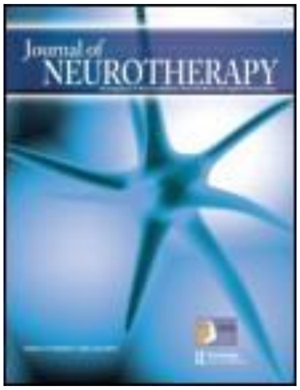

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Spectral Dynamics and Therapeutic Implications of the Theta/Alpha Crossover in Alpha-Theta Neurofeedback

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SCIENTIFIC FEATURES

SPECTRAL DYNAMICS AND THERAPEUTIC IMPLICATIONS OF THE THETA/ALPHA CROSSOVER IN ALPHA-THETA NEUROFEEDBACK

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The theta-over-alpha frequency crossover seen in alpha-theta neurofeedback, considered an important factor in the treatment's success, has had little definitive research. This study examined 182 alpha-theta session graphs from 10 subject case files for interactions between frequency band activity and subject reports of imagery or biographical memories during crossovers, as well as treatment outcomes. Statistical analyses revealed significantly more reports of imagery/memories during crossover conditions having specific spectral, amplitude, and duration characteristics. Imagery reports were more likely to occur during crossover activity of 1 microvolt or more, lasting at least 3 minutes, and including 3.75μv of 15–20 Hz beta. This defined *therapeutic crossover* condition also was significantly related to better treatment outcome measures.

For more than 20 years, alpha-theta brainwave biofeedback (neurofeedback) has been used successfully to treat anxiety-based disorders such as alcoholism (Peniston & Kulkosky, 1989, 1990; Saxby & Peniston, 1995) and post-traumatic stress disorder (PTSD; Peniston & Kulkosky, 1991; Peniston, Marrinan, Deming, & Kulkosky, 1993), and more recently for performance enhancement (Edge & Lancaster, 2004; Gruzelier, 2008; Gruzelier & Egner, 2005) and personal growth (Boynton, 2001; Norris & Curriere, 1999). Alpha-theta neurofeedback training is a form of ''deep states'' training (Demos, 2005) that targets increased amplitude production within the alpha (8–12 Hz) and theta (4–7 Hz) electroencephalographic (EEG) frequency bands. Dr. Eugene Peniston, developer of the multimodal *Peniston Protocol* for alpha-theta neurofeedback, reported observing an intrasession phenomenon he termed ''alpha/theta crossover'' (Saxby & Peniston, 1995). More accurately termed a *theta/alpha crossover*, this brainwave state typically consists of a temporary drop in the existing alpha amplitude accompanied by an increase in the amplitude of the theta signal above that of the alpha. This event is indicated in the session line graph by a ''crossover'' of theta over alpha amplitude that lasts several seconds to several minutes, after which alpha resumes dominant amplitude over theta. An example of a theta-over-alpha amplitude crossover is depicted in Figure 1 (Demos, 2005).

Peniston associated this amplitude crossover state with postsession subject reports of spontaneous imagery and biographical memories. He believed that this crossover state enabled subjects to access and process

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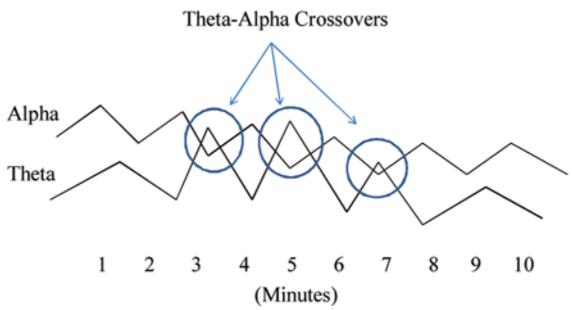

FIGURE 1. Theta-alpha crossover (broadly defined). (Color figure available online.)

emotionally salient material and contributed to ultimate therapeutic outcomes (Peniston, 1991). Following the initial publications by Peniston and his research partner, Paul Kulkosky, questions were raised about a connection between crossovers and reports of spontaneous imagery and memories (Moore et al., 2000). However, little subsequent attention has been given to clarifying the nature of the crossover phenomenon and its role in alpha-theta neurofeedback. The current investigation was undertaken to more thoroughly explore the dynamics and characteristics of this theta-over-alpha crossover event, as well as its relevance to clinical outcomes in alpha-theta neurofeedback.

DESCRIPTION OF THE PENISTON PROTOCOL FOR ALPHA-THETA NEUROFEEDBACK

Peniston and Kulkosky described in detail his multimodal alpha-theta protocol for alcoholism in 1999 (Periston & Kulkosky, 1999). He stated that in his study with military veterans (Peniston & Kulkosky, 1989), his brainwave-training subjects were first introduced to the concept of biofeedback training and instructed on how to interpret the auditory feedback sounds. They sat in comfortable recliner chairs with their eyes closed and received eight 30-min pretraining sessions of temperature biofeedback-assisted autogenic training in which the goal was to increase their hand temperature to 95° Fahrenheit or more, which correlated with deep relaxation and preliminary elevations in alpha and theta EEG bandwidths. Subjects then received 30-min neurofeedback sessions at the left occipital area five times a week for 28 days. At the beginning of each session, the therapist instructed participants to close their eyes, visualize alcohol rejection scenes, imagine increased alpha and theta amplitude activity, and visualize the normalization of their emotions and behaviors. Participants also were given personalized instructions based on their own therapeutic goals, such as to ''tell your unconscious to resolve the conflict,'' ''eliminate the urge to drink,'' or ''allow yourself to be more patient with your family.'' Finally, participants were instructed to ''sink down, keep your mind quiet and alert, and your body calm'' and ''tell your unconscious to 'just do it''' (E. Peniston, personal communication, 1991). The neurofeedback instrument was set to produce a reward sound (pleasant tone) when alpha brainwaves (8–12 Hz) exceeded a specified threshold. A second, different reward sound was produced when theta brainwave activity (4–7 Hz) exceeded a specified threshold. Alpha production was rewarded more heavily than theta; consequently, alpha amplitudes tended to increase more quickly than theta amplitudes in early training sessions. However, usually after 10 or more sessions, theta amplitude often was observed to begin exceeding the level of alpha amplitude during part of a session, manifesting the theta-over-alpha crossover pattern.

RESEARCH BASIS OF THE PENISTON PROTOCOL AND ITS MODIFICATIONS

It has been known for some time that the eyes-closed EEGs of alcoholics show a deficiency of alpha activity (Pollock, Volavka, Mednick, & Goodwin, 1983) and that the consumption of alcohol by nonalcoholic individuals increases alpha activity (Egner, Strawson, & Gruzelier, 2002; Ehlers & Shuckit, 1991; Pollock et al., 1983) and normalizes the EEG (Bauer & Hesselbrock, 1992). In addition to decreased slow wave activity, chronic alcoholics tend to exhibit more fast frequency beta activity in their EEGs (Ehlers & Shuckit, 1990; Winterer et al., 1998), which has been correlated with overarousal, tension, and anxiety (Ehlers & Shuckit, 1990). A familial history of alcoholism correlates with increased high beta brainwave activity (Ehlers & Shuckit, 1990; Winterer et al., 1998). It also has been shown that EEGs of combat veterans with PTSD show decreased alpha activity and increased beta activity (Jokic-Begic & Begic, 2003). Peniston's original protocol was developed to increase alpha and theta slow wave activity via EEG biofeedback (neurofeedback) in order to normalize brain activity by correcting the slow wave frequency deficits identified in the alcoholic population.

Peniston initially investigated his alpha-theta brainwave training protocol and measured beta-endorphin (stress hormone) levels with a group of 20 in-patient subjects with chronic alcoholism (Peniston & Kulkosky, 1989, 1990) in a Veteran's Administration hospital. The results of this study revealed that the 10 alcoholics in the control group who received the standard Veteran's Administration hospital alcoholism treatment displayed significantly higher levels of the stress-related beta-endorphins at treatment completion compared to their pretreatment levels and/or compared to levels of the experimental brainwave training group or to levels of a nonalcoholic control group. Peniston's study demonstrated that alpha-theta brainwave training effectively reduced self-rated depression scores (using the Beck Depression Inventory) and relapse rates in the 10 experimental alcoholic subjects. Furthermore, the brainwave-training group demonstrated significant increases of alpha and theta brainwave amplitudes following training. Eight of the 10 experimental subjects were totally abstinent 13 months following completion of treatment, whereas eight of the 10 controls had relapsed (Peniston & Kulkosky, 1989). After their initial reports on alcohol addiction, Peniston and Kulkosky (1991) reported similar findings for subjects who had combat-related PTSD in addition to substance abuse (Peniston & Kulkosky, 1991). Equally impressive results were later achieved in a much larger study with a polysubstance abuse inpatient population ($N = 121$) using a ''modified Peniston Protocol'' that initially targeted reduction of frontal slow wave activity (4–7 Hz) combined with increasing beta (15–18 Hz) and sensorimotor rhythm (SMR; 12–14 Hz) amplitudes prior to shifting to posterior alpha-theta training. Seventy-seven percent of the experimental group ($n = 55$) that received this combination of beta/SMR training followed by an alpha-theta protocol remained abstinent from substance use at 12 months compared to 44% of the control group ($n = 48$; Scott, Kaiser, Othmer, & Sideroff, 2005). This study approximated the 80% abstinence rates in Peniston's earlier substance abuse study. Additional replication studies have yielded similarly positive findings (Callaway & Bodenhamer-Davis, 2009; Saxby & Peniston, 1995; Scott et al., 2005; Sokhadze, Cannon, & Trudeau, 2008). In addition to Peniston and Kulkosky's research, several other studies have demonstrated that alpha-theta neurofeedback training can normalize personality measures (Bodenhamer-Davis & Callaway, 2003; Byers, 1992; Peniston & Kulkosky, 1991; Raymond, Varney, Parkinson, & Gruzelier, 2005; Scott et al., 2005). In all subsequent reports of alpha-theta neurofeedback applications, the training continued to be completed with eyes closed, with the participant seated in a relaxed position in a reclining chair. Researchers have reported placing the active sensor for the alpha-theta neurofeedback at occipital site O1 (used by Peniston), or at other posterior sites, including O2 (Moore et al., 2000) or parietal site PZ (Raymond, Varney, Parkinson, & Gruzelier, 2004; Scott, Kaiser, Othmer, & Sideroff, 2005; see Figure 3).

THEORIES OF ALPHA-THETA EFFECTIVENESS

Since these first reports of alpha-theta training, experts in the field have debated the nature of its effectiveness (Brownback & Mason, 1999; Moore et al., 2000; White, 1999). Although some have conjectured that enhanced mood resulting from decreased drug habits may contribute to outcomes (Raymond et al., 2005), others have speculated that flooding and systematic desensitization are key mechanisms as the subject retrieves traumatic memories (Trudeau, 2000). However, there seems to be some agreement that alpha-theta training addresses elements common to both PTSD and alcohol addiction. For instance, White (1999) suggested the following:

> Alpha brain waves (8–13 Hz) may be considered a bridge from the external world to the internal world and vice versa. With some addicts and patients previously exposed to major trauma, alpha amplitudes can be low, thereby, creating an inflexibility that keeps one from shifting readily between outward and inward states. (pp. 344–345)

Such patients may avoid or be unable to access internal states and, therefore, lack self-awareness. In turn, the production of alpha waves seems to facilitate greater theta wave activity, which some think is present any time personal insight occurs (Crane, 1992).

