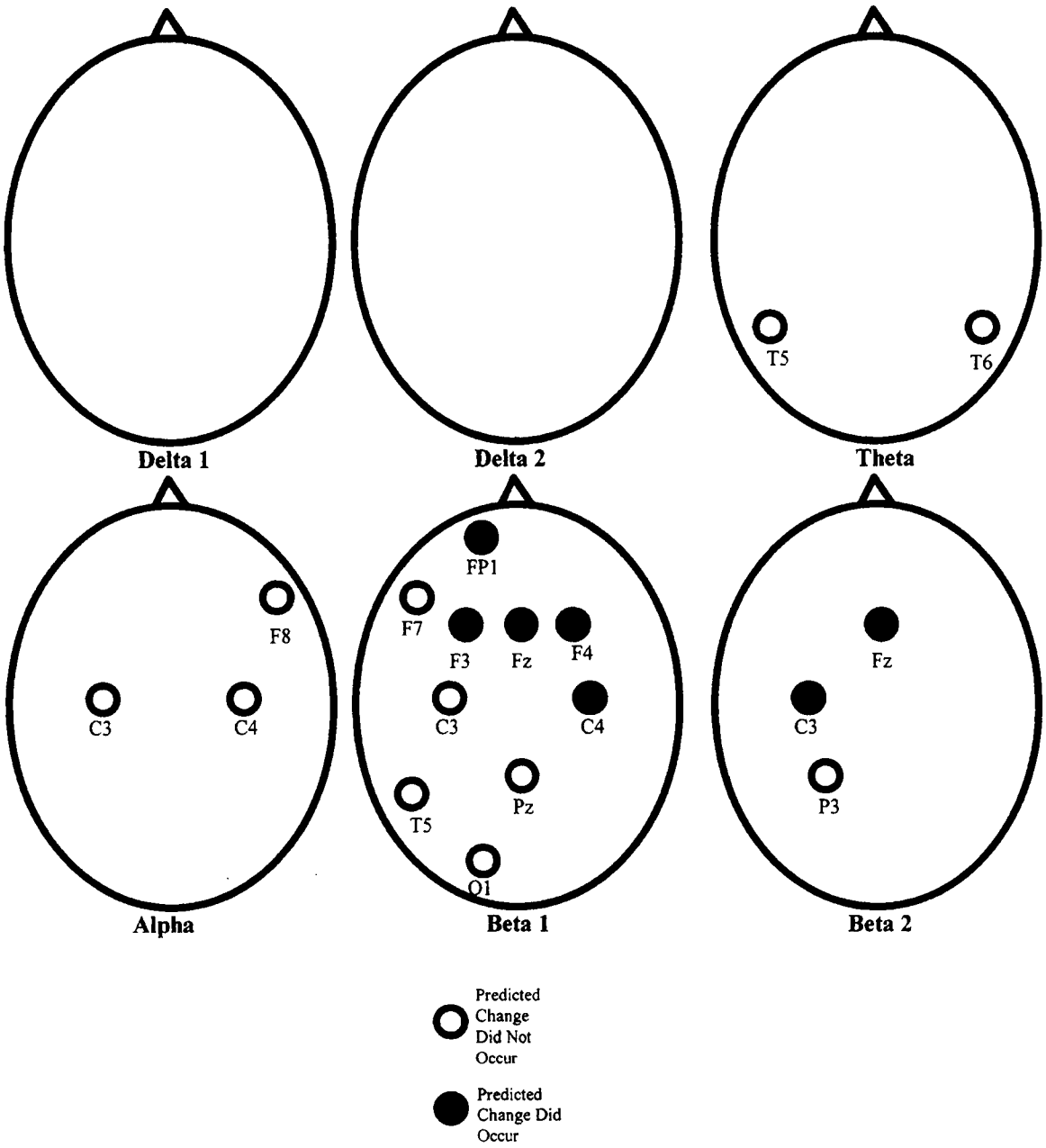

Figure 24. Predicted Significant Changes from the 20th Session Baseline to the Post Measure at Locations Showing Lasting Changes in Power for the Beta AVS Group as Indicated by the Pilot Study.

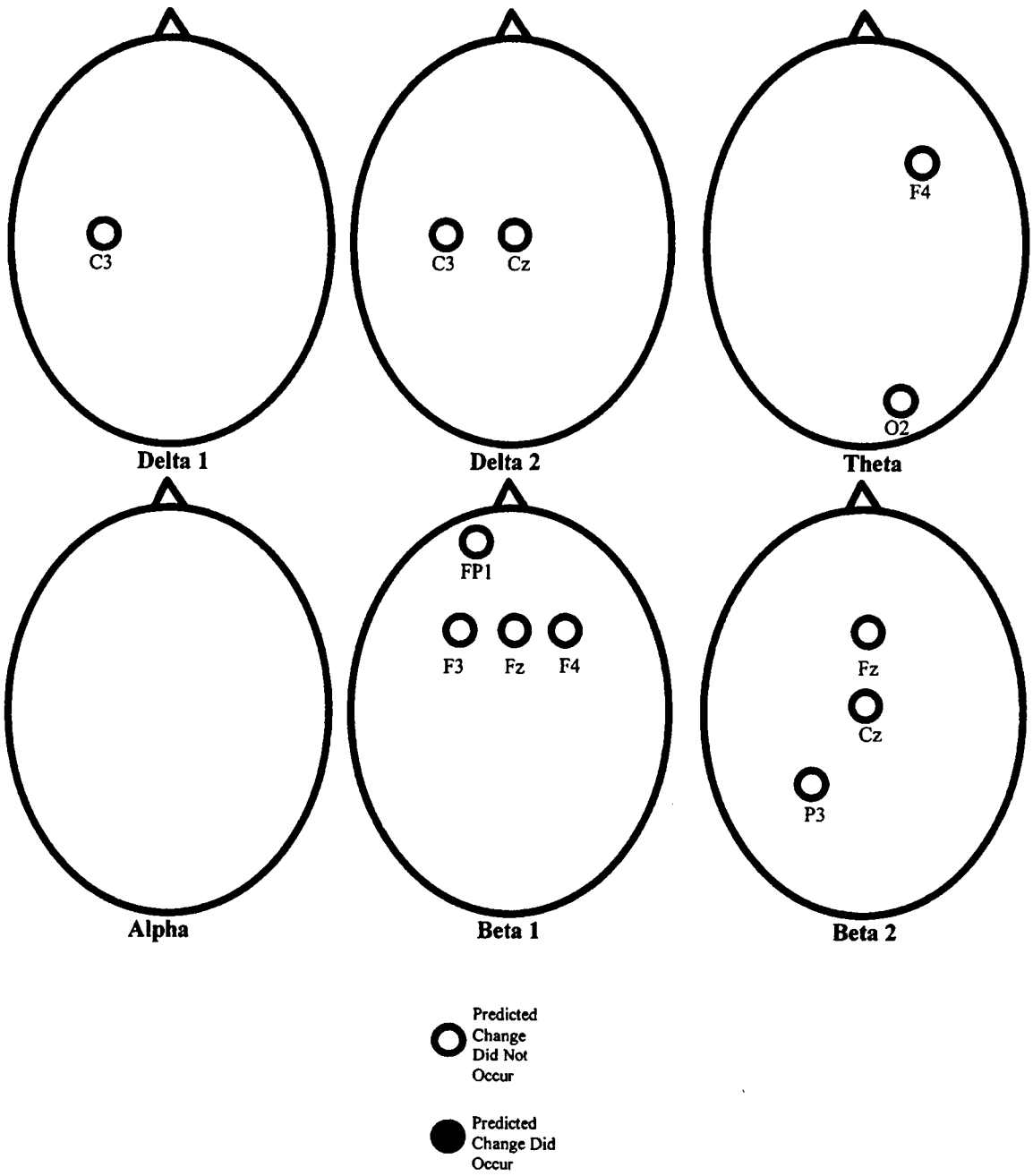

Figure 25. Predicted Significant Changes from Baseline to the 20th Session Baseline for the Alpha AVS Group at Locations Predicted by the Pilot Study as Showing Within Session Changes in Power.

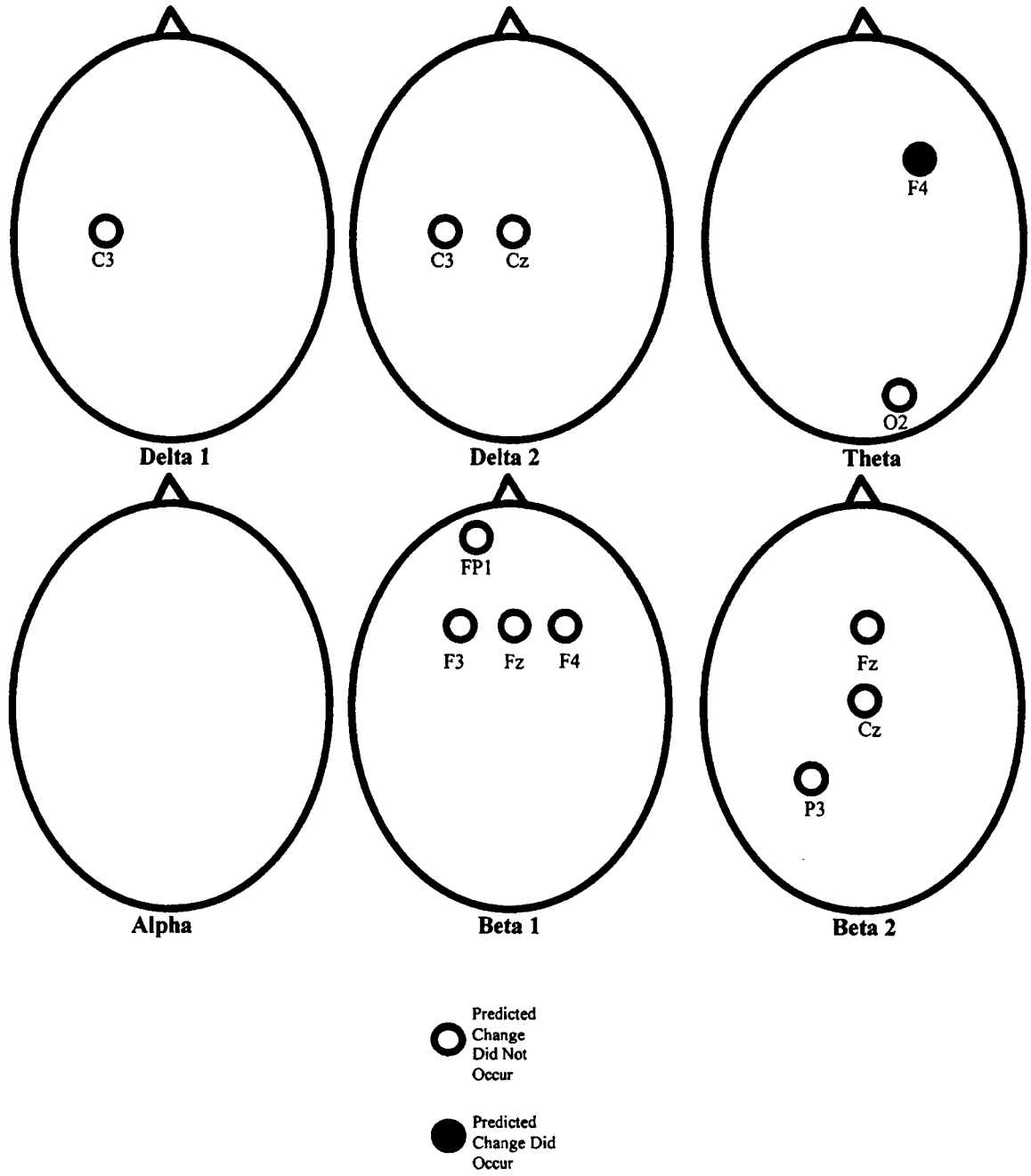

Figure 26. Predicted Significant Changes from Baseline to the Post Measure for the Alpha AVS Group at Locations Predicted by the Pilot Study as Showing Within Session Changes in Power.

