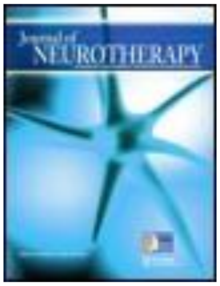

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Frequency Band Interaction in ADD/ADHD Neurotherapy

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This paper describes several successful cases of ADD/ADHD neurotherapy which were completed in less than 20 sessions. The paper also describes the protocol used to treat these patients and suggests neurophysiological bases for the protocol components. The protocol is unique in that theta is "rewarded" along with beta in one of its components. This combination produces complementary activity at another site which is believed to be partly responsible for the efficiency of this protocol. Experimental observations are reported to support the claim of frequency band interaction. Some ramifications on current treatment practices are discussed.

I am indebted to my wife, Ellen Ramos. She manages the clinic, serves as a clinic technician, and participated as a subject for this study. She was also invaluable as a source of discussion and insight, although whatever errors there may be are due to me alone. I am also indebted to an old friend Albert C. Smith, Ph. D., M. D. for critical reading of the manuscript. Final thanks go to a friend and colleague, Steven Stockdale, Ph. D. for technical assistance and being a source of inspiration.

Introduction

Bram is a 28 year old law student. In high school he worked very hard and achieved fairly good grades. He also worked very hard as an undergraduate, but his performance was fair. He got into law school, but reading and writing demands were almost overwhelming. His grades were mediocre despite tremendous work output. He was considered ADHD long before the diagnostic category was established. He was given 13 sessions of NEUROTHERAPY. When he returned to law school, he reported that it was as if a "block" had been removed. His mind was clear. He reported reading with good comprehension, his writing was organized and his grades improved significantly.

Adag is a seven year old boy, clearly ADHD. His mother came to me desperate. The school psychologist told her that if she did not accept his recommendation to have the child medicated with Ritalin, he would seek to press charges against her for child neglect. In addition to the ADHD, Adag showed soft neurological signs. He was given 15 sessions of NEUROTHERAPY, then asked to return monthly for one or two booster sessions. Before the 15 sessions were completed, he was turning in his class assignments, and became highly motivated to do well to the extent of staying in during recess to study his spelling. At this writing, he is being considered for main streaming.

Jake is a 12 year old boy who had been considered ADHD since the second grade. In his present school, he was referred to the office daily for one misbehavior or another. He was on Dexedrine when he came to me. His psychiatrist considered putting him on Zoloft when his parents said, "Enough!". At our clinic, he received 12 sessions of NEUROTHERAPY. His schoolwork is now uniformly excellent, he has not had any office referrals since the completion of his training, and he is off his Dexedrine.

The results of these three are typical of 20 - 30 patients treated during the past year for ADD/ADHD in our clinic. Yet, these results are probably unusual for the small number of training sessions. One major reason may be due to the role given to theta during training.

In training for ADD/ADHD, it is typical for neurofeedback therapists to inhibit theta. This practice derives from the observation of abundant theta relative to alpha and beta in these conditions. Theta has also been observed in abundance in certain pathological conditions such as in greatly reduced cerebral blood flow (Ingvar, et al, 1976), metabolic encephalopathies (Saunders and Westmoreland, 1979), and occurring after disturbances in deep midline structures (Gloor, 1976). Abundant theta is regarded as excessive and pathological, and treatment protocols are typically designed to train theta down. This practice appears the dominant approach today, yet little is written regarding the neuropsychological basis for this practice.

One difficulty faced in neurofeedback training is that it takes a long time to get treated. Patients are routinely informed that it takes about 40 sessions to complete training for a child with ADD/ADHD. Fifty, 60 and more sessions are not uncommon. This many treatments is very costly and intrusive; parents and insurance carriers balk at the investment, and other children go untreated for want of a therapist. Thus it is our challenge to improve treatment efficiency. In so doing, some of our assumptions will need to be reexamined.

Human physiology is replete with homeostatic mechanisms. They restore proper functioning when there is a threat to the economy of the organism. For example, when the skin is punctured and the area starts to bleed, factors of coagulation come into play to stem the loss of blood and promote healing . The physiologic mechanisms are automatic and require no conscious participation on our part. Yet, there was a time when we were entirely ignorant about platelates and coagulation or about blood for that matter, and blood was regarded not as it is now, but as a hindrance. So practices of blood-letting were performed in the name of healing.