There also has been speculation that state-dependent learning and state-dependent memory may be involved in alpha-theta neurofeedback effects. This has been hypothesized because the brainwave activity of children under age 6 is predominantly in the 4–8 Hz (theta) range. White (1999) stated, ''The surfacing of memories from early childhood during the alpha-theta brain wave training fits observations of state-dependent memory because information learned while in one state of consciousness may be more difficult to access when in another state of consciousness'' (p. 345). White also cited Budzynski (1971) conjecturing that ''a predominance of theta in the EEG was the ideal state for rescripting or reimprinting the brain'' (p. 346). Furthermore, Brownback and Mason (1999), who applied alpha-theta neurofeedback to treatment of women with multiple personality disorder, conceptualized the brain state resulting from this training as facilitating integration of traumatic memories with minimal risk, due to a lowered state of arousal. Houck (1994) noted that when an individual's dominant EEG activity is 7.81 to 7.83 Hz, a mental access opportunity occurs. Tansey, Tansey, and Tachiki (1994), who investigated specific (1 Hz wide) brainwave signatures, reported that the brainwave signature specific to memory was the 7 Hz frequency band. Thus, it may be a very narrow frequency range at the fulcrum of alpha and theta frequencies that enables access to this highly liminal state.

ALPHA, THETA AND BETA

Peniston's own view on the effectiveness of his protocol seemed to be that its success derived significantly from the psychotherapeutic advantages provided by the induction of the crossover state. It had been known for some time that the theta-over-alpha amplitude crossover was associated with a hypnagogic state in which spontaneous imagery as well as the recovery of repressed personal memories could occur (Green, Green, & Walters, 1970). Peniston noted that over the course of alpha-theta neurofeedback treatment, as the subject learned to increase alpha and theta amplitudes in his EEG, he may eventually access a ''window of opportunity,'' indicated by the specific crossover pattern in the EEG, in which emotionally charged, anxiety-provoking imagery could emerge and be associated with subsequent abreactive and integrative processes. In this newly acquired state of consciousness, some subjects were able to transfer accessed images to a more wakeful state for deliberate processing. Peniston et al. (1993) noted, ''These images, or the memories, can then be retrieved while in a normal beta-alpha state or conscious mode'' (p. 39). Peniston et al. cited Horowitz (1970), who posited, ''Increased theta *and beta* rhythms reflect a brain process that enables the patient to remember and/or relive the traumatic anxiety-provoking event'' and further postulated, ''The healing process (self-awareness) is manifested in high amplitude *beta and theta waves* [emphasis added] in conjunction with the aforementioned crossover patterns of alpha and theta waves'' (p. 46).

Peniston believed that this particular combination of frequency bandwidth interactions enabled patients to harness the cognitive state necessary to process their anxiety-provoking imageries. In a subsequent replication study, Saxby and Peniston (1995) also observed, "There were significant increases in the theta *and beta* [emphasis added], but not the alpha wave amplitudes in the abreactive session compared to pre-treatment measures" (p. 45). Dr. Peniston believed that much of the therapeutic benefit of this treatment came from an emergence of significant biographical memories, personally meaningful symbolic imagery, and emotional insights during or following these brainwave crossover experiences. He believed that once evoked, the vivid reexperiencing or reliving of repressed events via abreactive imagery afforded the individual the opportunity to constructively process and resolve negative psychological and/or physiological symptoms associated with such events. This capacity of his protocol may have been especially useful with the patient population of mostly Vietnam war veterans with PTSD with whom he worked. Peniston et al. (1993) suggested that the emergence of abreactive imageries and/or memories should be the target and goal of alpha-theta training. Paradoxically, Peniston (1998) later expressed uncertainty as to why the results of alpha-theta training were beneficial.

HISTORICAL ROOTS AND PSYCHOLOGICAL COMPONENTS OF ALPHA-THETA NEUROFEEDBACK

The application of alpha-theta neurofeedback to a variety of disorders began with research conducted in the 1960s and 1970s. The early pioneers of this training were exploring self-regulated brain wave activity and its effects on consciousness and physiology. This group of researchers included Joe Kamiya (1962, 1968, 1969), Elmer and Alyce Green (Green, 1993; Green et al., 1970; Green & Green, 1993), Dale Walters (Green et al., 1970), and Steven Fahrion (1995; Fahrion, Walters, Coyne, & Allen, 1992) of the Menninger Institute, as well as Barbara Brown (1970, 1974), Lester Fehmi (1978), and Thomas Budzynski (1971, 1973). The groundbreaking research of these individuals established the association between electroencephalographic activity and changes in states of subjective consciousness. One definition of consciousness, as a subjective experience, has been described simply as the monitoring of internal representations (Tassi & Muzet, 2001).

The electrical activity of the human brain was originally classified by electroencephalographers into broad aggregate frequency bands that correspond with different states of consciousness (Tansey, Tachiki, & Tansey, 1996). Although faster activity is often associated with greater arousal, slower brainwave frequency activity usually is associated with more subdued or even meditative states. Subjects trained to produce alpha wave activity have identified this (8–12 Hz) state with being relaxed and at peace (Kamiya, 1962). Alpha brainwave activity also has been associated with alterations in the perception of time (Wacker, 1996). Theta (4–7 Hz) can be associated with liminal states of consciousness often accompanied by hypnagogic (leading to sleep) or hypnapompic (waking from sleep) imagery (Brown, 1974). Hypnagogic imagery was described by Frederick Myers (1903) as being a spontaneous projection of impulses from unconscious sources (Brown, 1974) and thus has been associated with creativity and spontaneous imagery states. It was these associations of the alpha and theta frequency ranges with relaxation, creativity, and emergent imagery that led some early biofeedback researchers to speculate that alpha-theta training might promote insight and be a useful method for augmenting psychotherapy (Budzynski, 1973). In fact, Peniston later reported that it was while experiencing hypnagogic imagery during a Menninger Foundation EEG biofeedback workshop that he spontaneously envisioned his successful protocol for treating alcoholism and PTSD (Green, 1993).

Although not targeted directly in Peniston's original protocol, his writings just quoted mention the role of beta in alcoholism and PTSD and its possible role in the theta-alpha crossover phenomenon (Peniston et al., 1993). Beta of 15–20 Hz is associated with alert, outward focus of mental concentration, whereas higher frequency, fast beta (above 20 Hz) can be related to anxiety and cognitive rumination. Peniston also did not address in his protocol the delta frequency band (0–3 Hz), associated with sleep, but the role of delta in the crossover phenomenon is discussed later in this article.

ALPHA-THETA INDUCTION OF DEEPER STATES OF CONSCIOUSNESS

As just described, alpha-theta neurofeedback training reduces central nervous system arousal by inducing a deeply relaxed state that is similar to meditative or other altered states of consciousness. As with all forms of biofeedback, clinical results are achieved over time via a process of computer-facilitated operant conditioning. The therapist sets thresholds for feedback on selected EEG brainwave measures of the specified alpha and theta frequency bandwidths and arranges feedback rewards for increased production of these frequencies. In the eyes-closed, relaxed state, the posterior EEG shows highly rhythmic alpha waves that subside as drowsiness increases (Rowan & Tolunsky, 2003). In the drowsy state, as alpha activity declines, theta and delta waves become the dominant frequencies. In some cases, theta amplitude may temporarily rise above alpha activity without the aforementioned concurrent decline in alpha amplitude. The individual experiencing a crossover state is generally not aware of it at the time it occurs in a session (Egner et al., 2002), but the individual may report experiencing spontaneous images or sensations, memories, or other subjective phenomena associated with deeper states of consciousness following a session in which a crossover appeared in the EEG training record.

SPONTANEOUS IMAGERY AND BIOGRAPHICAL MEMORIES

Spontaneous imagery and biographical memories have been the focus of research related to both ordinary and nonordinary states of consciousness. Tinnin (1990) hypothesized that normal states of consciousness occur when dynamic brain processes generate a sense of mental unity. The loss of this sense of mental unity might cause one to experience a dissociated or altered state of consciousness. Altered states of consciousness may be spontaneously occurring (i.e., hypnagogic states), physically or physiologically induced (i.e., respiratory maneuvers), psychologically induced (i.e., biofeedback), disease induced (i.e., coma), or pharmacologically induced (Vaitl et al., 2005). Spontaneous occurrences of altered states of consciousness, such as hypnagogic states, are known to onset along the wake-drowsiness-sleep continuum (Vaitl et al., 2005). Eighty-six percent of reported occurrences of hypnagogic states were visual, 8% were acoustic, and other sensory modalities accounted for the remaining 6% (Vaitl et al., 2005). The average recall rate reported was 35%. Schacter (1976) described the hypnagogic state as a period between wakefulness and sleep in which spontaneous visual, auditory, or acoustic imagery may occur, possibly in conjunction with symbolic material representative of ongoing psychological or physiological processes. Freud (1910) used the term *repression* to refer to an individual's unconscious efforts (resistance) to prevent the emergence of emotionally painful memories from entering into conscious awareness. Thus, repression involves a disruption in the flow of emotional energy. An abreaction occurs when the continuation of energy is facilitated again. The American Psychiatric Association (1980) defined abreaction as ''an emotional release or discharge after recalling a painful experience that has been repressed because it was consciously intolerable. A therapeutic effect sometimes occurs through partial discharge or desensitization of the painful emotions and increased insight'' (p. 1). Anxiety-provoking imagery is often associated with the memory of a past trauma or aversive situation (Hirsch & Holmes, 2007). Research in the field of cognitive psychology has demonstrated that imagery has a greater impact on negatively valenced events than does verbal processing of the same material (Holmes & Mathews, 2005). Hirsch and Holmes (2007) noted, ''As imagery appears to have a special impact on emotion, it would appear to be an important cognitive process to target in therapy'' (p. 162). Bluck and Habermas (2000) construed autobiographical memories as memories that have emotional or motivational significance to that person's life.

Researchers in one study indexed retrieval of autobiographical memories before and after a cognitive behavioral therapy intervention and found that ''improvement in PTSD symptoms was significantly associated with improved retrieval of specific memories'' (Sutherland & Bryant, 2007, p. 2915).

NEUROPHYSIOLOGICAL CORRELATES OF ALTERED STATES OF CONSCIOUSNESS

The theta-alpha crossover state may be a unique consciousness state that defies classification in traditional categories such as meditation, lucid dreaming, or dreaming. However, to examine the possible mechanisms of action that may be involved in the emergence of imagery and/or memories during theta/alpha crossover states, the investigators thought it beneficial to review the literature on neurophysiological correlates of state change and recall mechanisms along the continuum of alterations of consciousness.

Neurophysiological Correlates of Meditation

Peniston and Kulkosky (1999) conceptualized his alpha-theta neurofeedback protocol as ''an EEG-based relaxation therapy'' (p. 158), which would be similar categorically to other relaxation therapies, including meditation. Early research showed that individuals who could learn to consciously control their brainwaves and produce alpha reported subjective experiences that closely resembled descriptions provided by those who practiced Zen and yoga meditation (Kamiya, 1968). Kamiya also found that experienced Zen meditators learned to self-regulate their alpha brainwave activity more rapidly than nonexperienced meditators. It has been suggested that increased alpha brainwave production is related to the ability to access the kinds of phenomena that are associated with altered states of consciousness, which can include a distorted perception of time (Wacker, 1996). However, theta, rather than alpha, has been reported to be the more reliable marker associated with central nervous system dearousal (Jacobs & Friedman, 2004), as well as the specific change in brainwave spectral activity associated with the practice of meditation (Ivanoski & Malhi, 2007). Ivanoski and Malhi (2007) reported finding ''theta activity strongly related to level of experience of meditation'' (p. 76). Kamiya (1968) similarly reported that mystics who had practiced Zen meditation for 20 years or more produced trains of theta brainwave activity. Although neurophysiological correlates of meditative altered states of consciousness have not yet been firmly established, the main findings implicate increased amplitude activity in both theta and alpha frequency bands, in conjunction with decreased overall EEG frequency (Cahn & Polich, 2006). Other research has shown that meditation increases upper band theta power and lower band alpha power (Takahashi et al., 2004). As such, it is plausible that a person experienced in meditation may respond more successfully to alpha-theta training compared to someone who is not experienced in meditation. Research also has shown parallels between relaxed states, hypnagogic states, and Stage 1 sleep (Jacobs & Friedman, 2004).