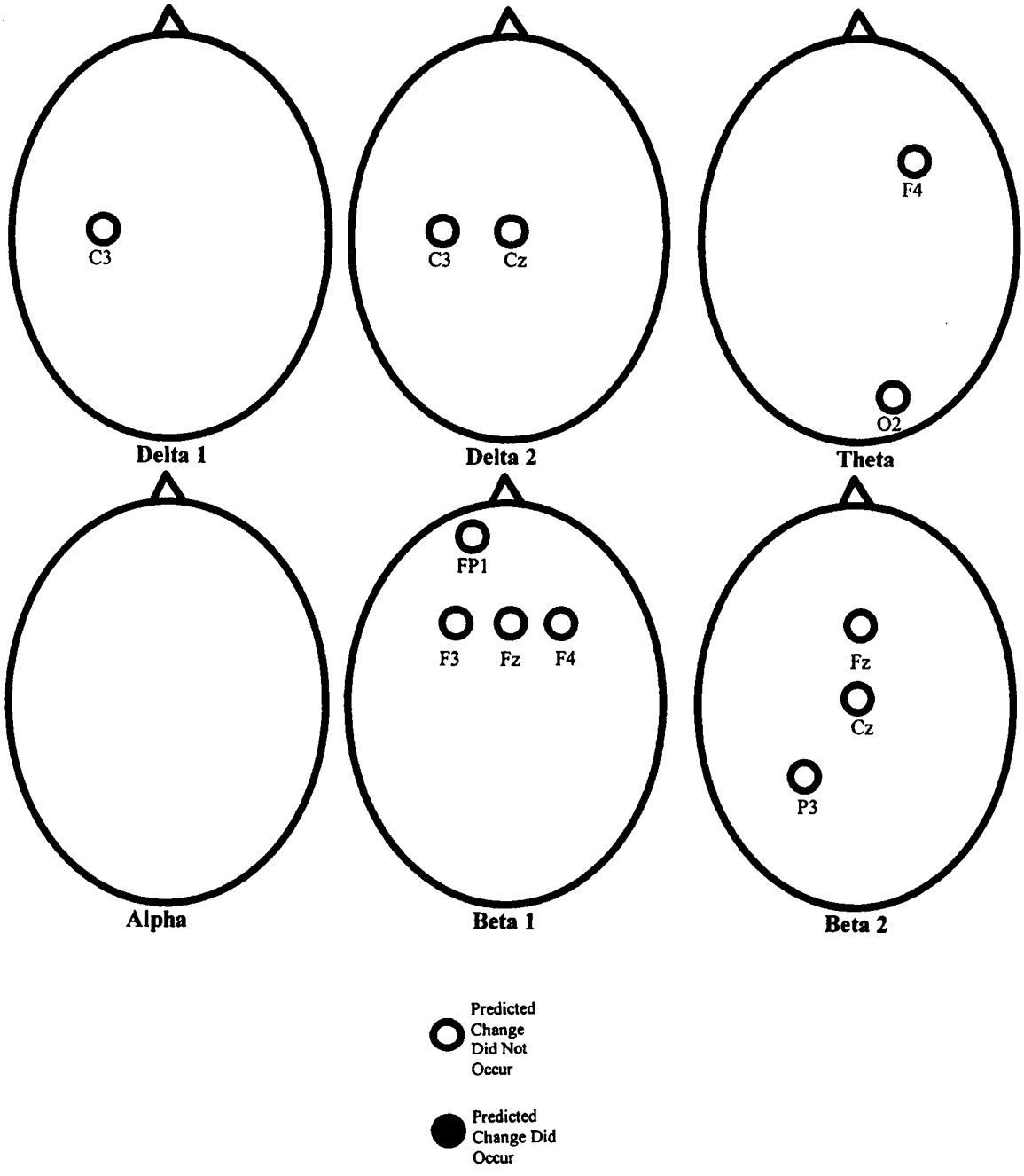

Figure 27. Predicted Significant Changes from 20th Session Baseline to the Post Measure for the Alpha AVS Group at Locations Predicted by the Pilot Study as Showing Within Session Changes in Power.

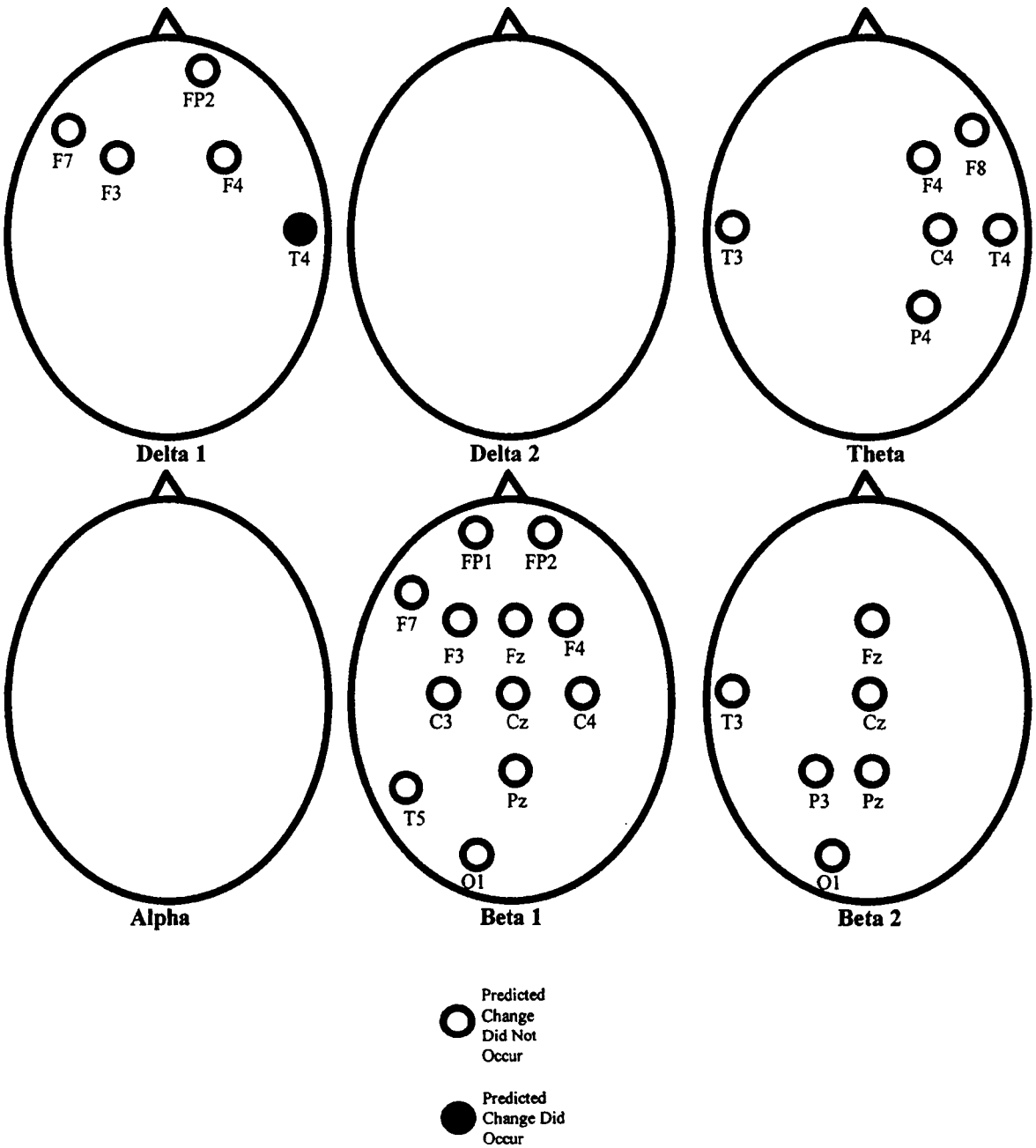

Figure 28. Predicted Significant Changes from Baseline to the 20th Session Baseline for the Beta AVS Group at Locations Predicted by the Pilot Study as Showing Within Session Changes in Power.

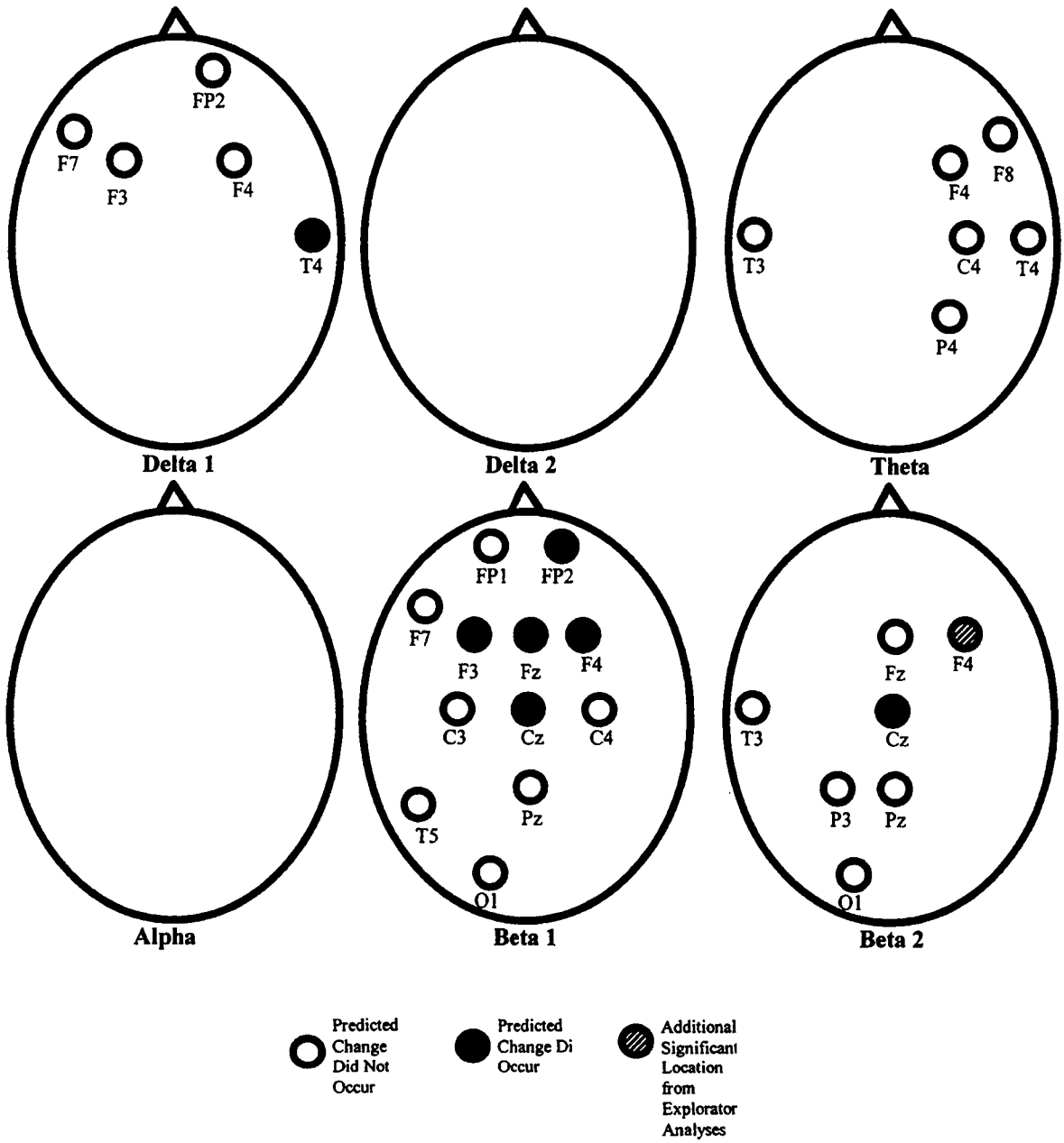

Figure 29. Predicted Significant Changes from Baseline to the Post Measure for the Beta AVS Group at Locations Predicted by the Pilot Study as Showing Within Session Changes in Power.