Consider the position that theta is not a hindrance, but rather part of an homeostatic mechanism invoked by our physiology to correct a non-adaptive condition. With this mind set, a positive role for theta in the economy of the brain can be investigated for the rehabilitation of ADD/ADHD and other CNS conditions.

Theta rhythms are found in cortical areas such as hippocampus, entorhinal cortex, and cingulate gyrus (Steriade, 1993, Waxman, 1996). Experimental results have suggested that the master structure controlling at least one type of theta activity is the septohippocampal cholinergic system driven from the brainstem reticular core. (Petsche et al, 1965; Lubar, 1997).

The literature on learning and memory has found that theta activity is intimately related to these structures and processes. Some earlier studies, for example, found that hippocampal theta plays an important role in the learning process (e.g., Powell and Joseph, 1974, Mapes, 1977). Others have observed that midline frontal theta, referred to as Fm theta, is conspicuous during concentration tasks (Mizuki, et al, 1987, 1982, 1980, Yamaguchi and Niwa, 1973). Because of the time of the appearance of Fm theta during the task, these researchers suggested that "...Fm theta is closely related to mechanisms of attention..." (Mizuki, et al, 1987).

More recent studies have demonstrated that reduction in the power of hippocampal theta rhythm was correlated with the magnitude of behavioral impairment of a spatial alternation learning task (Wan, Givens, and Olton, 1995). In a related study, Givens (1995) reported that impairment of neural activity in the septohippocampal pathway by ethanol impaired spatial working memory.

In a simulated driving task, theta activity was seen to increase during learning. This study showed that successful behavior produced more theta than unsuccessful behavior. The authors suggested that theta activity reflected "relaxed concentration" (Laukka, et al, 1995).

Research on memory has shown more and more the involvement of brain structures involved in the production of theta. Skaggs and McNaughton (1996) demonstrated that the pattern of activity of individual neurons in the rat hippocampus when asleep reflected activity of those same neurons while learning a spatial task. They found that this activity is reflected in discrete changes in hippocampal theta rhythm. In a very technically involved experiment, Qin, et al, (1997) demonstrated that traces of recent learning experiences are re-expressed in both hippocampal and neocortical circuits during sleep.

Using human subjects, band power changes in theta and alpha were investigated by Klimesch, et al (1996) in learning a list of words. They found that success in learning was associated with increases in theta power during the encoding process. This was not found to be true of alpha power. (See also: Klimesch, et al, 1997 and Burgess and Gruzelier, 1997).

In an intriguing experiment, Holscher, et al (1997) stimulated the positive phase of the hippocampal theta rhythm during a simple learning task in a rat. They found that learning/memory was facilitated, that long-term potentiation, which refers to a primitive form of memory mechanism in the synapse, was induced. Conversely, stimulation during the negative phase produced the opposite effect.

In a recent review, Klimesch (1996) hypothesized that short term memory demands lead to an increase in power in the theta band, whereas long-term memory demands lead to a suppression of power in the upper alpha band. He further suggests that short-term memory processes are reflected by activity in the anterior limbic system, whereas long-term memory is reflected in activity of the posterior thalamic system. Activity in these frequency bands possibly provide the basis for encoding, accessing, and retrieving cortical codes stored in the form of cell assemblies. In another review article, Vertes and Kocsis, (1997) presented a model for the generation of the theta rhythm of the hippocampus. Among their conclusions, they stated that recent work indicates that the theta rhythm is critically involved in memory functions of the hippocampus. Its disruption may block or temporarily suspend the mnemonic processes of the hippocampus.

This review of recent literature shows the intimate connection between theta-producing mechanisms and learning and memory. Specifically, the data seem quite clear that learning and memory during acquisition is related to increases and not decreases in theta power. Thus it would seem that during neurotraining one should facilitate theta rather than inhibit it. To inhibit theta would seem to result in slowing the process of acquisition, the laying down of the memory trace, and establishment of cell assemblies representing the learned components. The three cases reported above are cases in which theta was rewarded rather than inhibited. The training process is described below.

Method

Subjects

The three males described previously are from the Honolulu area and are of mixed Island ancestry. They are all in good health. Diagnoses of ADHD, in the case of Adag and Jake, were made by their pediatrician and other mental health professionals. Bram was diagnosed by this author on the basis of his history, the Connor's Inventories and the TOVA. Bram has also been known to this author for many years although not as a patient.

They all come from intact families consisting of both parents in the home and having at least one sibling. In the case of Adag, two other brothers are affected (autism/ pervasive developmental disorder and ADHD). For Jake at least one sister out of three siblings is affected (ADHD/motor disorder). For Bram, his one younger brother was later discovered to be affected (ADD). None of the three had any other chronic disease.