Neurophysiological Correlates of Lucid Dreaming

Alpha-theta neurofeedback training may be compared to lucid dreaming, a dream state in which the dreamer becomes consciously aware that he or she is dreaming. The investigators, therefore, reviewed research literature on lucid dreaming and the mechanism for bringing dream activity into conscious awareness. The main distinction that has been found between lucid dreaming and nonlucid dreaming is increased beta (13–19 Hz) activity in the parietal region seen in lucid dreaming, with the greatest increase at P3 in the left parietal lobe (Holzinger, LaBerge, & Levitan, 2006). Taylor (1997) suggested that the parietal area is a site essential to conscious brain activity, supporting findings by Holzinger et al. (2006) that increased beta in the parietal region was a physiological correlate of conscious activity. This conclusion also supports Maddock's (1999) research implicating the left posterior caudal region of the cingulate cortex, located behind the occipital lobe and visual cortex regions of the brain, near the O1 site, as a location important to the retrieval of autobiographical memories. Of related interest is the fact that Peniston used occipital site O1 as the active electrode placement site in his alpha-theta protocol.

Neurophysiological Correlates of Dream Recall

The theta/alpha state also has been characterized as a twilight state (Budzynski, 1973) associated with the hypnagogia that occurs while progressing from wakefulness into Stage 1 sleep. During the usual course of alpha-theta training, the presence of high-amplitude alpha waves gradually decreases, an event associated with the onset of Stage 1 sleep (Fuller, Gooley, & Saper, 2006) and conducive to the emergence of hypnagogic reverie. Alpha-theta training is designed to promote this liminal state bordering wake and sleep that would normally be unconscious to the individual. The current investigators were interested in both the emergence and the retention of imagery and memories, and it seemed plausible that neurophysiological correlates of memory retrieval and recall from either wake or sleep research could account for the occurrence of imagery/memory emergence and retention resulting from the theta/alpha crossover phenomenon. Because alpha-theta neurofeedback training facilitates the kind of hypnagogic activity that occurs in states bordering on sleep stages, it seemed relevant to consider research regarding the neurophysiological mechanisms of dream recall related to various stages along the wake–sleep continuum.

A study on the classification of waking, sleep onset, and deep sleep (Susmakova & Krakovska, 2007) revealed that the best discriminator between a wakeful state and Stage 1 light sleep (the stage associated with alpha-theta hypnagogia) was the power ratio of theta to alpha. The study reported that EEG activity in the 2–7 Hz range displayed the highest amplitude during Stage 1 sleep, whereas alpha activity constituted less than 50% of overall EEG activity in a sleep recording epoch (Susmakova & Krakovska, 2007). Therefore, in distinguishing the sleep/awake state in an EEG record, it is not just a question of which frequency activity is present, but what percentage and ratio of frequency is observed.

Investigations targeting events further along the wake–sleep continuum have found that dreaming is not specific to any single stage of sleep. Furthermore, research has shown that stages that include lower amplitude fast beta (>20 Hz) activity are more likely to contain vivid story like imagery than stages characterized only by higher amplitude slow (theta and delta) brainwave activity (P. C. Williamson, Csima, Galin, & Mamelak, 1986). The mental activity characterized by the presence of beta frequency brainwave activity is equally likely to occur in any stage of sleep and is considered to be a more thought like function of cortical arousal (P. C. Williamson et al., 1986). Williamson conducted research in which he used the Dreamlike Fantasy scale to rate subjects' reports of no recall, thinking, imagery, or dream activity and explored differences in the EEG power spectrum analysis based on the Dreamlike Fantasy level reported in relation to Stage 2, Stage 4, and REM sleep activity. Williamson and colleagues cited Itil, Gannon, Hsu, and Klingenberg (1970), who also associated the superimposition of fast frequency brainwave activity onto slower frequencies of activity as representing a functional stage-shift that might explain dream recall. The premise of the functional stage-shift model is that the more closely the EEG pattern in any stage of sleep resembles patterns observed during wakefulness, the more likely one is to recall the mental activity that occurred therein. Williamson's study supported this contention and concluded that higher amplitudes in the beta band were correlated with increased dream recall (P. C. Williamson et al., 1986).

Moffitt et al. (1982) conducted research on dream recall when subjects were aroused from different stages of sleep. In both REM sleep and Stage 2 sleep, beta activity was correlated with successful recall and longer reports of dream activity. Higher average beta power correlated with better dream quality characterized by enhanced color, vividness, activity, and the number of people and scenes the subject recalled. This was true for high recallers and low recallers. However, differences in beta activity were observed to depend upon which hemisphere and in which stage of sleep the beta activity occurred. Low recall of dreams has also been associated with greater endorsement of repression based on Minnesota Multiphasic Personality Inventory (MMPI) responses (Tart, 1962; R. W. Williamson, Heckel, & Boblitt, 2006).

Relationship of Delta Brainwave Activity to Deeper States of Consciousness

Delta brainwave activity (0–3 Hz) has traditionally been associated with sleep, early infancy stages, and neurological pathology (Fisch, 1999). Delta activity also positively correlates with P300 evoked responses to unexpected stimuli as a correlate of cognitive and attentional processes. Research indicates that delta activity may serve to inhibit irrelevant neural activity in order to increase one's attention to internal processing (Harmony et al., 1996). Alper (1999) stated, "Delta in normal awake humans can apparently be a correlate of the process of allocating attention and limiting access of extraneous stimuli during states in which the cortex is processing its own output" (p. 212). There is evidence that the presence of delta brainwave activity might be associated with cognitive processes, which includes abstract reasoning, and increased delta amplitude has been associated with peak euphoric experiences (Alper, 1999). Increased amplitude in delta and theta bands has also been associated with transformations in conscious experience that could involve insight, creativity, problem solving, or mystical experience (Don, 1977). Delta activity also has been demonstrated to occur during transpersonal experiences and transpersonal changes in consciousness (Sagi, 2003; Wilson, 1993). An EEG study revealed a pattern of increased delta, theta, and alpha amplitudes among an experienced group of transcendental meditation practitioners during subjectively reported higher states of consciousness during sleep (Mason et al., 1997).

DYNAMICS OF THE CROSSOVER PHENOMENON

The first experimental investigation to look closely at the purported connection between crossovers in alpha-theta neurofeedback and subsequent reports of memories and unconscious material was done by Moore and colleagues (2000). The question among clinicians and researchers alike, at that time, was whether the emergence of imagery and emotional memories produced during theta-over-alpha amplitude crossover experiences was in fact a necessary component to a successful treatment outcome.

Moore et al. (2000) found an inverse relationship between the incidence of theta-alpha crossovers and subject reports of the occurrence of visual imagery. Following their analysis of alpha and theta patterns produced by subjects undergoing the Peniston Protocol, these investigators found that self-reported visualizations were less likely to occur during the presence of "alpha-theta crossover" conditions. They reported that visualizations occurred with greater frequency in sessions where fewer crossovers were present. The researchers concluded that the theta-over-alpha crossover state was not related to retrieval of imagery or emotional memories as Peniston had contended.

Several methodological issues related to the Moore et al. (2000) study are important to note, however. Moore et al.'s subjects were trained in randomly assigned groups of two to six rather than individually, and it was not clear if the recording technician watching the subjects was a trained therapist. In the context of his research with marijuana subjects, Tart (1969) noted that the presence of other subjects and/or the presence of a technician who did not have a therapeutic relationship with the subjects could impact the subjective experience of an altered state of consciousness. Perhaps a major distinction, however, is that this study used site O2 instead of O1 for sensor placement. Furthermore, the Moore et al. study focused on alpha and theta brainwave activity and did not address the activity of other frequency bandwidths that may mediate or moderate subjects' abilities to self-report spontaneous visualization activity.

CLOSER ANALYSIS OF THE CROSSOVER PHENOMENON

Another way of viewing the theta/alpha crossover and imagery relationship question is to consider that the presence or absence of a theta-alpha crossover condition during a session may not be the only requisite precondition to imagery recall. As Peniston speculated, a sufficient percentage of beta activity may need to be present to enable the therapy participant to transfer the experience from unconscious experience to conscious awareness and retrieval of the imagery. Because the crossover phenomenon has not been thoroughly investigated beyond the research by Moore et al., it is possible that additional EEG components and dynamics are involved in the totality of the crossover experience. The current investigators looked to the research literature on the role in memory processes of a wider range of components of the EEG frequency spectrum, seeking more information that might help explain the subjective and objective phenomena observed during theta/alpha crossovers.

THETA AND HIPPOCAMPAL MEMORY

The hippocampus structure of the brain is involved in consolidating emotional experiences into long-term memory storage (Tesche & Karhu, 2000). The hippocampus generates theta wave oscillations when in its ''on-line'' state of functioning (Buzsaki, 2002), and theta oscillations have been strongly correlated with memory functions (Tesche & Karhu, 2000). It has also been suggested that theta facilitates the process of long-term potentiation to promote the formation of long-term memories (Cantero et al., 2003) and to correlate with successful encoding and retrieval of episodic memory tasks (Tesche & Karhu, 2000). Brief theta bursts recorded in the human hippocampus during REM sleep may support memory consolidation models that posit potentiated ''off-line'' memory consolidation during sleep (Cantero et al., 2003). Cantero et al. stated,

> A possible functional role for the human REM bursts reported here might be the ''off-line'' reactivation of memory traces within the hippocampus, perhaps priming the memory for replay to the neo-cortex during other sleep stages or in association with other electrophysiological events. (p. 10902)

NEUROPHYSIOLOGICAL CORRELATES OF WAKING MEMORY AND RECALL

Klimesch, Vogt, and Doppelmayr (2000) reported on interindividual differences in how alpha and theta frequency bands reflect memory performance. Their research demonstrated that desynchronized alpha activity in the upper range (10–12 Hz) reflects the encoding and processing of semantic (long-term) memory demands, whereas synchronized theta activity (4–7 Hz) reflects the encoding of new information as a function of working memory (Klimesch et al., 2000). Although some researchers have reported on the separate activity of decreasing alpha waves and increasing theta waves during alpha-theta training, studies such as this by Klimesch et al. suggest that it may prove more instructive to consider the combined interaction of alpha and theta frequency bands.

A study on mental imagery (von Stein & Sarnthein, 2000) revealed that the prominent feature of internal mental processing activity was increased theta and alpha *interactions*, suggesting that low-frequency EEG interactions might characterize top-down (mental internal processing) activities (as opposed to bottom-up sensory processing via the peripheral nervous system). The authors of this study proposed that higher amplitude alpha activity does not reflect an inactive, idling brain state but rather a state of internal mental activity driven by mental imagery and free-floating associations (von Stein & Sarnthein, 2000). Thus, alpha and theta frequency interactions may represent different types of internal mental-processing activity. However, waveform interactions where theta amplitude only briefly exceeds alpha amplitude may not be sufficient to produce emergent imagery or memories.

Schack, Klimesch, and Sauseng (2005) also reported, ''There is evidence that the activation and flow of information across widely distributed brain areas may be reflected or coordinated by phase coupling within and between different frequencies'' (p. 106). Their research on memory indicates that although the upper alpha frequency is dominant in memory retention, *alpha and theta* oscillations both become more prominent during memory retrieval. The findings of this research support the understanding of how a complex interplay between timing, different EEG oscillations, complex brainwave topographical patterns, and widely distributed brain areas and frequencies contribute to the process of working memory. Therefore, it would appear that alpha and theta amplitudes should not be examined in isolation for their relevancy to emotional memory and spontaneous imagery retrieval in alpha-theta neurofeedback training but that the complex interplay of additional EEG spectral activity and components should be addressed. Further investigation of the theta-alpha crossover visualization and memory retrieval phenomenon may necessitate taking a wider view of the ongoing EEG brainwave activity during alpha-theta training, especially the role that beta (15–20 Hz) may play in an individual's ability during the session to become aware of and recall the occurrence of memories that need to be transferred to alert consciousness in order to be used for psychotherapeutic benefit.