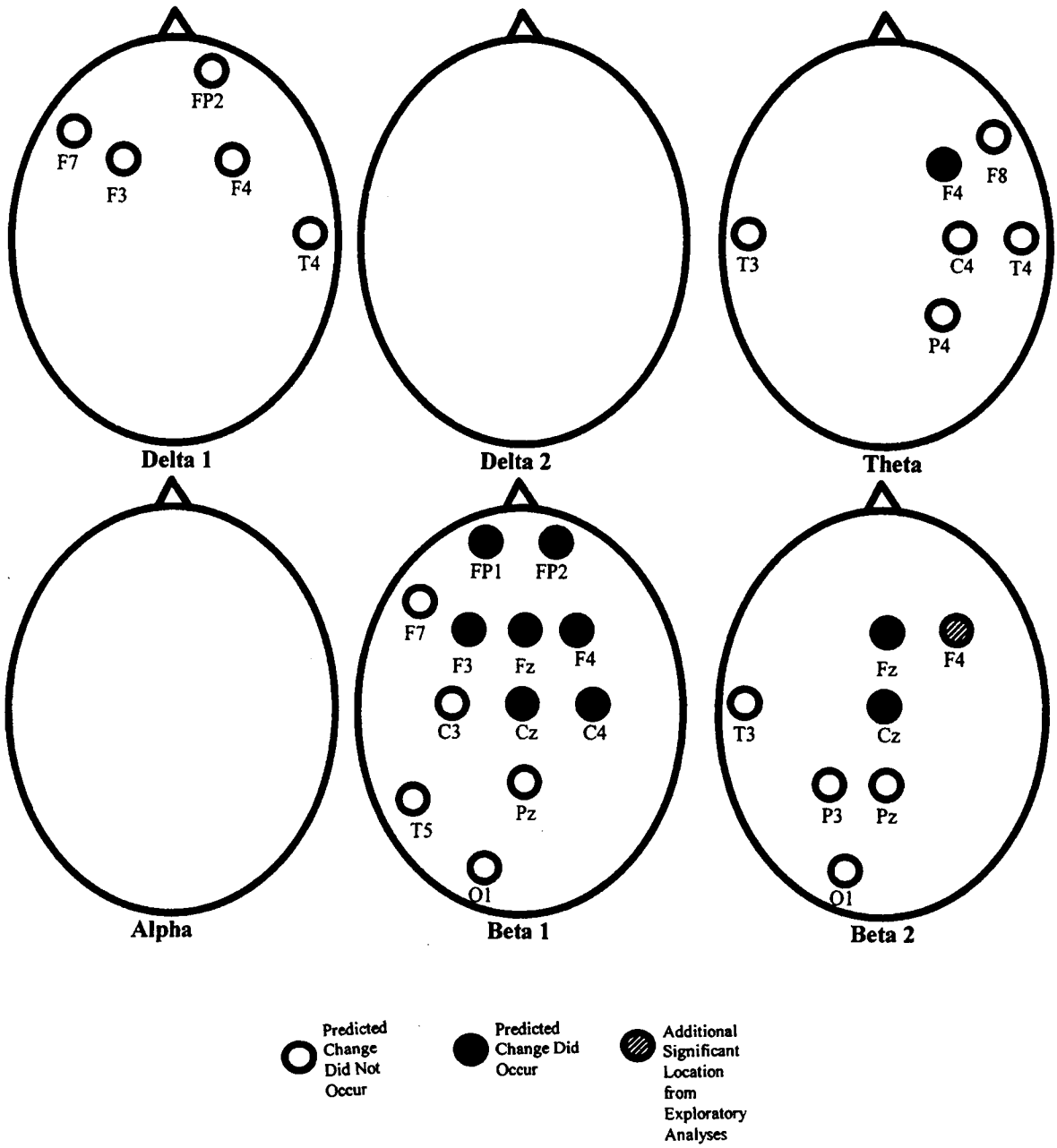

Figure 30. Predicted Significant Changes from 20th Session Baseline to the Post Measure for the Beta AVS Group at Locations Predicted by the Pilot Study as Showing Within Session Changes in Power.

APPENDIX B

Table 1.
Significant One-Way Repeated Measures ANOVAs for Alpha AVS Pilot Study.

Bandpass	Location	Univariate	Multivariate
Delta 1	T3	F(5,60) = 2.616, p<0.033	
	C3	F(5,60) = 4.130, p<0.017	
	Cz	F(5,60) = 4.114, p<0.033	
	C4	F(5,60) = 3.409, p<0.043	
Delta 2	F3	F(5,60) = 2.428, p<0.045	
	C3	F(5,60) = 3.917, p<0.035	
	Fz	F(5,60) = 3.648, p<0.039	
	Cz	F(5,60) = 4.422, p<0.027	
Theta	F4		F(5,8) = 5.012, p<0.022
	O2		F(5,8) = 8.808, p<0.004
	T6		F(5,8) = 3.688, p<0.050
Alpha	No Significant ANOVA Results.		
Beta 1	F7	F(5,60) = 2.853, p<0.022	
	Fp1	F(5,60) = 5.636, p<0.003	
	F3	F(5,60) = 7.649, p<0.0005	
	O1		F(5,8) = 3.956, p<0.042
	Fz	F(5,60) = 6.561, p<0.002	
	F4	F(5,60) = 4.577, p<0.001	
	F8	F(5,60) = 3.059, p<0.016	
Beta 2	T5		F(5,8) = 4.732, p<0.026
	F3	F(5,60) = 3.207, p<0.044	
	P3		F(5,8) = 6.043, p<0.013
	Fz	F(5,60) = 4.010, p<0.019	
	Cz	F(5,60) = 5.997, p<0.0005	

Table 2.

Means and Standard Errors of Significantly Different Natural Log-transformed Baseline, AVS, and Post Power Measures by Location and Frequency for Alpha AVS Pilot Study.

Bandpass	Location	Baseline	5 min AVS	10 min AVS	15 min AVS	20 min AVS	1/2 Hour Post AVS
		Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)
Delta 1	C3	4.120 (0.042)	4.142 (0.046)	4.164 (0.041)	**4.210 (0.043)***	4.223 (0.053)	4.148 (0.044)
Delta 2	C3	4.534 (0.044)	4.568 (0.048)	**4.618 (0.046)***	**4.626 (0.051)***	4.624 (0.065)	4.552 (0.051)
	Cz	4.648 (0.046)	4.690 (0.054)	**4.749 (0.049)***	**4.768 (0.053)***	4.756 (0.070)	4.659 (0.054)
Theta	F4	5.108 (0.066)	**5.156 (0.067)***	5.166 (0.068)	5.158 (0.068)	**5.174 (0.073)***	5.148 (0.068)
	O2	4.978 (0.095)	4.989 (0.088)	5.040 (0.089)	5.049 (0.089)	**5.081 (0.094)***	5.008 (0.101)
Alpha	No Significant Differences between Baseline and AVS or Post Measures						
Beta 1	FP1	4.551 (0.050)	4.599 (0.051)	4.584 (0.055)	4.624 (0.059)	**4.679 (0.063)***	**4.620 (0.048)***
	F3	4.778 (0.047)	4.832 (0.049)	4.839 (0.050)	**4.870 (0.048)***	**4.935 (0.056)***	**4.836 (0.049)***
	Fz	4.762 (0.047)	4.826 (0.046)	4.825 (0.047)	4.855 (0.044)	**4.922 (0.052)***	**4.826 (0.049)***
	F4	4.654 (0.040)	4.694 (0.040)	4.698 (0.039)	4.720 (0.040)	**4.782 (0.047)***	4.693 (0.048)
Beta 2	P3	4.309 (0.046)	**4.415 (0.046)***	4.356 (0.056)	4.333 (0.061)	4.371 (0.071)	4.319 (0.048)
	Fz	4.152 (0.035)	4.220 (0.039)	**4.218 (0.037)***	**4.227 (0.042)***	4.256 (0.053)	4.169 (0.046)
	Cz	4.313 (0.038)	**4.413 (0.046)***	**4.399 (0.047)***	4.393 (0.047)	4.420 (0.059)	4.325 (0.052)

*. Mean is significantly different from baseline mean at $p < .05$ (correction for multiple comparisons: Bonferroni)

Table 3.
Significant One-Way Repeated Measures ANOVAs for Beta AVS Pilot Study.

Bandpass	Location	Univariate	Multivariate
Delta 1	F7	F(5,60) = 2.395, p<0.048	
	F3	F(5,60) = 3.765, p<0.005	
	Fp2	F(5,60) = 2.362, p<0.050	
	F4	F(5,60) = 3.708, p<0.005	
	T4	F(5,60) = 3.108, p<0.015	
Delta 2	No Significant ANOVA Results.		
Theta	T3		F(5,8) = 3.953, p<0.042
	T5		F(5,8) = 3.898, p<0.044
	Fp1		F(5,8) = 5.611, p<0.016
	F4	F(5,60) = 3.107, p<0.015	
	C4		F(5,8) = 4.521, p<0.030
	P4		F(5,8) = 4.118, p<0.038
	F8	F(5,60) = 3.202, p<0.013	
	T4	F(5,60) = 2.974, p<0.018	
	T6		F(5,8) = 5.231, p<0.020
Alpha	C3		F(5,8) = 9.093, p<0.004
	C4		F(5,8) = 6.631, p<0.010
	F8		F(5,8) = 3.619, p<0.052
Beta 1	F7		F(5,8) = 8.832, p<0.004
	T5	F(5,60) = 2.358, p<0.051	
	Fp1		F(5,8) = 5.614, p<0.016
	F3	F(5,60) = 5.000, p<0.017	
	C3		F(5,8) = 7.487, p<0.007
	O1	F(5,60) = 3.659, p<0.006	
	Fz	F(5,60) = 4.765, p<0.019	
	Cz		F(5,8) = 4.801, p<0.025
	Pz		F(5,8) = 4.355, p<0.033
	Fp2		F(5,8) = 6.592, p<0.010
	F4	F(5,60) = 3.936, p<0.028	
	C4		F(5,8) = 4.241, p<0.035
Beta 2	T3	F(5,60) = 4.821, p<0.015	
	C3		F(5,8) = 4.638, p<0.028
	P3	F(5,60) = 2.384, p<0.049	
	O1	F(5,60) = 3.445, p<0.008	
	Fz		F(5,8) = 7.582, p<0.007
	Cz		F(5,8) = 8.067, p<0.005
	Pz		F(5,8) = 4.393, p<0.032

Table 4.
Means and Standard Errors of Significantly Different Natural Log-transformed Baseline, AVS, and Post Power Measures by Location and Frequency for Beta AVS Pilot Study.