Both Adag and Jake received treatment previously for ADHD as indicated earlier; Bram had not. Jake was on Dexedrine as indicated earlier. None of the three ever received neurofeedback treatment before.

Equipment

The equipment used for training were Lexicor NRS-2D and POD2 trainers. These were operated with dedicated IBM 486 clones. The frequency bands used were defined as follows: delta (0.5 - 4.0 Hz), theta (4.0 - 8.0 Hz), alpha (8.0 - 13.0 Hz), beta (16 - 20 Hz). These frequency bands came with the equipment, and there was no attempt to refine them into high and low beta, alpha, and so on. The band width could be the subject of a future study.

The International 10 - 20 system was used to determine placement of the electrodes. The electrodes used were five foot 10 mm gold cup electrodes from Grass Instruments.

Procedure

The three patients were seen individually twice a week as most of the neurofeedback patients are in our clinic except for Bram; he was seen daily because he was to return to law school within a short time. On the first meeting, the TOVA (Tests of Variables of Attention) was administered following the usual intake procedures.

The typical training procedure was that the patient was led to a separate room and seated in a recliner. The electrode sites were prepared with NuPrep with an alcohol-dampened cotton ball. The electrodes were attached using TEN20 electrode paste, an active electrode, one ground along the hairline and one reference on the earlobe. Impedances were checked and corrected as necessary. (The Lexicor equipment has a feature that allows impedances to be checked without using a separate impedance meter).

While all this preparation was going on, the patient was being queried as to how he was, how things have been going for him and so on. To see to the comfort of the seven year old Adag, he was given cushions to rest his arms on, a Teddy Bear to hold, and a light blanket for cover. The older boys declined the Teddy Bear and the blanket. The boys were also given and ice pack placed behind the neck. The major function was to slow down the firing in the area of the brainstem (Andersen and Andersen, 1968). When training was ready to commence, the patient was allowed to recline, and the following instructions were given:

"I want you to close your eyes softly. When I start the computer (program) if you relax properly, you will hear a sound. All you have to do is to relax and let the sound come out. If you relax a lot, the sound will go higher, and that is good; the higher, the better. If the sound stops, relax some more until it comes back. I will be right here. We will go for 30 minutes, then we'll stop, Okay?"

Instructions for F3 beta theta had the following modifications. "Today you will hear two sounds, one just higher that the other (300 Hz and 400 Hz). If you relax properly, they both will come on, and that is good. If one or both of them stop, relax some more until they come back. Okay?" A small trial of a few seconds was given for familiarization, threshold settings, and volume check. It was rare to need to repeat instructions or to have any of these patients refuse any portion of the treatment.

Thus the patient received no visual feedback, only auditory. The room was darkened and surroundings were kept as quiet as practicable. Patient movement was discouraged, and the patient was encouraged to remain quiet and still. For the first few sessions, the therapist remained in the room to see that the patient in fact understood the instructions. If the patient was in danger of falling asleep, he was gently stroked on the arm or lower leg or foot and asked to try to remain awake and pay attention to the sound. Despite this effort, however, there were times when the patient would fall off to sleep in the latter portions of the 30 minute session.

After a few sessions, the therapist would leave the room and observe from an observation window. The display on the monitor showed the frequency bands as colored bars that bounced up and down as the patient trained. The display also showed running averages for each of the frequency bands. Thus, both the record and the patient were under constant observation. When the session was over, the patient was gently allowed to reorient himself to his surroundings as the electrodes were removed and the recording sites cleaned up with damp alcohol cotton ball. The patient was debriefed at this time. Care was taken to insure that the patient was fully alert before he was allowed to leave.

The training protocols

The training protocols used by these three subjects are as follows: Cz alpha--6 sessions, F3 beta theta--3 sessions, Cz alpha--3 sessions.

The overall training goal is to reduce arousal and quiet the brain. Gross activity such as talking, moving about, even looking, reading, drawing, etc. are strongly discouraged during training. They are assumed to siphon away resources that can be applied to the creation of new CNS circuits that support new desired behavior to compete with hyperactive behavior. Insofar as these undesired behaviors are present, training quality is lessened and training time is prolonged. Besides, gross movement creates too much artifact, makes it difficult for the patient to receive feedback, and produces data difficult to interpret.