RELATIONSHIP OF BETA TO IMAGERY AND MEMORY

In contrast to alpha activity (8–12 Hz), which has been associated with shifting attention away from external stimuli in order to process internal experiences with greater efficiency, beta activity (16–20 Hz) has been associated with emotional and cognitive processes (Ray & Cole, 1985). Changes in the beta rhythm have been found to accompany changes in the alpha rhythm (Carlqvist, Nikulin, Stromberg, & Brismar, 2005). Carlqvist et al. investigated the relationship between resting state alpha (7.5–12.5 Hz) and beta (15–25 Hz) frequency oscillations. The strongest correlations of power and synchrony between the two bandwidths were observed in the occipital region of the brain, suggesting that these two bandwidths may be generated by a common mechanism. Visual imagery has been associated with the occipital lobe, which includes visual cortical areas (Fallgatter, Mueller, & Strike, 1997). Wrobel (2000) demonstrated that increased power in the beta band also appeared during visual attention in the primary visual cortex, lateral geniculate nucleus, and in the higher visual areas. Wrobel, who cited Mundy-Castle (1951) and von Stein, Rappelsberger, Filz, and Petsche (1993), noted ''increased beta activity in subjects habitually using vivid visual imagery as compared to negligible beta activity recorded in subjects with relatively inadequate visual imagery ability'' (p. 250). Wrobel subsequently ascribed to beta frequency brainwave activity the role of an attention carrier related to visual processes. Wrobel concluded from his investigations that activity in the beta frequency band reflects a specific attentional state of the visual system that can be activated during increased visual attention demands. Abarbanel (1995) noted that both theta and beta frequency bands are present in hippocampal circuitry and, furthermore, that gating functions, state changes, and frequency resonations among brain centers are important functions of oscillatory activity.

Although alpha activity may be characteristic of internal mental activity driven by mental imagery and free-floating associations of the visual system, beta activity, as a carrier of visual attention, may function to shift the visual system to an attentional state that subsequently enables perception and integration of visual stimuli via additional processes in the gamma (30–100 Hz) frequency range (Wrobel, 2000). Thus, alpha, beta, and gamma frequency bands related to visual pathways may be conceptualized as having gating functions that can shift processing levels from a state of internal visual system arousal to a state capable of carrying visual attention and then, finally, to a state that can integrate and process. This framework also suggests that each preceding stage might set the background necessary for the next level of higher functional processing to emerge. Wrobel's research supports a hypothesis that a concatenation of events needs to occur for successful therapeutic processes relevant to theta-alpha crossover phenomenon to occur.

Beta frequency brainwave activity might also have a unique connection to brain structures related to imagery and memory. Laufs et al. (2003) observed that increased functional magnetic resonance imaging signal in the retrosplenial cortex (Figure 2, #29) correlated with increased beta-2 (17–23 Hz) power.

It has been suggested that when a person is awake, but in a resting state, brain activity switches to a default mode in which the highest values of blood flow and metabolic activity occur in the retrosplenial cortex (Laufs et al., 2003). The retrosplenial cortex is a relatively unstudied brain region located caudal to the posterior cingulate cortex and is anatomically positioned to draw on amygdala, parahippocampal, and entorhinal cortices, which are known to be associated with emotional and episodic (long-term) memory processes (Maddock, 1999). Activation of the retrosplenial cortex has been associated with the retrieval of episodic autobiographical memories (Maddock, 1999). During autobiographical memory retrieval, the greatest activation has been shown on functional magnetic resonance imaging to occur in the left posterior caudal region of the cingulate cortex (Maddock, Garrett, & Buonocore, 2001). According to the cytoarchitecture of the brain outlined by Brodmann (1903), this brain region appears to be located behind the occipital lobe and visual cortex regions of the brain, possibly at the O1 site as measured by the International 10-20 electrode placement system (Figure 3; Jasper, 1958).

Maddock (1999), citing the research of Andreason et al. (1995), noted that these researchers suggested,

> Retrosplenial activity might be associated with the spontaneous mentation that occurs when human subjects are not engaged in a focused task. This mentation would typically include the retrieval of emotionally salient mental contents from autobiographical memory and possibly the encoding into memory of these episodes of reflection and thought. (Maddock, 1999, p. 314)

The retrosplenial (and parietal regions), which often show activation during episodic memory recall, became deactivated in a group of Vietnam veterans with PTSD during an experimental condition in which they were exposed to combat sounds intended to induce mental imagery from past personal experience (Liberzon et al., 1999). This deactivation of the retrosplenial cortex may serve to manage the symptoms of PTSD by limiting access to anxiety-provoking autobiographical memories. The retrosplenial cortex also has been known to be activated by pleasant stimuli as well (Maddock, 1999).

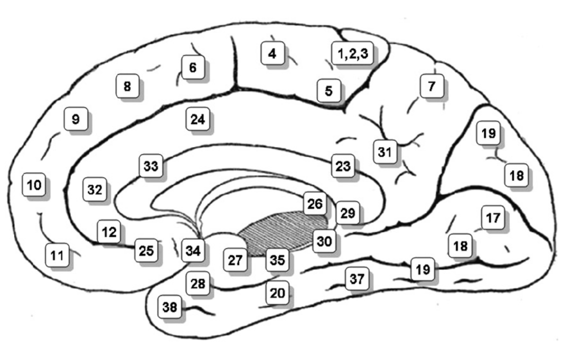

FIGURE 2. Anatomical location of the retrosplenial cortex. *Note*. Brodmann located the retrosplenial cortex (29) as being positioned adjacent to the occipital lobe and visual cortical areas (*Source*: http://en.wikipedia.org/wiki/Brodmann_area).

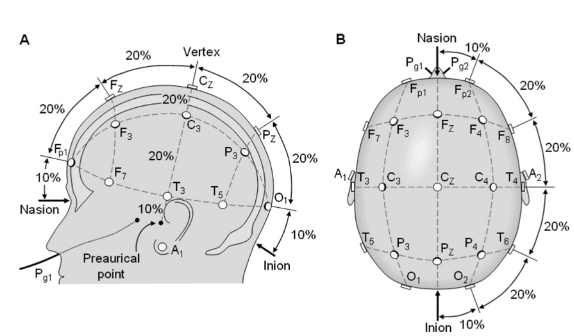

FIGURE 3. The International 10-20 System of Electrode Placement. *Note*: Site O1 is located on the left side of the occipital lobe at the back of the head (*Source*: http://www.bci2000.org/wiki/index.php/User_Tutorial:EEG_Measurement_Setup).

EEG SPECTRAL BAND INTERACTION PATTERN

As posited earlier, to understand the imagery recall function of the theta-over-alpha crossover phenomenon described by Peniston and others, not only does the interaction of specific frequency band activity need to be considered, but also the complex interactive dynamics of the wider collective brainwave frequency band activity. Bastiaansen, Oostenveld, Jensen, and Hagoort (2008) conducted a study in which they investigated EEG oscillatory brain dynamics as subjects engaged in a visual lexical (words related to imagery and colors) task. The researchers in this study found that although alpha power (8–12 Hz) decreased, both theta power (4–7 Hz), and beta (13–18 Hz) increased. This was consistent with Peniston, Marrinan, Deming, and Kulkosky's (1993) findings that during alpha-theta sessions in which subjectively relevant imagery was reported, significant amplitude increases occurred in both theta and beta ranges, but not in alpha. In addition to their other findings, Bastiaansen et al. reported the striking finding that larger theta amplitude increases produced by words with *auditory* semantic properties were observed in the left temporal cortex, whereas larger theta amplitude increases produced by words with *visual* semantic properties were observed in the occipital cortex, which was Peniston's location of choice for alpha-theta training and perhaps necessary to access imagery and visualizations. These topographical power changes were specific to theta power changes, but not found in relation to other frequencies, which would correspond to the clinically observed substantial rise in theta amplitude during subjectively relevant theta-alpha crossovers.

GATING FUNCTION OF FREQUENCY BANDS IN ACCESSING IMAGERY AND MEMORY

The literature previously cited helps clarify how EEG spectral band activity may interact and combine to produce the circumstances necessary for access to imagery and memory. This review led the authors to a hypothetical conceptualization of how each frequency, and combinations of frequencies, may provide ''gating functions'' to achieve certain consciousness conditions observed during alpha-theta neurofeedback. Alpha brainwave activity may shift attention inward to a state of visual system arousal (Wrobel, 2000). Beta may shift to a state capable of carrying visual attention (Wrobel, 2000). Theta may produce a shift that activates hippocampal (emotional and episodic memory) processes (Tesche & Karhu, 2000). Delta may shift to internal processing of cortical output and limit extraneous stimuli (Harmony et al., 1996), and co-occurring dominant delta and beta activity may facilitate a functional stage shift that might account for dream recall (Itil, Gannon, Hsu, & Klingenberg, 1970; see Table 1 for a summary of this process).

It could be concluded from electrophysiological research evidence to date that certain frequency band combinations (i.e., alpha, theta and beta; or alpha, theta and delta) may

TABLE 1. Gating Functions of Frequency Bands

Frequency band	Measurement in Hz	Corresponding state of consciousness	Gating function
Alpha	8–12	Internal mental activity driven by mental imagery (White, 1999)	Shifts attention inward to a state of visual system arousal
Beta 2*	15–20	Alert, outward focus of mental concentration (Wrobel, 2000)	Shifts to a state capable of carrying visual attention
Theta	4–7	Pre-sleep, hypnagogic (Tesche & Karhu, 2000)	Shift may activate hippocampal processes
Delta	1–3	Sleep, dreaming (Harmony et al. 1996)	Shifts to internal processing of cortical output and limits extraneous stimuli
Delta/Beta	1–3/Beta 2	Present during greater dream recall (Itil et al., 1970)	Functional stage shift that might explain dream recall

* Beta 2 refers to a specific range of beta involved in focused cognitive activity.

facilitate access to different types of imagery or memory experiences.

CATEGORIZATION OF SPONTANEOUS IMAGERY

It cannot be assumed that everyone experiences the same alterations of consciousness and visualization content when participating in alpha-theta training; there are a variety of patterns (Demos, 2005). Therefore, another important aspect of the theta-alpha crossover phenomenon explored in this investigation was the nature of subjective experiences reported by participants in alpha-theta neurofeedback therapy and their relationship to specific EEG frequency bandwidths. As stated earlier, many alpha-theta neurofeedback practitioners attribute the success of the treatment to the frequently observed emergence of imagery and memories that occurs during crossover experiences. The spontaneous emergence of imagery and memories range in depth from light hypnagogic imagery (e.g., colors, geometric shapes, etc.) to much deeper states of consciousness containing more personally relevant material. Previous studies of the theta-alpha crossover state do not provide specific descriptions of the kinds of visual imagery that subjects reported, although Moore et al. (2000) noted variability in the nature and complexity of self-reported imagery provided by subjects.

To explore relationships between spontaneous imagery and/or memories and frequency dynamics during crossovers, the current investigators used methods of earlier investigators for categorizing the imagery that emerges during states of consciousness induced by various brainwave frequency configurations. The following descriptive groupings are an adaptation of the categories or cartographies of subjective experience provided by early practitioners of EEG alpha and theta biofeedback (Brown, 1974; Crane, 1992; Tansey et al., 1994) as well as descriptions of levels of subjective experience provided by earlier consciousness researchers cited next. Tansey et al. (1994) also attempted to match categories of imagery/subjective experience to their possible EEG frequency correlates observed during neurofeedback clinical sessions.