Bandpass	Location	Baseline	5 min AVS	10 min AVS	15 min AVS	20 min AVS	1/2 Hour Post AVS
		Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)	Mean (Std. Error)
Delta 1	F7	4.528 (0.047)	**4.413 (0.065)***	4.516 (0.023)	4.519 (0.044)	4.535 (0.042)	4.456 (0.053)
	F3	4.336 (0.026)	**4.230 (0.046)***	4.317 (0.032)	4.336 (0.045)	4.351 (0.034)	4.264 (0.038)
	FP2	4.618 (0.080)	**4.421 (0.073)***	4.557 (0.057)	4.475 (0.048)	4.514 (0.036)	4.530 (0.071)
	F4	4.477 (0.058)	**4.303 (0.051)***	4.474 (0.067)	4.446 (0.032)	4.446 (0.042)	4.359 (0.039)
	T4	4.524 (0.082)	**4.341 (0.74)***	4.526 (0.079)	4.511 (0.035)	4.511 (0.052)	4.400 (0.046)
Delta 2	No Significant Differences between Baseline and AVS or Post Measures						
Theta	T3	4.778 (0.102)	4.822 (0.094)	**4.850 (0.098)***	4.836 (0.093)	**4.853 (0.097)***	4.846 (0.103)
	T5	4.990 (0.098)	5.017 (0.095)	5.050 (0.096)	5.044 (0.086)	5.054 (0.095)	**5.073 (0.105)***
	F4	5.059 (0.078)	5.099 (0.074)	**5.158 (0.076)***	5.118 (0.061)	**5.155 (0.072)***	5.121(0.086)
	C4	5.090 (0.092	5.109 (0.091)	**5.179 (0.089)***	5.139 (0.070)	5.169 (0.083)	5.164 (0.107)
	P4	5.073 (0.099)	5.119 (0.099)	**5.183 (0.098)***	5.153 (0.080)	5.169 (0.086)	5.158 (0.112)
	F8	4.944 (0.080)	4.966 (0.076)	**5.013 (0.082)***	4.988 (0.068)	**5.010 (0.076)***	5.005 (0.082)
	T4	4.860 (0.104)	4.917 (0.088)	**4.937 (0.096)***	4.930 (0.086)	4.937 (0.089)	4.911 (0.099)
	T6	4.948 (0.114)	4.982 (0.114)	5.029 (0.111)	5.021 (0.101)	5.025 (0.102)	**5.039 (0.123)***
Alpha	C3	5.343 (0.081)	5.390 (0.073)	5.342 (0.087)	5.342 (0.073)	5.381 (0.065)	**5.466 (0.076)***
	C4	5.367 (0.075)	5.385 (0.071)	5.363 (0.078)	5.353 (0.064)	5.395 (0.054)	**5.492 (0.073)***
	F8	5.066 (0.077)	5.098 (0.075)	5.096 (0.082)	5.075 (0.073)	5.106 (0.068)	**5.177 (0.074)***
Beta 1	F7	4.470 (0.050)	4.539 (0.057)	**4.533 (0.046)***	4.537 (0.050)	**4.571 (0.048)***	**4.539 (0.050)***
	T5	4.899 (0.070)	**4.978 (0.079)***	4.972 (0.069)	4.944 (0.071)	4.967 (0.060)	**5.013 (0.070)***
	FP1	4.480 (0.053)	**4.546 (0.053)***	4.544 (0.050)	4.563 (0.056)	4.586 (0.051)	**4.544 (0.054)***
	F3	4.722 (0.054)	**4.817 (0.060)***	**4.830 (0.050)***	**4.842 (0.053)***	**4.868 (0.054)***	**4.805 (0.062)***
	C3	4.800 (0.054)	**4.886 (0.058)***	**4.883 (0.044)***	4.888 (0.045)	4.903 (0.044)	**4.873 (0.059)***
	O1	4.930 (0.074)	**5.077 (0.080)***	**5.071 (0.076)***	5.044 (0.079)	5.045 (0.071)	**5.011 (0.078)***
	Fz	4.710 (0.057)	**4.804 (0.060)***	**4.820 (0.049)***	**4.832 (0.052)***	**4.853 (0.052)***	**4.785 (0.064)***
	Cz	4.824 (0.054)	**4.924 (0.058)***	**4.936 (0.044)***	4.939 (0.044)	**4.937 (0.043)***	4.884 (0.065)
	Pz	4.963 (0.076)	**5.090 (0.078)***	**5.078 (0.072)***	**5.069 (0.059)***	5.079 (0.046)	**5.034 (0.077)***
	FP2	4.430 (0.052)	4.476 (0.050)	**4.486 (0.048)***	**4.506 (0.056)***	**4.531 (0.048)***	4.497 (0.055)
	F4	4.569 (0.054)	4.643 (0.062)	**4.658 (0.049)***	**4.677 (0.051)***	**4.697 (0.052)***	**4.640 (0.063)***
	C4	4.703 (0.060)	4.775 (0.065)	**4.784 (0.053)***	**4.786 (0.050)***	4.804 (0.049)	**4.778 (0.067)***
Beta 2	T3	4.230 (0.088)	4.165 (0.082)	4.052 (0.059)	**3.974 (0.049)***	4.042 (0.066)	4.325 (0.129)
	C3	4.228 (0.053)	4.278 (0.048)	4.248 (0.046)	4.228 (0.046)	4.276 (0.059)	**4.286 (0.059)***
	P3	4.276 (0.056)	**4.366 (0.055)***	**4.341 (0.057)***	4.307 (0.056)	4.332 (0.046)	**4.333 (0.056)***
	O1	4.346 (0.082)	**4.521 (0.105)***	4.494 (0.108)	4.454 (0.107)	4.471 (0.105)	4.415 (0.088)
	Fz	4.125 (0.050)	**4.176 (0.044)***	4.166 (0.046)	4.155 (0.048)	4.185 (0.055)	**4.171 (0.053)***
	Cz	4.273 (0.062)	**4.334 (0.050)***	4.309 (0.046)	4.297 (0.045)	4.327 (0.054)	4.316 (0.066)
	Pz	4.303 (0.058)	**4.400 (0.054)***	4.376 (0.057)	4.355 (0.057)	4.372 (0.042)	4.353 (0.057)

*. Mean is significantly different from baseline mean at $p < .05$ (correction for multiple comparisons: Bonferroni).

Table 5.
One-tailed T-tests on Predicted Significant Eyes-Closed Locations' from Pilot Study During the Last Five Minutes of AVS: Alpha and Controls

Bandpass	Location	Group	Base Mean	5th Sess	10th Sess	15th Sess	20th Sess	Base - 5th Sess	Base - 10th Sess	Base - 15th Sess	Base - 20th Sess
								t score; probability of *t*	*t* score; probability of *t*	*t* score; probability of *t*	*t* score; probability of *t*
Delta 1	C3	Control	4.1617	4.3153	4.21	4.1793	4.2421	**t = 2.733; p< 0.012***	t = 1.156; p < 0.114	t = 0.446; p <0.333	t = 1.338; p < 0.107
		Alpha	4.0996	4.1852	4.1188	4.1168	4.1917	**t = 2.880; p < 0.009***	t = 0.584; p < 0.287	t = 0.468; p <0.326	**t = 1.891; p < 0.046***
Delta 2	C3	Control	4.6019	4.7304	4.6319	4.6367	4.6274	**t = 2.355; p < 0.022***	t = 0.674; p < 0.259	t = 0.842; p < 0.211	t = 0.879; p < 0.201
		Alpha	4.5412	4.6694	4.5999	4.6046	4.6599	**t = 2.866; p < 0.010***	t = 1.477; p < 0.087	t = 1.762; p < 0.056	**t = 2.063; p < 0.035***
	Cz	Control	4.69	4.8173	4.7254	4.7283	4.681	t = 1.722; p < 0.060	t = 0.725; p < 0.244	t = 0.884; p< 0.200	t = -0.194; p < 0.574
		Alpha	4.6505	4.7748	4.708	4.7088	4.7836	**t = 2.343; p < 0.022***	t = 1.224; p < 0.126	t = 1.752; p< 0.057	**t = 2.508; p < 0.017***
Theta	F4	Control	5.173	5.2175	5.116	5.2107	5.201	t = 0.500; p < 0.315	t = -0.680; p < 0.743	t = 0.623; p < 0.275	t = 0.457; p < 0.329
		Alpha	5.0244	5.1608	5.0548	5.0928	5.1525	**t = 2.352; p < 0.022***	t = 0.719; p < 0.245	t = 1.767; p < 0.056	**t = 3.243; p < 0.005***
	O2	Control	4.9239	5.1582	4.9015	5.0612	5.0301	**t = 2.989; p < 0.008***	t = -0.292; p < 0.611	t = 1.689; p < 0.063	**t = 1.949; p < 0.042***
		Alpha	4.8797	5.043	4.9919	5.0243	5.1033	**t = 4.518; p < 0.0005***	t = 1.418; p < 0.095	t = 1.757; p < 0.057	**t = 2.377; p < 0.022***
Alpha	No Significant Locations Indicated in Pilot Study										
Beta 1	Fp1	Control	4.5364	4.6758	4.5061	4.5693	4.6531	**t = 2.950; p < 0.008***	t = -0.788; p < 0.774	t = 1.299; p < 0.113	**t = 2.088; p < 0.033***
		Alpha	4.5352	4.5211	4.5516	4.537	4.567	t = -0.399; p < 0.650	t = 0.464; p < 0.327	t = 0.055; p < 0.479	t = 0.971; p < 0.179
	F3	Control	4.8049	4.9734	4.7653	4.8771	4.8945	**t = 2.653; p < 0.013***	t = -0.988; p < 0.825	**t = 1.944; p < 0.042***	t = 1.641; p < 0.068
		Alpha	4.731	4.8301	4.8238	4.8191	4.8842	**t = 3.280; p < 0.005***	**t = 3.247; p < 0.005***	**t = 2.974; p < 0.008***	**t = 6.301; p < 0.0003***
	Fz	Control	4.7899	4.9696	4.7634	4.868	4.8857	**t = 2.802; p < 0.011***	t = -0.661; p < 0.737	**t = 1.877; p < 0.047***	t = 1.292; p < 0.115
		Alpha	4.7195	4.8231	4.8174	4.8023	4.8901	**t = 3.774; p < 0.002***	**t = 3.124; p < 0.006***	**t = 2.774; p < 0.011***	**t = 7.199; p < 0.0003***
	F4	Control	4.6073	4.7732	4.5785	4.7296	4.7573	**t = 2.439; p < 0.019***	t = -0.640; p < 0.731	**t = 2.494; p < 0.017***	t = 1.324; p < 0.109
		Alpha	4.5391	4.6455	4.6105	4.616	4.7004	**t = 3.529; p < 0.003***	**t = 2.178; p < 0.029***	**t = 2.516; p < 0.017***	**t = 4.146; p < 0.001***
Beta 2	P3	Control	4.257	4.3684	4.2374	4.3157	4.3272	t = 1.281; p < 0.116	t = -0.255; p < 0.598	t = 0.681; p < 0.257	t = 0.836; p < 0.213
		Alpha	4.3313	4.3536	4.3435	4.4082	4.3509	t = 0.554; p < 0.297	t = 0.256; p < 0.402	**t = 2.325; p < 0.023***	t = 0.351; p < 0.367
	Fz	Control	4.1432	4.2335	4.1139	4.1805	4.2467	**t = 2.129; p < 0.031***	t = -0.500; p < 0.685	t = 1.174; p < 0.136	t = 0.910; p < 0.194
		Alpha	4.152	4.2098	4.2163	4.2432	4.2534	t = 1.325; p < 0.109	t = 1.538; p < 0.080	t = 1.762; p < 0.056	**t = 3.111; p < 0.006***
	Cz	Control	4.2078	4.284	4.1496	4.2161	4.2586	t = 1.281; p < 0.116	t = -0.982; p < 0.824	t = 0.165; p < 0.438	t = 0.587; p < 0.286
		Alpha	4.2707	4.3411	4.31	4.3516	4.3717	**t = 2.454; p < 0.019***	t = 1.078; p < 0.154	**t = 1.905; p < 0.045***	**t = 2.492; p < 0.017***

'. All data are natural log-transformed.

*. The mean difference is significant at the .05 level.

A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

Table 6.
One-tailed T-tests on Predicted Significant Eyes-Closed Locations' from Pilot Study During the Last Five Minutes of AVS: Beta and Controls.