ACQUISITION OF DATA FROM SUBJECT REPORTS FOLLOWING CROSSOVER EXPERIENCES

Researchers who attempt to determine the psychological correlates of consciousness states must depend on subjective reports of research participants. Investigators in the present study accessed the content of imagery experienced by the alpha-theta neurofeedback participants through the written session notes located in subject files and recorded by the neurotherapists. The investigators treated these subjective reports as qualitative observational data derived from carefully recorded neurofeedback session notes. These reports were elicited by questions routinely posed by therapists after the EEG feedback was completed toward the end of a session. Such questions would take the form of, ''Did anything come up for you in this session?'' or ''Did you have any images or memories this time?'' as suggested by Peniston (personal communication, 1992). When imagery experiences were reported, the therapist immediately recorded the report using the participant's own words as closely as possible. It should be noted that Peniston advised that the neurotherapist maintain a neutral, nonjudgmental attitude toward the content of such reports, neither directly suggesting nor implying that imagery reports or memories should occur or not occur during treatment. Participants can be asked what particular images, sensations, memories, or symbols mean to them personally, but the subjective report content is not to be interpreted by the therapist (Peniston, personal communication, 1992). This is one way in which alpha-theta neurofeedback differs from the psychoanalytic model of therapist interpretation. All such participant reports are to be handled in the customary clinical, as well as research, manner of unbiased objectivity.

The following classification system was designed to provide a framework for examining the relationship between alpha-theta session spectral configurations, frequency ratios, and content of subject postsession reports of imagery and emotional experiences. An in-depth examination of subjective experiences and content reported by individuals undergoing alpha-theta neurofeedback not only may contribute to better understanding the dynamics involved in crossover states but also may inform neurotherapists of the types of participant reports that can be expected to emerge during sessions with specific frequency configurations.

CATEGORIES OF IMAGERY ASSOCIATED WITH VARIOUS LEVELS OF CONSCIOUSNESS

Based on the work of earlier researchers, the following classification system was developed for use in this study.

Category 1: Abstract/Aesthetic

As identified in previous research (Brown, 1974), Category 1 contains abstract/aesthetic experiences possibly occurring in the range of 10–15 Hz (SMR/Alpha). Category 1 may include visual (intense colors, geometric shapes, after images, optical illusions, animation of visual material, colored spots, exotic scenes, and geometric/abstract designs), acoustic (hypersensitivity to sound, acoustical illusions, and synaesthesia), and emotional experiences (interpretation of the environment as beautiful, comical, or magical). Example of a subject report classified as Category 1: ''There was swirly imagery and sounds that were like voices.''

Category 2: Biographical

Category 2 includes biographical experiences and is possibly associated with brainwave frequencies in the range of 5–10 Hz (Alpha/Theta). This level includes important memories, emotional problems, and unresolved conflicts from various periods in an individual's life and may include physical/motor responses that precede the emergence of Category 2: nausea/vomiting, breathing difficulties, cardiovascular complaints, profuse salivation, sweating, diarrhea, pain, skin rashes, stereotyped movement, and mechanical verbal repetition. Example of a subject report classified as Category 2: ''I re-experienced being molested by my stepfather when I was 7 years old.''

Categories 3 and 4 contain imagery that might best be described as personally relevant dreamlike or symbolic material. Images or experiences in these categories would be classified as content not directly related to ordinary reality (Grof, 1976; Tart, 1962, 1969; Wilbur, 1993).

Category 3: Perinatal (Grof, 1976)

Category 3 may be related to the same brainwave frequencies as Category 2, in the range of 5–10 Hz (alpha/theta) and includes reports of images or sensory experiences that subjects themselves associate with events surrounding birth or metaphorical birth-like experiences. Example of a subject report classified as Category 3: ''I saw myself being born. A nurse kept throwing towels of blood. I was drenched in blood. It felt like it was my actual birth.''

Category 4: Transpersonal

Category 4 is probably associated with EEG frequencies in the range of 0–4 Hz (delta/theta). Reports grouped in this category include what might be termed mystical, spiritual, or archetypal images, such as those of ''angels,'' ''guides,'' or other nonordinary subject matter (Jung & van Franz, 1964; Wilbur, 1993). Example of a subject report classified as Category 4: ''At first, it was like I was in a submarine exploring my body and traveling through my arteries. Then there was a spiritual being that was doing healing work with its hands over my heart, with glowing blue light.''

REFINEMENT OF THE CROSSOVER DEFINITION

Given the research literature just summarized, it appeared to the investigators that a broader conceptualization of the theta/alpha crossover was warranted, one that recognizes the complex nature of this event. Basar, Basar-Eroglu, Karakas, and Schurmann (2001) defined complex brain functions as being characterized by several superimposed brainwave oscillations that vary

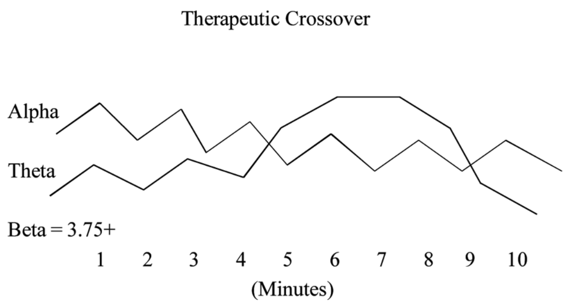

FIGURE 4. Refinement of the therapeutic crossover definition.

in their degrees of amplitude, duration, and timing. The term *therapeutic crossover* can be used to describe the type of phenomenon Peniston and others have reported occurring during alpha-theta neurofeedback. In a preliminary visual inspection of crossover events obtained from a sample of 182 clinical alpha-theta sessions (sample described in detail in the Methods section to follow), the authors were able to identify specific amplitude and temporal criteria that distinguish *therapeutic crossovers* from theta/alpha crossovers that do not yield personally relevant material. The specific amplitude and temporal criteria were then evaluated with exploratory modeling analysis, and a model of best fit for mean amplitude within the superimposed beta range was defined. This analysis indicated that a *therapeutic crossover* that is likely to accompany emergent imagery would be distinguished as a theta-over-alpha amplitude crossover that rises at least 1 microvolt or more in amplitude above alpha and remains dominant over alpha amplitude for 3 to 10 min or longer, as well as contains the 15–20 Hz beta superimposed brainwave frequency components (Figure 4). This definition provides quantifiable and heuristic criteria that may describe the type of crossover that Peniston identified as a significant contributor to therapeutic success in his protocol.

HYPOTHESES GENERATED FOR THIS INVESTIGATION

The authors decided to test several hypotheses derived from their review of the electrophysiological and neurophysiological research just summarized and from preliminary visual inspection of their data set of 182 alpha-theta clinical session crossover records. Questions of interest derived from the aforementioned reviews related to the frequency interaction dynamics apparently involved in crossovers, specifically whether the duration of crossover, amplitude of difference (i.e., amplitude of theta above alpha), and interactions between duration and crossover have an effect on imagery/memory, as well as the precise nature of these relationships in alpha-theta neurofeedback. Additional questions of interest focused on relationships between specific frequency band activity during crossovers and content of reported imagery/memory experiences. Finally, the investigators wanted to test Peniston's contention that there is an important relationship between crossovers and therapeutic outcomes in alpha-theta neurofeedback. The preliminary literature and crossover clinical session reviews produced the following empirical research questions:

RQ1.0: What constitutes a *therapeutic* (as defined above) theta-alpha crossover?
RQ1.1: Is the amount of theta amplitude increase in the theta-over-alpha crossover and its duration important to the emergence of spontaneous imagery and memory?
RQ1.2: Is a minimum amount of beta amplitude increase necessary to recall the content of imagery and memories evoked in alpha-theta training after a subject returns to an alert state of consciousness?
RQ2.0: Are there relationships and ratios of specific bandwidths that are relevant to the type of imagery content that emerges?
RQ2.1: Is there a relationship between delta brainwave activity and Category III & IV (deeper/transpersonal) states of consciousness?
RQ3.0: Are higher quality *therapeutic* crossovers related to better overall treatment outcomes?

Hypotheses

The following hypotheses were developed and statistically tested:

H1: Subjects who produced *therapeutic* crossover activity (minimum of 1 microvolt

in amplitude and minimum duration of 3 min) will show significantly more occurrences of Category II, III, and IV imagery than those who did not.
H2: Subject reports of Category II, III, and IV imagery will occur only following sessions in which theta-alpha crossovers occurred along with a mean amplitude of at least 3.5 microvolts in the 15–20 Hz beta range.
H3: There will be a significant positive correlation between increased delta frequency activity and Categories III and IV levels of imagery.
H4: Participants with more *therapeutic* crossovers will show greater improvement on treatment outcome measures than those with fewer *therapeutic* crossovers.

METHODS

Participants

Data for this study were obtained through a retrospective review of case files of individuals who completed alpha-theta neurofeedback training as part of their treatment for substance abuse, depression, or posttraumatic stress disorder at a university-based clinic and at a private neurofeedback practice. All subjects were treated and their data recorded between 2002 and 2008. Ten files of individuals who participated in alpha-theta neurofeedback were found to contain sufficient EEG session data and participant postsession subjective report information to permit analysis for this study. As a prerequisite to treatment, subjects whose records were used in this study were required to have read and signed an informed consent document that explained treatment requirements and possible side effects or risks of the treatment. Subjects also had given written permission for any information gained through their neurofeedback treatment to be used anonymously for educational or research purposes. The sample of subjects was gender balanced (five women, five men). All were Caucasian, ranging from 22 to 58 years of age (M age = 41). The mean session length of alpha-theta training was 32.97 min. Although participants were intended to receive 30 alpha-theta training sessions, the actual number of sessions completed varied due to attrition. With the exception of one subject who completed only three sessions (but did have a significant crossover with accompanying biographical imagery), other subjects received treatment that ranged from 11 to 29 sessions. Alpha-theta session graphs and therapist session notes ($N = 182$) were analyzed for quantitative crossover characteristics, reports of associated imagery content, and treatment outcomes.

Instrumentation and Protocol

Alpha-theta brainwave training for the selected clinical sessions was provided using BrainMaster Atlantis version 3.0 software ($n = 8$) and Lexicor, Biolex software ($n = 2$) EEG-biofeedback instrumentation. BrainMaster equipment was set to include a 60 Hz notch filter, a data sampling rate of 256 samples per second, a 125μv artifact threshold, and a peak-to-peak amplitude scale. This equipment was set to reward theta (5.0–8.0 Hz) amplitude increases above threshold 30 to 40% of the time, and alpha (8.5–11.5 Hz) amplitudes were to be to be rewarded 70 to 90% of the time. Lexicor equipment was set for a 60 Hz notch filter and for a data sampling rate of 128 samples per second with theta (4–7 Hz) enhanced 20 to 25% of the time and alpha (8–12 Hz) enhanced 70 to 75% of the time. All active electrode placements were at O1 (Figure 3), with left ear (A1) reference sites. The right ear was used for the ground site. These slight variations between equipment and software protocol settings should have had little or no influence on the kinds of variables of interest in this study because both instruments and protocols reliably enabled subjects to produce increased amplitudes of alpha and theta frequencies. Each subject sat with eyes closed in a comfortable recliner chair, received progressive muscle relaxation instructions, behavioral outcome visualization suggestions (e.g., alcohol rejection behaviors), and usually a 30- 40-min brainwave training session. For the most part, this session activity procedure was consistent across all subjects and followed Peniston's researched protocol only, or a modified Peniston Protocol based on QEEG findings for the individual in which 10 or more initial sessions focused on reducing excessive frontal/central slowing (2–7 Hz down at Fz and/or Cz) prior to initiation of the posterior alpha-theta training.

Methods

Selected alpha-theta neurofeedback session graphs and session report data were extrapolated into a Microsoft Excel spreadsheet from archived subject files from both clinical sites. These data were then imported into the statistical analysis software program SPSS (Statistical Package for the Social Sciences) for analysis. The variables of interest included subject demographic and training information (meditation experience, length of session, and time of day); theta-over-alpha crossovers (amplitude and duration); mean frequencies and amplitude differences in delta, theta, alpha, beta (15–20 Hz), and high beta (>20 Hz) bandwidths; and subject reports of imagery and memories documented by therapists in session reports.

ANALYSES

Overview

A multinomial regression was developed to address Research Questions 1 through 4. This statistical model was chosen for its predictive value and capability to evaluate association of covariates with mutually exclusive patterns of dependence as well as its ability to accurately describe relationships among the variables of interest in this study. Figure 5 depicts a flow chart representing the hierarchical and multivariable predictive pathway that was investigated using the multinomial regression analysis procedure to evaluate the likelihood of occurrences of imagery.

A means comparison analysis (analysis of variance) was performed to address Hypothesis 4. Chi-square tests were performed to evaluate the independence of therapeutic versus non-therapeutic crossovers, addressed in Hypothesis 1. In this analysis, the number of therapeutic crossovers was the independent variable and treatment outcome measures, which consisted of the Beck Anxiety Inventory (BAI), Beck Depression Inventory (BDI), Beck Hopelessness Scale (BHS), Pittsburg Sleep Quality Inventory (PSQI), and MMPI, were the dependent variables.

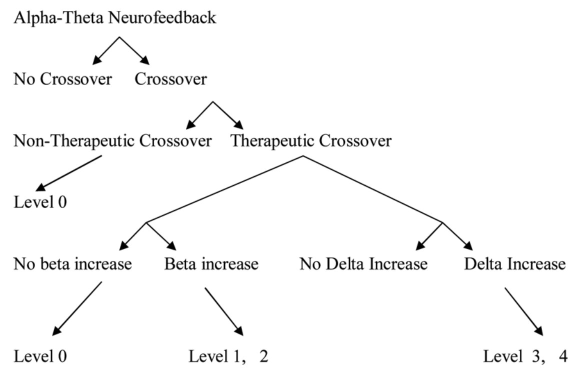

FIGURE 5. Design of the study; sequence of investigational questions.

First conducted were crosstab analyses and chi-square significance tests regarding the category of visual imagery by crossover type with and without beta. Next, additional crosstab analyses were conducted to assess changes extant in the data when only therapeutic events (spontaneous biological, perinatal, transpersonal imagery or experiences) were reported by the subject to the therapist, and whether increases in the mean amplitudes of slower brainwave activity correlated with progression into deeper states of consciousness, as defined by the category of imagery/memory reported. For purposes of this study, in the 25% of cases where subjects experienced multiple categories of imagery, the higher category was reported (e.g., a report of a biographical memory and a transpersonal experience was coded as the latter). However, in 75% of cases, the subject reported one category of imagery, which the therapist categorized and documented according to specified criteria. Two imagery content reviewers rated the documentation independent of brainwave data for categorization as well. The two reviewers achieved 100% interrater reliability in classifying all imagery reports into one of the four imagery categories defined earlier in this article. Third, multinomial regression was used to examine the model's accuracy in predicting visual imagery during sessions where a therapeutic crossover occurred with beta conditions and deeper imagery levels (Category IV) when higher amplitudes of delta were present. Because a subject may have experienced differing types of crossovers in the course of treatment, he or she would be categorized according to overall tendency (e.g., a subject who experienced one or two therapeutic crossovers with sufficient beta but also experienced eight therapeutic crossovers without sufficient beta would be placed in the latter category). Fourth, an analysis of variance was performed to assess whether treatment outcomes showed greater improvement when therapeutic crossover conditions were present.

RESULTS

Occurrence of Crossover Activity

Crosstab analysis was used to examine crossover activity in which theta brainwave frequency rose in amplitude above alpha brainwave frequency activity. This analysis indicated that 27.9% of the alpha-theta neurofeedback session graphs contained no crossover activity, 34.1% contained nontherapeutic crossover activity, and 37.9% contained therapeutic crossover activity. A follow-up crosstab analysis assessing occurrences of categorical imagery types revealed that no imagery was reported in 67.4% of the sessions, hypnagogic imagery was reported in 14.7%, biographical imagery was reported in 7.1%, perinatal imagery was reported in 2.1%, and transpersonal imagery was reported in 6%, $\chi^2(8,\ N = 182) = 47.4$, $p < .001$. Table 2 summarizes the reports of imagery according to crossover type in sufficient beta and in insufficient beta conditions.

Relationship of Crossover Activity to Other EEG Frequencies and Categories of Imagery

Because a primary question motivating this research was whether imagery and memories of emotionally salient material are related to the occurrence of crossovers in alpha-theta neurofeedback therapy sessions (Saxby & Peniston, 1995), a thorough analysis was performed on the relationships between crossovers and imagery reports. Because amorphous hypnagogic activity was more frequently observed in sessions with no crossover or nontherapeutic crossover activity, it was decided to focus on reports of biographical, perinatal, and transpersonal imagery in sessions where therapeutic crossover activity was observed (Table 3). These three types of potentially personally meaningful imagery were reported 85.7% of the time in the therapeutic crossover condition, with 71.4% of reports conveyed when beta was of sufficient amplitude.

The multinomial regression, using the design illustrated in Figure 5, produced a well-fitting model under the likelihood ratio test that compares the final model with predictors to the intercept or null model, $\chi^2(6,\ N = 182) = 83.3$, $p < .001$. The final model had a medium-sized effect, Nagelkerke pseudo-$R^2 = .457$, with each predictor making a statistically significant contribution to the overall model fit (see Table 4).

TABLE 2. Category of Visual Imagery by Crossover Type With and Without Beta

		Non-therapeutic crossover n = 62		Therapeutic crossover n = 69	
Imagery	No crossover n = 51	No beta	Beta	No beta	Beta
No imagery	26.3%	12.6%	10.4%	14.3%	3.8%
Hypnagogic	1.6%	4.9%	3.8%	4.4%	2.2%
Biographical	0%	1.1%	1.1%	.5%	4.4%
Perinatal	0%	0%	0%	.5%	1.6%
Transpersonal	0%	0%	0%	1.1%	4.9%

($\chi^2_{(df = 8, N = 182)} = 47.4$, $p < .001$).

Note. *N* represents the total number of sessions (182) which are characterized by no crossover activity (51), Non-therapeutic crossover activity (with or without sufficient beta) (62), or Therapeutic crossover activity (with or without beta) (69). The 5 table columns sum to illustrate 100% of the session graph activity examined.

TABLE 3. Category of Visual Imagery by Crossover Type With and Without Beta Excluding No Imagery and Hypnagogic Imagery Conditions

		Non-therapeutic crossover ($n = 4$)		Therapeutic crossover ($n = 24$)	
Imagery	No crossover ($n = 0$)	No beta	Beta	No beta	Beta
Biographic	0.0%	7.1%	7.1%	3.6%	28.6%
Perinatal	0.0%	0.0%	0.0%	3.6%	10.7%
Transpersonal	0.0%	0.0%	0.0%	7.1%	32.1%
Total Imagery	0.0%	7.1%	7.1%	14.3%	71.4%

Note. The five table columns collectively sum to reflect 100% of client reported imagery of salient material while excluding no imagery and hypnagogic imagery categories.

TABLE 4. Multinomial Regression Model Fit/Parameter Tests

	−2 Log Likelihood	χ^2	*df*	*p*
Overall Model*	30.998	83.3	6	<.001
Rise in Delta	59.109	28.1	2	<.001
Rise in Beta	46.362	15.4	2	<.001
Therapeutic Crossover	60.322	29.3	2	<.001

*$N = 182$. Cox & Snell's $R^2 = .367$; Nagelkerke $R^2 = .457$; McFadden $R^2 = .281$.

The regression model included three categorical predictors, two that indicate a rise in beta and delta frequencies and one that indicates whether a therapeutic crossover occurred during each session. The outcome variable was visual experience, which had three levels: no imagery, biographical imagery, and transpersonal imagery. The Pearson and deviance goodness-of-fit tests were nonsignificant, $\chi^2(8) = 4.6$, $p = .796$, and $\chi^2(8) = 5.1$, $p = .744$, respectively, suggesting an adequate model-data fit. The model's classification rate was 75.3%, and this was substantively higher than the proportional chance hit-rate (i.e., sum of the squared marginal percentages $= .676^2 + .242^2 + .082^2 = .5223$ or 52.2%). The odds of experiencing deeper levels of imagery for each predictor (therapeutic crossover, rise in beta, rise in delta) were modeled using "no imagery" as the reference category (Table 5).

The odds ratios were higher for individuals with a rise in beta than those experiencing a rise in delta for both biographical and perinatal/transpersonal imagery. For instance, individuals who experienced a rise in beta were 2.8 times more likely to report biographical imagery than those who reported no imagery. Participants who experienced a therapeutic crossover were 3.4 times more likely to experience biographical imagery compared with those who did not report imagery during a therapeutic crossover.

Similarly, the odds of reporting perinatal or transpersonal imagery were increased when there was also a rise in amplitude and presence of therapeutic crossover activity. Participants who experienced a rise in delta during a session and reported imagery were more than 9 times more likely to report perinatal or transpersonal imagery; those who experienced a rise in beta along with delta were almost 16 times more likely to report perinatal or transpersonal imagery than individuals that reported no imagery. Finally, although therapeutic crossover was a statistically significant predictor for perinatal and transpersonal imagery, the occurrence of cells that contained no observations (i.e., cell's with zero frequency), the data were insufficient to determine the true effect therapeutic crossover had on visual imagery relative to the no imagery reference group. Cells with no observations cause a biased estimation of standard error and an overestimation of the likelihood ratio. Therapeutic crossover notwithstanding, the rise in beta together with a rise in delta provides strong evidence that participants who experience these changes during a session are much more likely to experience perinatal or transpersonal imagery than participants that report no imagery during treatment (Table 6 contains mean frequency amplitudes associated with each category of visualization).

TABLE 5. Parameter Estimates for Multinomial Logistic Regression Predicting Imagery Experiences

	Estimates					
Variable	*B*	*SE*	*Wald*	*df*	*p*	$e^{(B)}$
Biographical						
Intercept	−1.85	0.361	26.4	1	<.001	
Rise in Delta	−2.13	0.787	7.3	1	0.007	0.119
Rise in Beta	1.06	0.396	7.2	1	0.007	2.884
Therapeutic Crossover	1.23	0.400	9.5	1	0.002	3.434
Transpersonal						
Intercept	−24.73	1.259	385.6	1	<.001	
Rise in Delta	2.23	0.887	6.3	1	0.012	9.334
Rise in Beta	2.74	1.132	5.9	1	0.016	15.456
Therapeutic Crossover	20.51	0.000	.	1	.	8.05E+08

For this analysis, $n = 44$ for Biographical and $n = 15$ for Transpersonal. Positive B indicates that the group scored higher on the variable in question compared to the base group exclusive of other variables. The reference category was: ‘No imagery’.

TABLE 6. Imagery by Mean Amplitudes Measured in Microvolts

	Hypnagogic imagery	Biographic imagery	Perinatal imagery	Transpersonal imagery
Beta	3.63	4.14	4.45	4.52
Alpha	5.87	6.82	10.65	8.62
Theta	5.30	6.91	11.02	9.75
Delta	5.93	6.59	7.92	9.15

Note. Mean amplitudes measured in microvolts are observed to increase from left to right and progress from lighter to deeper states of consciousness as indicated by Crosstabs Analysis. Analysis of Variance (ANOVA) indicated significantly higher mean amplitudes in microvolts of delta as level of imagery increased ($F = 3.429$, $p = .011$).

Relationship of Therapeutic Crossovers to Treatment Outcomes

Treatment outcome measures included the BAI, BDI, BHS, PSQI, and MMPI for eight participants. (Outcome measures were not available for two participants who terminated treatment prematurely.) Due to the small sample size of eight subjects, a repeated measures analysis of number of crossovers to treatment outcomes yielded no significant differences. Therefore, it was decided to perform a descriptive analysis comparing the therapeutic outcome measures to conditions of no crossover, therapeutic crossover without sufficient beta, and therapeutic crossover with sufficient beta. The highest improvements in therapeutic scores across most treatment measures occurred for subjects in the condition of therapeutic crossover with sufficient beta (Table 7 and Figure 6).