Bandpass	Location	Group	Base Mean	5th Sess	10th Sess	15th Sess	20th Sess	Base - 5th Sess	Base - 10th Sess	Base - 15th Sess	Base - 20th Sess
								t score; probability of *t*	*t* score; probability of *t*	*t* score; probability of *t*	*t* score; probability of *t*
Delta 1	F7	Control	4.3142	4.4123	4.3314	4.367	4.3524	t = 1.566; p < 0.924	t = 0.296; p < 0.613	t = 1.072; p < 0.844	t = 0.816; p < 0.782
		Beta	4.3143	4.3325	4.3252	4.3143	4.3029	t = 0.450; p < 0.668	t = 0.239; p < 0.592	t = 0.000; p < 0.500	t = -0.158; p < 0.439
	F3	Control	4.2067	4.332	4.2602	4.2365	4.253	t = 1.893; p < 0.904	t = 1.380; p < 0.899	t = 0.819; p < 0.783	t = 1.125; p < 0.855
		Beta	4.2238	4.2231	4.292	4.2312	4.2321	t = -0.020; p < 0.493	t = 1.066; p < 0.843	t = 0.214; p < 0.582	t = 0.201; p < 0.757
	FP2	Control	4.3328	4.406	4.4313	4.4067	4.4018	t = 0.893; p < 0.802	t = 1.497; p < 0.915	t = 1.565; p < 0.924	t = 0.901; p < 0.804
		Beta	4.3642	4.3525	4.4201	4.3023	4.3603	t = -0.212; p < 0.419	t = 0.769; p < 0.769	t = -1.265; p < 0.119	t = -0.059; p < 0.477
	F4	Control	4.2446	4.3027	4.2912	4.3092	4.2747	t = 0.856; p < 0.793	t = 1.225; p < 0.874	t = 1.318; p < 0.890	t = 0.794; p < 0.776
		Beta	4.219	4.2112	4.2847	4.2498	4.221	t = -0.315 p < 0.380	t = 0.885; p < 0.800	t = 0.737; p < 0.760	t = 0.049; p < 0.519
	T4	Control	4.1825	4.1557	4.1396	4.1339	4.2142	t = -0.419; p < 0.343	t = -0.766; p < 0.232	t = -0.924; p < 0.190	t = 0.434; p < 0.663
		Beta	4.1707	4.1002	4.114	4.0988	4.1351	t = -1.198; p < 0.131	t = -0.753; p < 0.236	t = -1.025; p < 0.166	t = -0.448; p < 0.333
Delta 2	No Significant Differences Indicated in Pilot Study										
Theta	T3	Control	4.9039	4.9914	4.8457	4.9474	4.94	t = 1.265; p < 0.119	t = -0.832; p < 0.786	t = 1.166; p < 0.137	t = 0.949; p < 0.184
		Beta	4.7883	4.8707	4.873	4.8652	4.8806	t = 1.848; p < 0.049*	t = 1.442; p < 0.092	t = 1.200; p < 0.131	t = 1.215; p < 0.128
	T5	Control	5.0835	5.1862	4.9937	5.1301	5.0975	t = 1.547; p < 0.078	t = -1.162; p < 0.862	t = 0.940; p < 0.186	t = 0.374; p < 0.359
		Beta	4.9256	5.0024	5.0168	5.0212	5.0714	t = 1.843; p < 0.049*	t = 1.322; p < 0.110	t = 1.365; p < 0.103	t = 2.049; p < 0.036*
	F4	Control	5.173	5.2175	5.116	5.2107	5.201	t = 0.500; p < 0.315	t = -0.680; p < 0.743	t = 0.623; p < 0.275	t = 0.457; p < 0.329
		Beta	5.1096	5.1737	5.2318	5.1864	5.1825	t = 1.262; p < 0.120	t = 2.070; p < 0.034*	t = 1.401; p < 0.098	t = 1.046; p < 0.162
	C4	Control	5.2426	5.2941	5.1606	5.2649	5.2485	t = 0.541; p < 0.301	t = -1.238; p < 0.876	t = 0.367; p < 0.361	t = 0.117; p < 0.455
		Beta	5.1231	5.2101	5.2654	5.2195	5.2244	t = 2.283; p < 0.024*	t = 2.676; p < 0.013*	t = 1.822; p < 0.061*	t = 1.518; p < 0.082
	P4	Control	5.2323	5.3112	5.1458	5.2819	5.2378	t = 0.898; p < 0.196	t = -1.385; p < 0.900	t = 0.685; p < 0.256	t = 0.108; p < 0.458
		Beta	5.1201	5.2021	5.2514	5.2137	5.2274	t = 2.706; p < 0.012*	t = 1.778; p < 0.055	t = 1.367; p < 0.103	t = 1.438; p < 0.092
	F8	Control	5.0837	5.1391	5.0191	5.104	5.102	t = 0.626; p < 0.274	t = -0.855; p < 0.792	t = 0.335; p < 0.373	t = 0.319; p < 0.379
		Beta	4.996	5.0429	5.0961	5.0477	5.0324	t = 1.039; p < 0.163	t = 1.709; p < 0.061	t = 0.899; p < 0.196	t = 0.477; p < 0.323
	T4	Control	4.9473	5.0186	4.8734	4.9885	4.9718	t = 0.758; p < 0.234	t = -1.013; p < 0.831	t = 0.657; p < 0.264	t = 0.421; p < 0.342
		Beta	4.7846	4.8618	4.9168	4.8932	4.8714	t = 1.907; p < 0.045*	t = 1.989; p < 0.039*	t = 1.690; p < 0.063	t = 1.041; p < 0.163
	T6	Control	5.1063	5.1462	5.0018	5.1509	5.1089	t = 0.447; p < 0.333	t = -1.347; p < 0.772	t = 0.612; p < 0.278	t = 0.047; p < 0.482
		Beta	4.9728	5.0082	5.0985	5.0412	5.0603	t = 1.088; p < 0.153	t = 1.558; p < 0.077	t = 0.873; p < 0.203	t = 1.054; p < 0.160
Alpha	No Within-Session Significant Differences Indicated in Pilot Study										

Table 6, cont.

Beta 1	F7	Control	4.5172	4.6193	4.4453	5.543	4.5788	**t = 2.155; p < 0.030***	**t = 2.037; p < 0.036***	t = 1.168; p < 0.137	t = 1.356; p < 0.104
		Beta	4.5682	4.566	4.6176	4.6154	4.6291	t = -0.060; p < 0.523	t = 1.492; p < 0.085	t = 1.657; p < 0.066	**t = 2.082; p < 0.034***
	T5	Control	4.8586	5.0474	4.8333	4.9202	4.8938	**t = 4.132; p < 0.003***	t = -0.365; p < 0.629	t = 1.011; p < 0.170	t = 0.829; p < 0.215
		Beta	4.9924	5.0555	5.0656	5.0635	5.0771	t = 1.333; p < 0.108	t = 1.216; p < 0.128	t = 1.461; p < 0.089	**t = 1.801; p < 0.053***
	FP1	Control	4.5384	4.6758	4.5061	4.5693	4.6531	**t = 2.950; p < 0.008***	t = -0.788; p < 0.774	t = 1.299; p < 0.113	**t = 2.088; p < 0.033***
		Beta	4.5974	4.6373	4.678	4.6433	4.7016	t = 1.085; p < 0.153	**t = 2.499; p < 0.017***	**t = 2.524; p < 0.017***	**t = 3.172; p < 0.006***
	F3	Control	4.8049	4.9734	4.7653	4.8771	4.8945	**t = 2.653; p < 0.013***	t = -0.988; p < 0.824	**t = 1.944; p < 0.042***	t = 1.641; p < 0.068
		Beta	4.8305	4.9239	4.9863	4.9656	4.9863	**t = 2.422; p < 0.020***	**t = 5.086; p < 0.0005***	**t = 4.312; p < 0.001***	**t = 4.433; p < 0.001***
	C3	Control	4.8595	4.9962	4.797	4.9015	4.9029	**t = 2.656; p< 0.013***	t = -1.547; p< 0.992	t = 1.290; p< 0.115	t = 0.980; p < 0.176
		Beta	4.9159	5.0092	5.0349	5.0302	5.0287	**t = 2.236; p< 0.026**	**t = 3.254; p< 0.005***	**t = 2.970; p< 0.008***	**t = 3.546; p < 0.003***
	O1	Control	4.902	5.1466	4.9266	5.0208	4.97	**t = 2.955; p < 0.008***	t = 0.245; p < 0.406	t = 0.887; p < 0.204	t = 0.813; p < 0.219
		Beta	5.0676	5.1147	5.1218	5.14	5.1267	t = 0.738; p < 0.240	t = 1.025; p < 0.166	t = 1.182; p < 0.134	t = 1.003; p < 0.171
	Fz	Control	4.7899	4.9696	4.7634	4.868	4.8857	**t = 2.802; p < 0.011***	t = -0.661; p < 0.737	**t = 1.877; p < 0.047***	t = 1.292; p < 0.115
		Beta	4.8271	4.9287	4.9943	4.9509	4.9844	**t = 2.714; p< 0.024***	**t = 4.708; p <0.001***	**t = 2.993; p < 0.015***	**t = 3.698; p < 0.005***
	Cz	Control	4.7949	4.964	4.7327	4.8447	4.829	**t = 2.137; p<0.032***	t = -1.553; p< 0.922	t = 1.482; p< 0.086	t = 0.792; p < 0.225
		Beta	4.8749	4.9878	5.0234	4.9969	5.0225	**t = 3.415; p< 0.004***	**t = 4.235; p< 0.001***	**t = 3.591; p< 0.003***	**t = 3.672; p < 0.003***
	Pz	Control	4.9378	5.0381	4.8183	4.9214	4.9003	t = 1.423; p < 0.094	t = -2.347; p < 0.978	t = -0.376; p < 0.642	t = -1.027; p < 0.834
		Beta	5.0516	5.2069	5.1954	5.1808	5.1742	**t = 2.440; p < 0.019***	**t = 1.950; p < 0.042***	**t = 2.230; p < 0.027***	**t = 2.247; p < 0.026***
	FP2	Control	4.5046	4.638	4.4928	4.6278	4.6325	**t = 2.381; p < 0.021***	t = -0.358; p < 0.635	**t = 2.210; p < 0.027***	**t = 2.468; p < 0.018***
		Beta	4.5252	4.5879	4.6317	4.586	4.6432	t = 1.718; p < 0.060	**t = 3.609; p < 0.003***	**t = 1.835; p < 0.050***	**t = 3.764; p < 0.003***
	F4	Control	4.6073	4.7732	4.5785	4.7296	4.7573	**t = 2.439; p < 0.019***	t = -0.640; p < 0.731	**t = 2.494; p < 0.017***	t = 1.324; p < 0.109
		Beta	4.6526	4.7349	4.806	4.7616	4.7875	**t = 2.551; p < 0.016***	**t = 4.102; p < 0.002***	**t = 2.849; p < 0.010***	**t = 3.890; p < 0.002***
	C4	Control	4.7334	4.8801	4.6632	4.8315	4.8255	**t = 2.050; p < 0.036***	t = -1.731; p < 0.941	**t = 2.047; p < 0.036***	t = 0.967; p < 0.180
		Beta	4.8247	4.8978	4.9488	4.918	4.9265	t = 1.660; p < 0.066	**t = 2.453; p < 0.019***	**t = 1.846; p < 0.049***	**t = 2.069; p < 0.035***
Beta 2	T3	Control	4.3023	4.5126	4.1943	4.2404	4.1917	t = 1.308; p < 0.112	t = -1.069; p < 0.843	t = -0.369; p < 0.639	t = -0.953; p < 0.817
		Beta	4.3204	4.3166	4.3145	4.2747	4.3174	t = -0.037; p < 0.514	t = -0.055; p < 0.521	t = -0.654; p < 0.735	t = -0.051; p < 0.520
	P3	Control	4.257	4.3684	4.2374	4.3157	4.3272	t = 1.281; p < 0.116	t = -0.255; p < 0.598	t = 0.681; p < 0.257	t = 0.836; p < 0.213
		Beta	4.4099	4.4457	4.4885	4.4765	4.4545	t = 0.733; p < 0.241	t = 1.699; p < 0.062	t = 1.675; p < 0.064	t = 0.950; p < 0.184
	O1	Control	4.3203	4.7111	4.5329	4.57	4.5114	**t = 2.445; p < 0.019***	t = 1.406; p < 0.097	t = 1.190; p < 0.132	t = 1.428; p < 0.094
		Beta	4.5554	4.5233	4.526	4.6302	4.529	t = -0.299; p < 0.614	t = -0.276; p < 0.605	t = 0.935; p < 0.187	t = -0.220; p < 0.585
	Fz	Control	4.1432	4.2335	4.1139	4.1805	4.2467	**t = 2.129; p < 0.031***	t = -0.500; p < 0.685	t = 1.174; p < 0.136	t = 0.910; p < 0.194
		Beta	4.2706	4.304	4.3437	4.3054	4.3274	t = 0.936; p < 0.187	t = 1.292; p < 0.115	t = 0.675; p < 0.258	t = 1.448; p < 0.091
	Cz	Control	4.2078	4.284	4.1496	4.2161	4.2588	t = 1.281; p < 0.116	t = -0.982; p < 0.824	t = 0.165; p < 0.436	t = 0.587; p < 0.288
		Beta	4.2836	4.3543	4.4093	4.3785	4.3878	**t = 2.240; p < 0.026***	**t = 2.092; p < 0.033***	**t = 2.095; p < 0.033***	**t = 2.885; p < 0.009***
	Pz	Control	4.2395	4.3078	4.1558	4.2189	4.2639	t = 0.728; p < 0.243	t = -1.138; p < 0.857	t = -0.251; p < 0.598	t = 0.292; p < 0.389
		Beta	4.3606	4.4521	4.4595	4.4593	4.4493	**t = 2.203; p < 0.028***	**t = 2.356; p < 0.022***	**t = 2.581; p < 0.015***	**t = 1.830; p < 0.050***

'All data are natural log-transformed.

*. The mean difference is significant at the .05 level.

A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

Table 7.
Significant One-Way Repeated Measures ANOVAs Conducted with Natural Log-transformed Data Comparing Original Baseline with the Last Five Minutes of the 5th, 10th, 15th, and 20th Eyes-Closed Measures for Control, Alpha AVS, and Beta AVS Groups.

Bandpass	Location	Univariate	Multivariate
Delta 1	No Significant ANOVA Results.		
Delta 2	F7		F(4,4) = 4.383, p<0.008
	T3		F(4,4) = 3.242, p<0.028
	T5		F(4,4) = 3.065, p<0.035
	Fp1		F(4,4) = 3.259, p<0.028
Theta	F7		F(4,4) = 2.855, p<0.045
	C4		F(4,4) = 3.312, p<0.026
	P4		F(4,4) = 2.695, p<0.054
	O2		F(4,4) = 2.907, p<0.042
Alpha	No Significant ANOVA Results.		
Beta 1	F7	F(4,8) = 2.356, p<0.022	
	T5	F(4,8) = 2.160, p<0.036	
	Fp1		F(4,4) = 3.200, p<0.030
	F3	F(4,8) = 2.574, p<0.013	
	C3	F(4,8) = 2.315, p<0.025	
	P3		F(4,4) = 3.562, p<0.020
	O1		F(4,4) = 2.911, p<0.042
	Fz	F(4,8) = 2.107, p<0.041	
	Cz	F(4,8) = 2.696, p<0.010	
	Pz		F(4,4) = 3.154, p<0.031
	Fp2		F(4,4) = 3.080, p<0.034
	C4		F(4,4) = 4.062, p<0.011
	P4		F(4,4) = 2.970, p<0.039
	O2	F(4,8) = 2.085, p<0.043	
	F8		F(4,4) = 2.691, p<0.054
	T4	F(4,8) = 3.195, p<0.003	
	T6		F(4,4) = 3.687, p<0.017
Beta 2	T5		F(4,4) = 3.852, p<0.014

Table 8.

Two-tailed Significant T-tests Conducted with Natural Log-transformed Data at Locations Indicated by ANOVAs as Showing Significance During the Last Five Minutes of AVS.

Bandpass	Location	Group	Base Mean	5th Sess	10th Sess	15th Sess	20th Sess	Base - 5th Sess	Base - 10th Sess	Base - 15th Sess	Base - 20th Sess
								t score; probability of *t*	*t* score; probability of *t*	*t* score; probability of *t*	*t* score; probability of *t*
Delta 1	No Significant Differences Indicated by ANOVAs										
Delta 2	T3	Control	4.3591	4.4539	4.3526	4.3813	4.363	t = 2.121; p < 0.063	t = -0.161; p < 0.876	t = 0.510; p < 0.622	t = 0.103; p < 0.920
		Alpha	4.2543	4.3767	4.2996	4.3206	4.358	**t = 3.534; p < 0.006***	t = 1.268; p < 0.237	t = 1.839; p < 0.099	t = 1.983; p < 0.079
		Beta	4.3413	4.3869	4.4054	4.3599	4.3579	t = 1.279; p < 0.233	t = 1.325; p < 0.218	t = 0.476; p < 0.645	t = 0.357; p < 0.730
	T5	Control	4.4875	4.5434	4.4611	4.4649	4.4416	t = 1.191; p < 0.264	t = -0.655; p < 0.529	t = -0.487; p < 0.638	t = -1.021; p < 0.334
		Alpha	4.3521	4.511	4.4639	4.4641	4.5253	**t = 3.571; p < 0.006***	t = 2.640; p < 0.027	**t = 3.312; p < 0.009***	**t = 3.455; p < 0.007***
		Beta	4.4577	4.4864	4.4881	4.4847	4.5082	t = 0.783; p < 0.454	t = 0.583; p < 0.574	t = 0.520; p < 0.616	t = 1.193; p < 0.263
Theta	No Significant Differences Indicated by Bonferroni-corrected *t*-tests										
Alpha	No Significant Differences Indicated in AVOVAs										
Beta 1	F7	Control	4.5172	4.6193	4.4453	5.543	4.5788	t = 2.155; p < 0.060	t = 2.037; p < 0.072	t = 1.168; p < 0.273	t = 1.356; p < 0.208
		Alpha	4.4652	4.5167	4.5269	4.517	4.5514	t = 1.274; p < 0.235	t = 1.824; p < 0.101	t = 1.485; p < 0.172	**t = 3.935; p < 0.003***
		Beta	4.5682	4.566	4.6176	4.6154	4.6291	t = -0.060; p < 0.954	t = 1.492; p < 0.170	t = 1.657; p < 0.132	t = 2.082; p < 0.067
	T3	Control	4.7354	4.9437	4.6546	4.7563	4.6763	**t = 3.075; p < 0.013***	t = -1.511; p < 0.165	t = 0.233; p < 0.821	t = -0.923; p < 0.380
		Alpha	4.6434	4.6739	4.707	4.6867	4.709	t = 0.682; p < 0.513	t = 1.484; p < 0.172	t = 0.883; p < 0.400	t = 1.438; p < 0.184
		Beta	4.7706	4.8489	4.8379	4.8413	4.8352	t = 0.873; p < 0.405	t = 1.267; p < 0.237	t = 1.644; p < 0.135	**t = 3.092; p < 0.013***
	Cz	Control	4.7949	4.964	4.7327	4.8447	4.829	t = 2.137; p<0.061	t = -1.553; p< 0.155	t = 1.482; p< 0.172	t = 0.792; p < 0.449
		Alpha	4.8046	4.9056	4.8885	4.8834	4.9506	t = 2.818; p< 0.020	t = 2.139; p< 0.061	t = 2.274; p< 0.049	**t = 4.158; p < 0.002***
		Beta	4.8749	4.9878	5.0234	4.9969	5.0225	**t = 3.415; p< 0.008***	**t = 4.235; p< 0.002***	**t = 3.591; p< 0.006***	**t = 3.672; p < 0.005***
Beta 2	No Significant Differences Indicated by Bonferroni-corrected *t*-tests										

*. The mean difference is significant at the .05 level. (Correction for multiple comparisons: Bonferroni.)

A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

Table 9.
One-tailed T-tests Conducted with Natural Log-transformed Data at Predicted Eyes-Closed Locations Showing Lasting Changes in Power as Indicated by Pilot Study Data for both Alpha and Beta AVS.

AVS Session	Bandpass	Location	Group	Base Mean	20th Sess	Post Mean	Base - 20th	Base - Post	20th - Post
							t score (probability of *t*)	*t* score (probability of *t*)	*t* score (probability of *t*)
Alpha AVS:	Beta 1	Fp1	Control	4.5364	4.49	4.5841	t = -1.774; p < 0.945	t = 0.737; p < 0.240	t = 1.617; p < 0.070
			Alpha	4.5352	4.4883	4.4914	t = -2.042; p < 0.964	t = -0.846; p < 0.790	t = 0.059; p < 0.478
		F3	Control	4.8049	4.761	4.7962	t = -2.025; p < 0.963	t = -0.201; p < 0.577	t = 0.980; p < 0.177
			Alpha	4.731	4.7363	4.7037	t = 0.414; p < 0.344	t = -0.688; p < 0.745	t = -0.947; p < 0.816
		Fz	Control	4.7899	4.7408	4.7464	t = -3.363; p < 0.996	t = -1.413; p < 0.904	t = 0.193; p < 0.426
			Alpha	4.7195	4.7325	4.7086	t = 0.650; p < 0.266	t = -0.238; p < 0.591	t = -0.670; p < 0.740
Beta AVS:	Theta	T5	Control	5.0835	5.1139	5.0657	t = 0.819; p < 0.217	t = -0.473; p < 0.676	t = -2.113; p < 0.968
			Beta	4.9256	5.0185	4.9836	t = 1.225; p < 0.126	t = 0.634; p < 0.271	t = -0.470; p < 0.675
		T6	Control	5.1063	5.0639	5.0781	t = -1.234; p < 0.876	t = -0.613; p < 0.722	t = 0.517; p < 0.309
			Beta	4.9728	5.0549	5.0744	t = 1.034; p < 0.164	**t = 1.824; p < 0.050***	t = 0.431; p < 0.339
	Alpha	C3	Control	5.3845	5.3058	5.3661	t = -2.002; p < 0.962	t = -0.600; p < 0.718	t = 1.299; p < 0.113
			Beta	5.2937	5.4021	5.4125	t = 1.007; p < 0.155	t = 1.411; p < 0.096	t = 0.199; p < 0.424
		C4	Control	5.366	5.2835	5.3358	t = -1.975; p < 0.960	t = -1.982; p < 0.960	t = 1.212; p < 0.128
			Beta	5.2981	5.389	5.4178	t = 0.856; p < 0.207	t = 1.645; p < 0.067	t = 0.511; p < 0.311
		F8	Control	5.0283	4.9399	4.9819	t = -3.092; p < 0.993	t = -2.543; p < 0.984	t = 1.108; p < 0.149
			Beta	4.945	4.9723	4.9656	t = 0.333; p < 0.373	t = 0.342; p < 0.370	t = -0.132; p < 0.551
	Beta 1	F7	Control	4.5172	4.4672	4.4943	t = -1.926; p < 0.957	t = -0.757; p < 0.766	t = 0.881; p < 0.201
			Beta	4.5682	4.5304	4.5712	t = -0.864; p < 0.795	t = 0.088; p < 0.466	t = 1.171; p < 0.136
		T5	Control	4.8586	4.8713	4.8182	t = 0.476; p < 0.323	t = -1.458; p < 0.910	t = -1.788; p < 0.946
			Beta	4.9924	4.9793	4.9641	t = -0.258; p < 0.599	t = -0.572; p < 0.709	t = -0.268; p < 0.602
		FP1	Control	4.5364	4.49	4.5841	t = -1.774; p < 0.945	t = 0.737; p < 0.240	t = 1.617; p < 0.070
			Beta	4.5974	4.5709	4.6613	t = -0.682; p < 0.743	t = 1.323; p < 0.109	**t = 1.838; p < 0.050***
		F3	Control	4.8049	4.761	4.7962	t = -2.025; p < 0.963	t = -0.201; p < 0.577	t = 0.980; p < 0.177
			Beta	4.8305	4.8556	4.9205	t = 0.828; p < 0.215	**t = 2.208; p < 0.028***	**t = 2.272; p < 0.025***
		C3	Control	4.8595	4.8232	4.8117	t = -1.895; p< 0.954	t = -1.944; p< 0.958	t = -0.417; p< 0.657
			Beta	4.9159	4.9259	4.9665	t = 0.299; p< 0.150	t = 1.589; p< 0.074	t = 1.715; p< 0.060
		O1	Control	4.902	4.9241	4.9301	t = 0.396; p < 0.350	t = 0.294; p < 0.388	t = 0.077; p < 0.470
			Beta	5.0676	5.0349	5.0513	t = -0.448; p < 0.667	t = -0.209; p < 0.580	t = 0.356; p < 0.365
		Fz	Control	4.7899	4.7408	4.7464	t = -3.363; p< 0.996	t = -1.413; p< 0.904	t = 0.193; p< 0.426
			Beta	4.8271	4.8416	4.919	t = 0.434; p< 0.338	**t = 1.875; p<0.047***	**t = 2.376; p< 0.021***
		Pz	Control	4.9378	4.8783	4.8485	t = -2.061; p < 0.965	t = -2.345; p < 0.978	t = -0.816; p < 0.782
			Beta	5.0516	5.0573	5.092	t = 0.129; p < 0.450	t = 0.754; p < 0.235	t = 1.369; p < 0.102
		F4	Control	4.6073	4.5686	4.6102	t = -1.444; p < 0.908	t = 0.107; p < 0.459	t = 1.473; p < 0.088
			Beta	4.6526	4.6452	4.7436	t = -0.210; p < 0.581	**t = 2.662; p < 0.013***	**t = 3.977; p < 0.002***
		C4	Control	4.7334	4.6943	4.695	t = -2.019; p < 0.963	t = -1.566; p < 0.923	t = 0.024; p < 0.491
			Beta	4.8247	4.8385	4.8797	t = 0.294; p < 0.388	t = 1.275; p < 0.117	**t = 1.942; p < 0.042***
	Beta 2	C3	Control	4.277	4.2083	4.2632	t = -0.961; p < 0.819	t = -0.222; p < 0.585	t = 1.501; p < 0.084
			Beta	4.3832	4.3534	4.4182	t = -0.778; p < 0.771	t = 1.017; p < 0.168	**t = 1.898; p < 0.045***
		P3	Control	4.257	4.2441	4.2953	t = -0.297; p < 0.613	t = 0.942; p < 0.186	t = 1.183; p < 0.134
			Beta	4.4099	4.382	4.4092	t = -0.528; p < 0.695	t = -0.015; p < 0.506	t = 0.666; p < 0.261
		Fz	Control	4.1432	4.0887	4.169	t = -1.564; p< 0.924	t = 0.562; p< 0.294	t = 1.786; p< 0.054
			Beta	4.2706	4.256	4.336	t = -0.647; p< 0.733	t = 1.183; p< 0.134	**t = 1.826; p< 0.050***