This group comprised four subjects who were then separated into high-count number of crossovers with sufficient beta versus low-count number of crossovers with sufficient beta. The subject in the high-count category showed the greatest improvements on BAI, BDI, BHS, PSQI, and MMPI Scales 1 (hypochondriasis), 2 (depression), 3 (hysteria), and 6 (paranoia) and 7 (psychasthenia). (See Table 7 and Figure 6.) The three subjects in the low-count category showed the next greatest improvements on the BAI, PSQI, and MMPI scales 3 (hysteria), 4 (psychopathic deviance), 7 (psychasthenia), and 8 (schizophrenia). (See Table 7 and Figure 6.) This latter group reversed on Scales 5 (male/female) and 6 (paranoia).

SUMMARY OF FINDINGS AND DISCUSSION

This study consisted of an examination of the spectral and temporal dynamics and clinical content characteristics of the theta-over-alpha amplitude crossover phenomenon in alpha-theta neurofeedback therapy and the relationship of the crossover to treatment outcomes. Observations and analyses performed in the study revealed the complex interactive frequency dynamics taking place in alpha-theta neurofeedback crossover conditions as well as the existence and association of specific correlative relationships within these dynamics to the therapeutic potential of the treatment.

TABLE 7. Pre and post BAI, BDI, BHS and PSQI Outcome Measures by Crossover Type

		No Crossover		Crossover No Beta <3.75		Crossover w/Beta >3.75	
Measure	Cond.	M	SD	M	SD	M	SD
BAI (Anxiety)	Pre	8.0	2.8	17.5	6.4	18.8	12.3
	Post	6.0	1.4	3.5	0.7	16.5	6.7
BDI (Depression)	Pre	9.0	5.7	13.5	14.8	10.5	8.4
	Post	2.5	3.5	5.0	0.0	11.3	3.8
BHS (Hopelessness)	Pre	1.5	2.1	4.5	0.7	7.0	2.4
	Post	1.0	1.4	3.5	0.7	4.3	1.7
PSQI (Sleep)	Pre	11.5	2.1	8.0	5.7	7.3	4.2
	Post	9.0	5.7	5.5	4.9	7.8	4.1

The therapeutic value of crossovers would seem to be largely dependent upon the accessibility of any imagery or memories exposed during the crossover period to conscious recall and processing by the treatment participant.

Because of differing conclusions among previous researchers on the therapeutic value of the crossover in alpha-theta neurofeedback treatment, it was first necessary to examine the definition of the crossover, which had previously been defined simply as a condition in which theta amplitude brainwave activity becomes predominant over alpha amplitude brainwave activity during the course of a treatment session (see Figure 1). This broad definition might explain why some researchers (Moore et al., 2000) found an inverse relationship in which greater numbers of crossovers were associated with fewer reports of imagery. Careful analysis of crossover data from 182 sessions from 10 case files reviewed in the current study led to a more precise operational definition of the alpha-theta crossover. This refinement produced the term *therapeutic crossover* that restricts the definition of ''crossover'' to theta amplitude rising over that of alpha by 1μv or more for 3 min or more. It was hypothesized that the defined minimum level of crossover activity would result in significantly more subject reports of imagery than crossover activity not meeting these criteria.

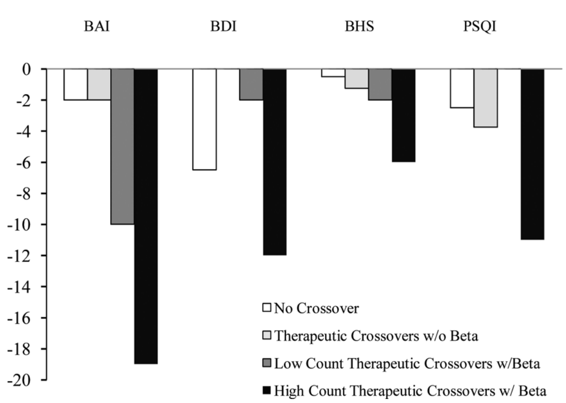

FIGURE 6. Beck Anxiety Inventory (BAI), Beck Depression Inventory (BDI), Beck Hopelessness Scale (BHS), and Pittsburgh Sleep Quality Inventory (PSQI) outcome measures by crossover type. *Note*. Mean difference comparison scores of pre- and post-outcome measures on the BAI, BDI, BHS, and PSQI for clients with no crossovers ($n = 2$), therapeutic crossovers without rise in beta ($n = 4$), low-count therapeutic crossovers with rise in beta ($n = 1$), and high-count therapeutic crossovers with rise in beta ($n = 1$).

In addition, the crossover data analysis resulted in a decision to exclude ''no imagery'' and ''hypnagogic imagery'' categories in favor of those categories more likely to contribute to treatment outcomes, including biographical, perinatal, and transpersonal categories of experience. Crosstab analyses revealed that the overwhelming majority of reports of imagery in the biographical, perinatal, and transpersonal categories occurred in the therapeutic crossover condition. Thus, crossovers were reconceptualized as theta-over-alpha amplitude crossover activity that met these stipulated conditions of a *therapeutic crossover* that was more likely to correlate with access to personally meaningful imagery and memories.

The investigators also were interested in the relationship between 15–20 Hz beta and imagery recall. It was hypothesized that imagery reports were more likely to follow sessions in which sufficient 15–20 Hz beta brainwave amplitude (3.5μv or more) occurred to mediate imagery recall during a therapeutic crossover event. Upon further evaluation of amplitudes ranging from 3.5μv to 4μv, it was discovered that 3.75μv of low beta was the most dependable threshold for predicting reports of imagery. Therefore, this more empirically based threshold was used for examining relationships in the data. It was found that the majority of reported imagery (biographical, perinatal, and transpersonal) occurred in the therapeutic crossover condition where 15–20 Hz beta amplitude was at least 3.75μv; yet a small percentage of reported imagery occurred when beta activity was less than 3.75μv. The overall conclusion from this finding was that a subject with sufficiently elevated 15–20 Hz beta amplitude occurring along with a theta/alpha crossover is more likely to recall and retain imagery and memories than a subject with insufficient beta amplitude in this range. This finding is consistent with clinical observations in which some subjects who experience therapeutic crossover activity, but with insufficient beta amplitude, sometimes report limited access to the mental contents of their sessions, evidenced by statements such as, ''It seemed like a lot was going on in my mind, but I just can't recall it.''

The investigators further hypothesized that increased amplitudes in lower frequency bandwidths would correspond with deeper subjective states of consciousness. In other words, a subject who achieved higher amplitudes of progressively slower brainwaves (i.e., alpha » theta » delta) would be more likely to progress along the continuum of hypnagogic to biographical to perinatal/transpersonal experience. An analysis of category level of imagery content by mean amplitude of each frequency (beta, alpha, theta, and delta) indicated that increased amplitude across all frequency bandwidths was associated with transition to deeper states of consciousness. For example, the hypnagogic imagery category comprised beta (3.63μv), alpha (5.87μv), theta (5.3μv), and delta (5.93μv) mean amplitudes. The transpersonal imagery category, at the other side of the spectrum, consisted of beta (4.52μv), alpha (8.62μv), theta (9.75μv), and delta (9.15μv) mean amplitudes. It could be concluded that higher amplitude in the delta frequency range was associated with greater access to deeper levels of imagery. Alpha-theta neurofeedback treatment was successful in increasing the amplitude of all of these frequencies, and imagery type was dependent upon which frequencies were dominant.

This study revealed that specific ratios of frequency ranges and temporal durations during the crossover periods were required for subject recall and processing of personally relevant material. Alpha-theta session graphs were inspected to see if patterns emerged among fluctuations in different frequency bands, most specifically to determine if beta fluctuations occurred concurrently with crossover activity. In the majority of cases (approximately 75%), beta activity did rise concurrently with crossover activity, even when the beta amplitude was insufficient in facilitating recall. Typically, beta would rise (sometimes gradually, sometimes dramatically) toward the end of the session, which was when higher amplitude crossover activity was observed. This observation supports earlier cited neurophysiological research reporting that beta activity superimposed on slower wave activity may explain a consciousness stage shift that could account for recall during such a state (Itil et al., 1970).

Further, findings from this study indicated that certain spectral activity patterns appear to be associated with reports of specific imagery category content. Several actual subject alpha-theta session graphs provide clinical examples of this finding. Figure 7 provides a session graph with elevated alpha activity in which the subject reported hypnagogic imagery. An example of a session in which the subject reported biographical imagery contained a therapeutic crossover with sufficient beta (Figure 8). An example of a session in which the subject reported perinatal imagery also had a therapeutic crossover with sufficient beta, was marked by higher amplitudes of alpha and theta, and had elevated delta amplitude activity (Figure 9). An example of a session in which the subject reported transpersonal imagery was characterized by therapeutic

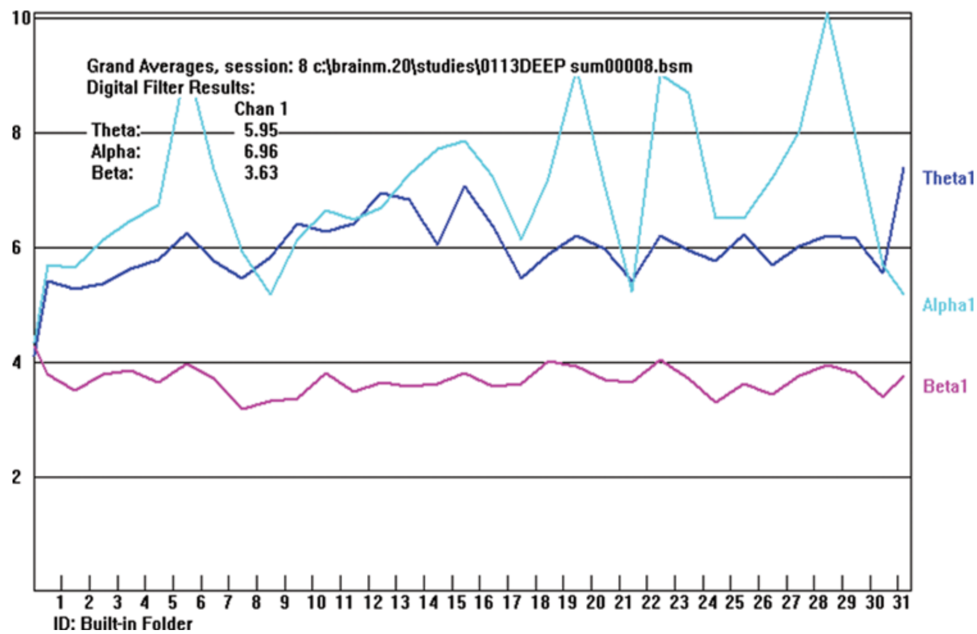

FIGURE 7. Session exemplifying hypnagogic imagery. *Note*. Example of a session in which the subject reported hypnagogic imagery was characterized primarily by elevated alpha activity. Example of a subject report classified as Category 1: ''There was swirly imagery and sounds that were like voices.'' (Color figure available online.)

crossover with sufficient beta, and highest amplitudes in alpha, theta, and delta activity (Figure 10).