*. The mean difference is significant at the .05 level.
A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

Table 10.
One-tailed T-tests Conducted with Natural Log-transformed Data at Predicted Eyes-Closed Locations Showing Changes in Power During Alpha AVS as Indicated by Pilot Study Data.

Bandpass	Location	Group	Base Mean	20th Sess	Post Mean	Base - 20th	Base - Post	20th - Post
						t score (probability of *t*)	*t* score (probability of *t*)	*t* score (probability of *t*)
Delta 1	C3	Control	4.1617	4.2024	4.1731	t = 0.949; p< 0.184	t = 0.295; p < 0.388	t = -1.138; p <0.857
		Alpha	4.0996	4.0906	4.1212	t = -0.266; p < 0.602	t = 0.454; p < 0.333	t = 0.519; p <0.309
Delta 2	C3	Control	4.6019	4.6253	4.6024	t = 0.667; p < 0.261	t = 0.013; p < 0.495	t = -1.105; p < 0.851
		Alpha	4.5412	4.5834	4.555	t = 1.024; p < 0.167	t = 0.296; p < 0.387	t = -0.936; p < 0.813
	Cz	Control	4.69	4.7068	4.6918	t = 0.388; p < 0.354	t = 0.043; p < 0.483	t = -0.561; p< 0.705
		Alpha	4.6505	4.6906	4.6573	t = 1.203; p < 0.130	t = 0.118; p < 0.455	t = -1.152; p< 0.860
Theta	F4	Control	5.173	5.1449	5.1391	t = -1.156; p < 0.861	t = -1.056; p < 0.840	t = -0.250; p < 0.596
		Alpha	5.0244	5.0656	5.0661	t = 1.657; p < 0.066	**t = 1.855; p < 0.049***	t = 0.017; p < 0.494
	O2	Control	4.9239	4.9412	4.9165	t = 0.356; p < 0.365	t = -0.127; p < 0.549	t = -0.533; p < 0.696
		Alpha	4.8797	4.9328	4.9754	t = 0.926; p < 0.190	t = 1.268; p < 0.119	t = 0.702; p < 0.250
Alpha	No Significant Locations Indicated in Pilot Study							
Beta 1	Fp1	Control	4.5364	4.49	4.5841	t = -1.774; p < 0.945	t = 0.737; p < 0.240	t = 1.617; p < 0.070
		Alpha	4.5352	4.4883	4.4914	t = -2.042; p < 0.964	t = -0.846; p < 0.790	t = 0.059; p < 0.478
	F3	Control	4.8049	4.761	4.7962	t = -2.025; p < 0.963	t = -0.201; p < 0.577	t = 0.980; p < 0.177
		Alpha	4.731	4.7363	4.7037	t = 0.414; p < 0.344	t = -0.688; p < 0.745	t = -0.947; p < 0.816
	Fz	Control	4.7899	4.7408	4.7464	t = -3.363; p < 0.996	t = -1.413; p < 0.904	t = 0.193; p < 0.426
		Alpha	4.7195	4.7325	4.7086	t = 0.650; p < 0.266	t = -0.238; p < 0.591	t = -0.670; p < 0.740
	F4	Control	4.6073	4.5686	4.6102	t = -1.444; p < 0.908	t = 0.107; p < 0.459	t = 1.473; p < 0.088
		Alpha	4.5391	4.5526	4.5095	t = 0.752; p < 0.236	t = -0.723; p < 0.756	t = -1.211; p < 0.871
Beta 2	P3	Control	4.257	4.2441	4.2953	t = -0.297; p < 0.613	t = 0.942; p < 0.186	t = 1.183; p < 0.134
		Alpha	4.3313	4.2804	4.2525	t = -1.992; p < 0.961	t = -2.288; p < 0.976	t = -1.181; p < 0.866
	Fz	Control	4.1432	4.0887	4.169	t = -1.564; p< 0.924	t = 0.562; p< 0.294	t = 1.786; p< 0.054
		Alpha	4.152	4.1525	4.0832	t = 0.020; p< 0.493	t = -1.576; p< 0.925	t = -2.192; p< 0.972
	Cz	Control	4.2078	4.1624	4.2214	t = -0.979; p<0.823	t = 0.373; p< 0.359	t = 1.578; p< 0.075
		Alpha	4.2707	4.2972	4.1999	t = 0.974; p < 0.178	t = -2.110; p < 0.968	t = -2.445; p < 0.981

*. The mean difference is significant at the .05 level.
A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

Table 11.
One-tailed T-tests Conducted with Natural Log-transformed Data at Predicted Eyes-Closed Locations Showing Changes in Power During Beta AVS as Indicated by Pilot Study Data.

Bandpass	Location	Group	Base Mean	20th Sess	Post Mean	Base - 20th	Base - Post	20th - Post
						t score (probability of *t*)	*t* score (probability of *t*)	*t* score (probability of *t*)
Delta 1	F7	Control	4.3142	4.347	4.373	t = 0.828; p < 0.785	t = 0.997; p < 0.827	t = 0.800; p < 0.778
		Beta	4.3143	4.2884	4.3578	t = -0.465; p < 0.327	t = 0.805; p < 0.779	t = 1.240; p < 0.876
	F3	Control	4.2067	4.2261	4.2154	t = 1.016; p < 0.832	t = 0.290; p < 0.610	t = -0.500; p < 0.315
		Beta	4.2238	4.1995	4.2172	t = -0.516; p < 0.310	t = -0.147; p < 0.443	t = 0.415; p < 0.656
	FP2	Control	4.3328	4.4213	4.3805	t = 2.813; p < 0.990	t = 1.288; p < 0.885	t = -0.867; p < 0.205
		Beta	4.3642	4.3407	4.3239	t = -0.412; p < 0.345	t = -0.555; p < 0.296	t = -0.288; p < 0.390
	F4	Control	4.2446	4.2585	4.2972	t = 0.307; p < 0.617	t = 0.942; p < 0.814	t = 1.187; p < 0.867
		Beta	4.219	4.2146	4.2591	t = -0.096 p < 0.463	t = 0.935; p < 0.813	t = 1.279; p < 0.883
	T4	Control	4.1825	4.1489	4.0722	t = -0.689; p < 0.254	**t = -2.119; p < 0.032***	**t = -2.399; p < 0.020***
		Beta	4.1707	4.0273	3.9999	**t = -1.807; p < 0.052***	**t = -2.343; p < 0.022***	t = -0.440; p < 0.335
Delta 2	No Significant Differences Indicated in Pilot Study							
Theta	T3	Control	4.9039	4.9138	4.906	t = 0.316; p < 0.380	t = 0.055; p < 0.479	t = -0.263; p < 0.600
		Beta	4.7883	4.8221	4.8131	t = 0.478; p < 0.322	t = 0.334; p < 0.373	t = -0.126; p < 0.548
	F4	Control	5.173	5.1449	5.1391	t = -1.156; p < 0.861	t = -1.056; p < 0.840	t = -0.250; p < 0.596
		Beta	5.1096	5.1136	5.1816	t = 0.090; p < 0.465	t = 1.313; p < 0.111	**t = 2.613; p < 0.014***
	C4	Control	5.2426	5.215	5.1999	t = -1.475; p < 0.913	t = -1.345; p < 0.895	t = -0.760; p < 0.766
		Beta	5.1231	5.1892	5.2162	t = 1.130; p < 0.144	t = 1.771; p < 0.055	t = 0.695; p < 0.253
	P4	Control	5.2323	5.1937	5.1888	t = -1.510; p < 0.917	t = -1.327; p < 0.891	t = -0.284; p < 0.608
		Beta	5.1201	5.2119	5.2221	t = 1.492; p < 0.085	t = 1.761; p < 0.056	t = 0.243; p < 0.407
	F8	Control	5.0837	5.0461	5.0553	t = -1.484; p < 0.914	t = -0.810; p < 0.780	t = 0.392; p < 0.352
		Beta	4.996	4.9773	5.0093	t = -0.290; p < 0.389	t = 0.228; p < 0.413	t = 0.735; p < 0.241
	T4	Control	4.9473	4.9281	4.9246	t = -0.674; p < 0.741	t = -0.567; p < 0.707	t = -0.139; p < 0.554
		Beta	4.7846	4.8199	4.8216	t = 0.451; p < 0.332	t = 0.484; p < 0.320	t = 0.022; p < 0.492
Beta 1	F7	Control	4.5172	4.4672	4.4943	t = -1.926; p < 0.957	t = -0.757; p < 0.766	t = 0.881; p < 0.201
		Beta	4.5682	4.5304	4.5712	t = -0.864; p < 0.795	t = 0.088; p < 0.466	t = 1.171; p < 0.136
	T5	Control	4.8586	4.8713	4.8182	t = 0.476; p < 0.323	t = -1.458; p < 0.910	t = -1.788; p < 0.946
		Beta	4.9924	4.9793	4.9641	t = -0.258; p < 0.599	t = -0.572; p < 0.709	t = -0.268; p < 0.602
	FP1	Control	4.5364	4.49	4.5841	t = -1.774; p < 0.945	t = 0.737; p < 0.240	t = 1.617; p < 0.070
		Beta	4.5974	4.5709	4.6613	t = -0.682; p < 0.743	t = 1.323; p < 0.109	**t = 1.838; p < 0.050***
	F3	Control	4.8049	4.761	4.7962	t = -2.025; p < 0.963	t = -0.201; p < 0.577	t = 0.980; p < 0.177
		Beta	4.8305	4.8556	4.9205	t = 0.828; p < 0.215	**t = 2.208; p < 0.028***	**t = 2.272; p < 0.025***
	C3	Control	4.8595	4.8232	4.8117	t = -1.895; p< 0.954	t = -1.944; p< 0.958	t = -0.417; p< 0.657
		Beta	4.9159	4.9259	4.9665	t = 0.299; p< 0.150	t = 1.589; p< 0.074	t = 1.715; p< 0.060
	O1	Control	4.902	4.9241	4.9301	t = 0.396; p < 0.350	t = 0.294; p < 0.388	t = 0.077; p < 0.470
		Beta	5.0676	5.0349	5.0513	t = -0.448; p < 0.667	t = -0.209; p < 0.580	t = 0.356; p < 0.365
	Fz	Control	4.7899	4.7408	4.7464	t = -3.363; p< 0.996	t = -1.413; p< 0.904	t = 0.193; p< 0.426
		Beta	4.8271	4.8416	4.919	t = 0.434; p< 0.338	**t = 1.875; p<0.047***	**t = 2.375; p< 0.021***
	Pz	Control	4.9378	4.8783	4.8485	t = -2.061; p < 0.965	t = -2.345; p < 0.978	t = -0.816; p < 0.782
		Beta	5.0516	5.0573	5.092	t = 0.129; p < 0.450	t = 0.754; p < 0.235	t = 1.369; p < 0.102
	Cz	Control	4.7949	4.7674	4.7545	t = -1.157; p<0.861	t = -1.827; p< 0.949	t = -0.505; p<0.677
		Beta	4.8749	4.9041	4.9636	t = 0.690; p< 0.254	**t = 1.880; p< 0.047***	**t = 2.138; p< 0.031***
	FP2	Control	4.5046	4.4704	4.5823	t = -1.783; p < 0.946	t = 1.294; p < 0.114	t = 1.771; p < 0.056
		Beta	4.5252	4.5043	4.6298	t = -0.522; p < 0.693	**t = 2.010; p < 0.038***	**t = 2.551; p < 0.016***
	F4	Control	4.6073	4.5686	4.6102	t = -1.444; p < 0.908	t = 0.107; p < 0.459	t = 1.473; p < 0.088
		Beta	4.6526	4.6452	4.7436	t = -0.210; p < 0.581	**t = 2.662; p < 0.013***	**t = 3.977; p < 0.002***
	C4	Control	4.7334	4.6943	4.695	t = -2.019; p < 0.963	t = -1.566; p < 0.923	t = 0.024; p < 0.491
		Beta	4.8247	4.8385	4.8797	t = 0.294; p < 0.388	t = 1.275; p < 0.117	**t = 1.942; p < 0.042***
Beta 2	T3	Control	4.3023	4.2529	4.3606	t = -0.470; p < 0.675	t = 0.361; p < 0.363	t = 0.716; p < 0.246
		Beta	4.3204	4.2893	4.2561	t = -0.446; p < 0.667	t = -0.713; p < 0.753	t = -0.328; p < 0.625
	P3	Control	4.257	4.2441	4.2953	t = -0.297; p < 0.613	t = 0.942; p < 0.186	t = 1.183; p < 0.134
		Beta	4.4099	4.382	4.4092	t = -0.528; p < 0.695	t = -0.015; p < 0.506	t = 0.666; p < 0.261
	O1	Control	4.3203	4.4098	4.48	t = 0.914; p < 0.193	t = 1.263; p < 0.119	t = 0.428; p < 0.340
		Beta	4.5554	4.4653	4.4584	t = -0.696; p < 0.748	t = -0.717; p < 0.754	t = -0.098; p < 0.462
	Fz	Control	4.1432	4.0887	4.169	t = -1.564; p< 0.924	t = 0.562; p< 0.294	t = 1.786; p< 0.054
		Beta	4.2706	4.256	4.336	t = -0.647; p< 0.733	t = 1.183; p< 0.134	**t = 1.826; p< 0.050***
	Cz	Control	4.2078	4.1624	4.2214	t = -0.979; p<0.824	t = 0.373; p< 0.359	t = 1.578; p< 0.075
		Beta	4.2836	4.3086	4.3895	t = 0.726; p<0.0.243	**t = 2.101; p< 0.033***	**t = 2.442; p < 0.019***
	Pz	Control	4.2395	4.1856	4.2539	t = -0.967; p < 0.820	t = 0.359; p < 0.364	t = 1.574; p < 0.075
		Beta	4.3606	4.3609	4.3916	t = 0.004; p < 0.499	t = 0.548; p < 0.299	t = 0.851; p < 0.209

* The mean difference is significant at the .05 level.

A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

Table 12.
Significant One-Way Repeated Measures ANOVAs Conducted with Natural Log-transformed Data Comparing Original Eyes-Closed Baseline, 20th Session Baseline, and Post Measures for Control, Alpha AVS and Beta AVS Groups.

Bandpass	Location	Univariate	Multivariate
Delta 1	Fp1		F(2,2) = 3.564 p<0.042
	Fp2	F(2,4) = 3.305 p<0.017	
Delta 2	Fp1		F(2,2) = 3.794 p<0.035
	Fp2		F(2,2) = 3.524 p<0.044
	F4		F(2,2) = 4.430 p<0.022
	C4		F(2,2) = 3.256 p<0.054
	P4		F(2,2) = 3.326 p<0.051
	T6		F(2,2) = 3.935 p<0.032
Theta	No Significant Differences Indicated by ANOVAs		
Alpha	No Significant Differences Indicated by ANOVAs		
Beta 1	C3		F(2,2) = 3.495 p<0.045
	P3		F(2,2) = 4.002 p<0.030
	Fz	F(2,4) = 2.617 p<0.045	
	Cz	F(2,4) = 2.655 p<0.043	
	Fp2	F(2,4) = 2.912 p<0.030	
	F4	F(2,4) = 3.386 p<0.015	
Beta 2	Fz	F(2,4) = 2.738 p<0.038	
	Cz	F(2,4) = 4.323 p<0.004	
	Fp2		F(2,2) = 3.789 p<0.035
	F4	F(2,4) = 3.069 p<0.024	

Table 13.
Two-tailed Paired Difference T-tests Conducted with Natural Log-transformed Data at Significant Locations as Indicated by ANOVAs Comparing Baseline, 20th Session, and Post Means for All Eyes-Closed Groups.

Bandpass	Location	Group	Base Mean	20th Sess	Post Mean	Base - 20th	Base - Post	20th - Post
						t score (probability of *t*)	*t* score (probability of *t*)	*t* score (probability of *t*)
Delta 1	No Significant Differences Indicated by Bonferroni-corrected *t*-tests.							
Delta 2	FP1	Control	4.6181	4.7077	4.652	**t = 3.188; p < 0.011***	t = 0.677; p < 0.516	t = -1.456; p < 0.179
		Alpha	4.6843	4.6095	4.6118	t = -1.471; p < 0.175	t = -1.082; p < 0.308	t = 0.057; p < 0.956
		Beta	4.6218	4.6493	4.6808	t = 0.547; p < 0.598	t = 0.874; p < 0.405	t = 0.584; p < 0.574
Theta	No Significant Differences Indicated by ANOVA							
Alpha	No Significant Differences Indicated by ANOVA							
Beta 1	Fz	Control	4.7899	4.7408	4.7464	**t = -3.363; p < 0.008***	t = -1.413; p < 0.191	t = 0.193; p < 0.851
		Alpha	4.7195	4.7325	4.7086	t = 0.650; p < 0.532	t = -0.238; p < 0.817	t = -0.670; p < 0.520
		Beta	4.8271	4.8416	4.919	t = 0.434; p < 0.675	t = 1.875; p < 0.094	t = 2.375; p < 0.042
Beta 2	No Significant Differences Indicated by Bonferroni-corrected *t*-tests.							

*. The mean difference is significant at the .05 level. (Correction for multiple comparisons: Bonferroni.)
A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

Table 14.

Significant One-Way Repeated Measure ANOVAs Conducted with Natural Log-transformed Data Comparing Original Eyes-Open Baseline, 20th Session Baseline, and Post Measures for Control, Alpha AVS and Beta AVS Groups.

Bandpass	Location	Univariate	Multivariate
Delta 1	F8	$F(2,4) = 3.262$ $p<0.018$	
Delta 2	F8		$F(2,2) = 4.292$ $p<0.024$
Theta	F8		$F(2,2) = 4.058$ $p<0.029$
Alpha	C4		$F(2,2) = 3.458$ $p<0.046$
Beta 1	P3		$F(2,2) = 4.075$ $p<0.028$
Beta 2	C4	$F(2,4) = 3.973$ $p<0.007$	
	F8		$F(2,2) = 3.297$ $p<0.052$

Table 15.
Two-tailed Paired Difference T-tests Conducted with Natural Log-transformed Data at Significant Locations Indicated by ANOVAs Comparing Original Eyes-Open Baseline with 20th Session and Post Means for All Groups.

Bandpass	Location	Group	Base Mean	20th Sess	Post Mean	Base - 20th	Base - Post	20th - Post
						t score (probability of *t*)	*t* score (probability of *t*)	*t* score (probability of *t*)
Delta1:	F8	Control	4.0708	4.1168	4.1548	t = 0.638; p < 0.540	t = 0.789; p < 0.451	t = 0.656; p < 0.528
		Alpha	3.9614	4.0577	3.968	t = 1.725; p < 0.119	t = 0.114; p < 0.912	t = -1.673; p < 0.129
		Beta	4.228	4.0788	3.9993	t = -1.983; p < 0.079	**t = -3.186; p < 0.011**	t = -1.202; p < 0.260
Delta2:	F8	Control	4.4842	4.4895	4.5563	t = 0.148; p < 0.886	t = 0.989; p < 0.349	t = 0.983; p < 0.351
		Alpha	4.4408	4.4974	4.4019	t = 1.319; p < 0.220	t = -0.804; p < 0.442	t = -1.943; p < 0.084
		Beta	4.6006	4.5125	4.4276	t = -1.258; p < 0.240	t = -2.733; p < 0.023	t = -0.917; p < 0.383
Theta:	F8	Control	4.9236	4.9334	4.9718	t = 0.211; p < 0.838	t = 0.839; p < 0.423	t = 0.868; p < 0.408
		Alpha	4.7981	4.822	4.7883	t = 0.626; p < 0.547	t = -0.269; p < 0.794	t = -0.825; p < 0.431
		Beta	5.0176	4.9029	4.8649	t = -2.272; p < 0.049	t = -2.099; p < 0.065	t = -0.510; p < 0.622
Alpha:	C4	Control	5.1941	5.2498	5.2318	t = 1.330; p < 0.216	t = 1.089; p < 0.305	t = -0.377; p < 0.715
		Alpha	4.9182	4.956	4.8922	t = 0.926; p < 0.379	t = -0.393; p < 0.703	t = -1.333; p < 0.215
		Beta	5.1955	5.1997	5.334	t = 0.073; p < 0.944	t = 1.631; p < 0.137	t = 1.947; p < 0.083
Beta1:	P3	Control	4.8051	4.8202	4.828	t = 0.610; p < 0.557	t = 0.883; p < 0.400	t = 0.300; p < 0.771
		Alpha	4.7334	4.7065	4.6473	t = -1.274; p < 0.234	t = -2.171; p < 0.058	t = -2.006; p < 0.076
		Beta	4.8881	4.9107	4.9347	t = 0.514; p < 0.620	t = 1.226; p < 0.251	t = 0.518; p < 0.617
Beta2:	C4	Control	3.954	3.9197	3.9229	t = -1.788; p < 0.107	t = -1.323; p < 0.218	t = 0.154; p < 0.881
		Alpha	3.9565	3.9239	3.822	t = -0.677; p < 0.515	t = -2.832; p < 0.020	t = -2.353; p < 0.043
		Beta	4.0903	4.0208	4.1039	t = -2.694; p < 0.025	t = 0.357; p < 0.730	t = 2.330; p < 0.045
	F8	Control	4.0688	4.0471	4.1302	t = -0.275; p < 0.790	t = 0.849; p < 0.418	t = 1.202; p < 0.260
		Alpha	4.0893	4.0034	4.0012	t = -1.066; p < 0.314	t = -1.207; p < 0.258	t = -0.050; p < 0.962
		Beta	4.2525	4.0836	4.0431	t = -1.888; p < 0.092	t = -2.507; p < 0.033	t = -0.503; p < 0.627

*. The mean difference is significant at the .05 level. (Correction for multiple comparisons: Bonferroni.)
A positive *t* value indicates mean is higher than the baseline mean; a negative value indicates mean is lower than baseline.

VITA

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