It was expected that therapeutic crossover activity would be associated with better treatment outcomes. Results showed that therapeutic

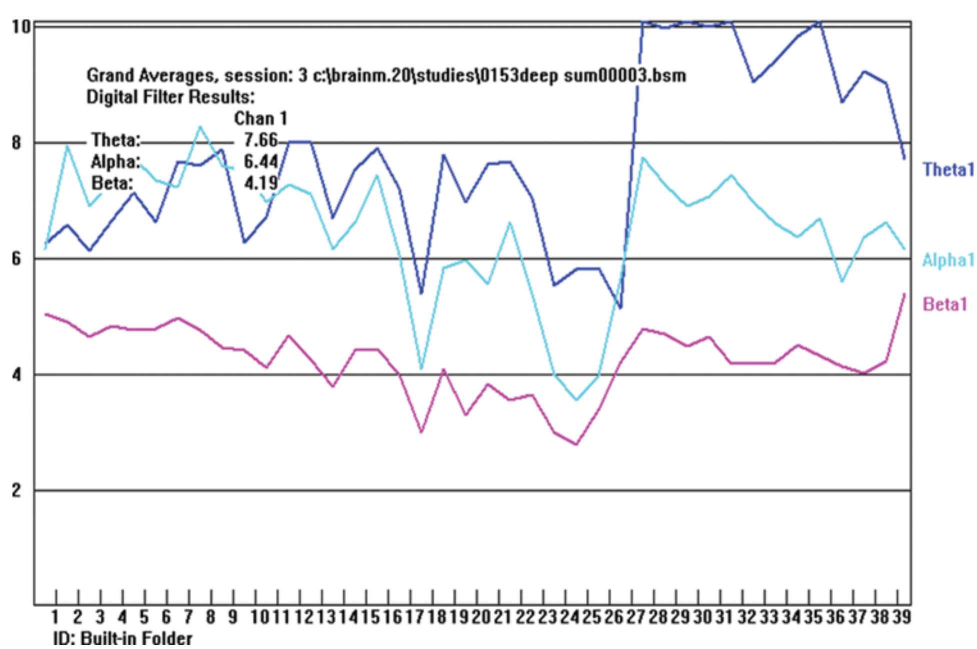

FIGURE 8. Session exemplifying biographical imagery. *Note*. Example of a session in which the subject reported biographical imagery was characterized primarily by therapeutic crossover with sufficient beta. Example of a subject report classified as Category 2: ''I re-experienced being molested by my stepfather when I was 7 years old.'' (Color figure available online.)

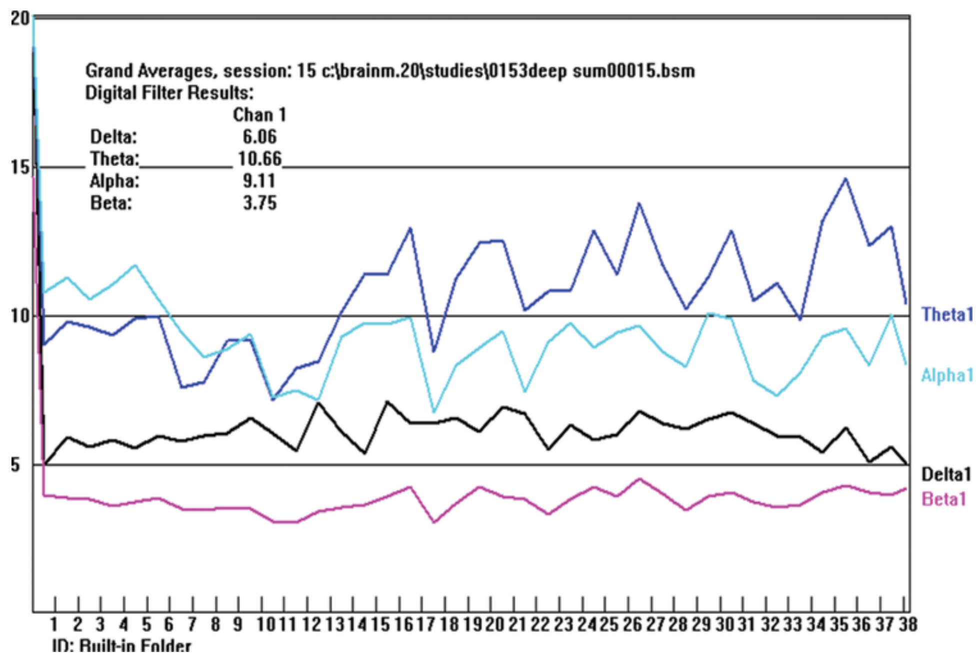

FIGURE 9. Session exemplifying perinatal imagery. *Note*. Example of a session in which the subject reported perinatal imagery was characterized by therapeutic crossover with sufficient beta, marked by higher amplitudes of alpha and theta, and increasingly elevated delta amplitude activity. Example of a subject report classified as Category 3: ''I saw myself being born. A nurse kept throwing towels of blood. I was drenched in blood. It felt like it was my actual birth.'' (Color figure available online.)

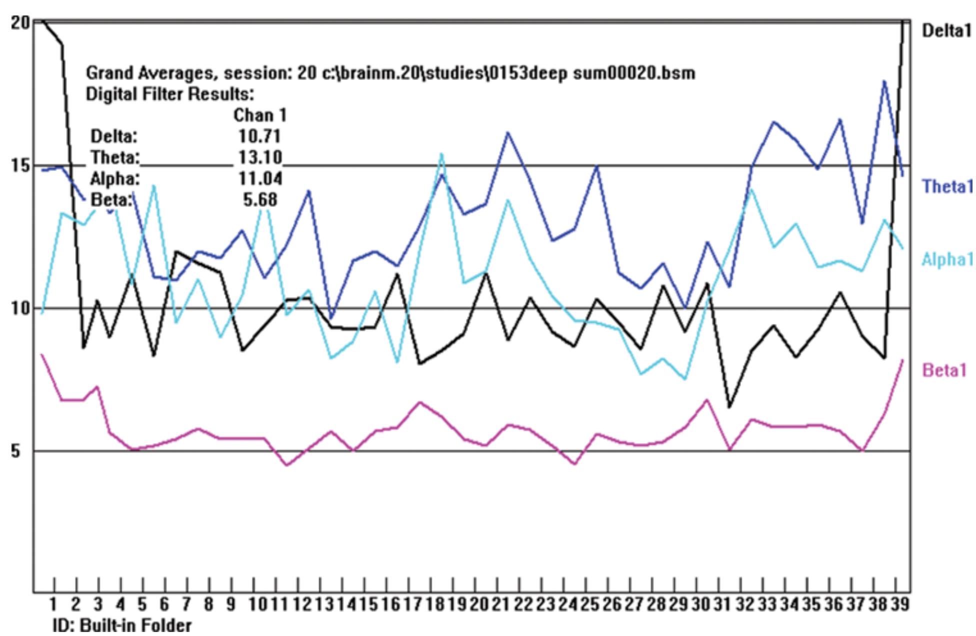

FIGURE 10. Session exemplifying transpersonal imagery. *Note*. Example of a session in which the subject reported transpersonal imagery was characterized primarily by therapeutic crossover with sufficient beta, and highest amplitudes in alpha, theta, and delta activity. Example of a subject report classified as Category 4: ''At first, it was like I was in a submarine exploring my body and traveling through my arteries. Then there was a spiritual being that was doing healing work with its hands over my heart, with glowing blue light.'' (Color figure available online.)

crossovers with sufficient beta amplitude were associated with the best improvements on posttreatment assessment measures, and the individual who had the most therapeutic crossovers showed the greatest improvements. This finding lends support to Peniston's contention that emergent emotionally salient imagery should be the target and goal of neurofeedback-assisted therapy. Although the three subjects in the low count of therapeutic crossovers with sufficient beta condition showed clinical improvement, their posttreatment scores did not improve to the same extent as the subject who had the highest count of therapeutic crossovers with sufficient beta amplitude. However, the subject with the highest crossover count also presented with higher baseline scores, indicating greater initial pathology. It is possible that this group of three subjects with fewer crossovers with sufficient beta had somewhat less pathology at baseline and, consequently, less need for personally significant material to emerge, and therefore fewer crossovers in treatment. It is also possible that a subject may not have fully divulged the contents, or fully processed emergent material with the therapist for optimal therapeutic benefit. Overall, it was found that the subject in the highest count of therapeutic crossovers with sufficient beta amplitude (and concomitant reports of imagery and memories) condition experienced better outcomes (greater improvement on pre-to-post treatment measure BAI, BDI, BHS, PSQI, and MMPI scores) than subjects in each of the other crossover conditions. This subject also reported greater recall of her dreams following treatment, which is of interest to note because this subject had the greatest emergence of repressed material, and repression has been associated with low dream recall (Tart, 1962).

The two subjects in the therapeutic crossovers without sufficient beta condition showed slight improvements on most treatment outcome measures, comparable to the two subjects in the no crossovers condition. It was interesting to find, however, that one of the subjects in this condition experienced 11 therapeutic crossovers without sufficient beta amplitude and had no reports of imagery or memories. However, the subject showed much improvement overall on clinical outcome measures, a fact not clearly represented in the treatment outcomes bar graph. A possible explanation for this subject's improvement in spite of having reported no imagery experiences during the course of treatment is that it may not be necessary for emergent emotionally salient material to translate into a normal wakeful state of consciousness for the experience to render therapeutic benefit. It may be enough that this material be manifest for subconscious processing. This conjecture is supported by anecdotal reports from experienced alpha-theta neurofeedback clinicians.

Subjects in the no-crossover condition also showed an elevation on MMPI Scale 5 (Male/Female) and greatest improvement on MMPI Scale 0 (Social Introversion). The reversal on the MMPI Male/Female scale could indicate a shift away from, or toward, a more balanced view of gender role behavior. All eight subjects also showed increased scores on MMPI 9 (Mania), which may have reflected increased energy following biofeedback.

In general, the results of this study are in agreement with Saxby and Peniston's (1995) speculation that beta activity is involved in recall of memories/imagery following "alpha-theta" crossover activity in alpha-theta neurofeedback treatment. Findings in this study lend some support to his belief that crossover activity is a significant factor in the therapeutic effectiveness of alpha-theta neurofeedback treatment.

Implications for Alpha-Theta Treatment

The findings from this study imply that neurotherapists doing alpha-theta training may want to use a software program that permits monitoring of all frequencies during treatment sessions, allowing the therapist to track crossover frequency configurations and anticipate the type of crossover reports that might emerge, if any. In addition, results of this study would support the use in a modified Peniston Protocol of a reward contingency for 15–20 Hz beta activity to encourage participant recall and possible subsequent therapeutic processing of any spontaneous images/experiences produced during the crossover condition. Finally, inhibiting delta activity during modified Peniston Protocol alpha-theta sessions, supposedly to prevent sleep, might be discouraged because this study showed that therapeutically useful imagery/experiences can be recalled even when increased delta amplitude is in the mix of frequency elevations during crossovers (see Figure 10).

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This retrospective study based on data from treatment files of 10 subjects resulted in a tentative model for describing the theta-alpha crossover that occurs during alpha-theta neurofeedback. However, further research will be needed to validate the model presented here. Another limitation of this investigation was the necessity for reliance on subjective reports of subjects' imagery experiences during their treatment sessions. It is possible that some subjects may have experienced relevant imagery but did not feel comfortable reporting the material to the therapist. Any lack of subject willingness to process what emerged also could have affected treatment outcomes.

Because the small sample of therapeutic outcome measures acquired in this study permits only tentative conclusions about the role of therapeutic crossover activity, with or without sufficient beta amplitude, in alpha-theta neurofeedback treatment, a future study that could replicate this investigation with a larger sample size might better determine if treatment outcome measures are more positively influenced by conscious or subconscious processing of emergent material. The observation that outcome measures improved for some subjects who had no therapeutic crossovers during treatment should be explored further to determine if any variables distinguish those subjects from the ones who had therapeutic crossovers. Finally, it would be helpful to further explore the observation that at least one subject who had therapeutic crossovers without sufficient beta showed good overall improvement on treatment outcome measures. Replication of these findings could hold important implications for neurotherapy as well as psychotherapy regarding the role of unconscious versus conscious processing of emotional material.

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