Cz alpha

This simple protocol exemplifies the approach taken with our patients. The goal is to achieve quietude, for quietude is assumed to be conducive to good training and is a necessary condition for therapy to proceed. The analogy is that surgery is better done on a patient who is not kicking and screaming. ADD/ADHD people usually have extensive histories of being hyper-aroused and experiencing mental chaos. Six sessions of Cz alpha training appears sufficient to calm the patient.

F3 beta theta

This is a very powerful protocol that has been observed to calm the patient, sharpen the thinking process and reduce emotional reactions. In this protocol, both beta and theta are "rewarded". One frequency band produces one sound, the other band produces another. This training also addresses cognitive difficulties as well, and does so in a quiet and relaxing manner. The goal of providing quiet and non-stressful therapy is maintained.

Cz alpha

The training is completed with a return to Cz alpha training. This portion of the protocol has the effect of cooling the brain down. It is assumed that therapy involves creating new circuits when training at F3 in this instance. Cz alpha training is given to exercise the newly formed circuits. Patients also report a return of a pleasant and positive feel with this protocol component.

This protocol also allows you to evaluate the effects of the F3 training on the profile at Cz. One may also have different training sites for other CNS conditions. By returning to Cz after each training segment, progress can be monitored.

The major dependent variable

The effect of training is seen in the power by frequency profile at Cz. That is to say that a function declining in intensity as frequency increases (negatively accelerated curve) is assumed to be the ideal function at rest. Any significant deviation represents a dysfunctional or pathological condition. Thus, not only is power of a frequency band important, but so is its power relationship to other frequency bands. For therapy, the training goal would be to restore the ideal profile at Cz.

Results

As indicated earlier, all three patients achieved significant behavioral and cognitive improvements. Reports from parents and teachers in the case of Jake and Adag were highly positive. Bram's improvement were noted in his law school studies. All three patients also noted significant corrections on TOVA post-testing. Both Bram and Jake saw scores in the normal range for all four TOVA variables. Adag saw improvements in three of the four variables into the normal range; his

Inattention score improved from severe to mildly deficient. He was given three more sessions which ran his total sessions to 15; Bram was given an additional session for good measure before he returned to law school running his total sessions to 13.

Bram was available for retesting one semester later. There were no changes in his improved condition. Jake has not been available for follow-up; Adag is receiving various forms of support services from the school. His school performance continues to improve.

Follow-up Observations

In these protocols we noted that both Cz alpha and F3 beta theta training produced very pleasant states of relaxation. This has been reported by all our patients, and I have experienced this myself. For a possible mechanism, Cz alpha training is assumed through volume conduction to access the alpha producing processes in the brainstem (Aminoff, 1986; Andersen and Andersson, 1968; Lubar, 1997). By doing so, arousal through the thalamocortical tracts is inhibited, and behavioral calm is achieved.

What was less expected was the deep and pleasant relaxation produced by F3 beta theta training. Although many colleagues use Cz alpha training to produce relaxation and calm, none that I know have used F3 beta theta to produce a similar effect. Since the patient becomes very relaxed with this protocol, the brainstem arousal system was thought to be involved. We note that the frontal area may communicate with the brainstem through the corticopontine tract (Carpenter and Sutin; 1983; Parent, 1997). Thus, it is possible that a functional relationship between these sites exists as well.

To test this idea the following observations were conducted. We asked the question: to what extent was the observed calming effect attributed to the combination of beta and theta when both are rewarded at F3. If such evidence could be found, then dynamic relationships among different sites as well as among frequency bands may be studied in the clinic using relatively simple methods.

Method

Subjects

The subjects were two nonpatient adult staff in our office, one female and one male. Both were familiar with neurofeedback and had experienced training for relaxation in this clinic. Opportune data were also obtained from two patients, a male and a female who were in therapy for brain injury rehabilitation training. Finally, additional control observations were obtained from a volunteer 19 year old male college student with no prior experience with neurofeedback.

Equipment

The equipment used were the same as those described in the previous equipment section.

Procedure

Two training units were attached to the subject. One trainer was set up for F3 beta theta rewarding both frequency bands. The other trainer simply monitored alpha, beta and theta at Cz and provided no feedback. The subject trained with eyes closed in quiet surroundings. This was the same procedure as was used with the three patients noted earlier with a single trainer.

Following F3 beta theta training, the subjects were trained on F3 beta alone on one day, and F3 theta alone the following day as control conditions. Beta and theta were rewarded in both control conditions. All subjects (except myself) were blind to which protocol was being used at any time.

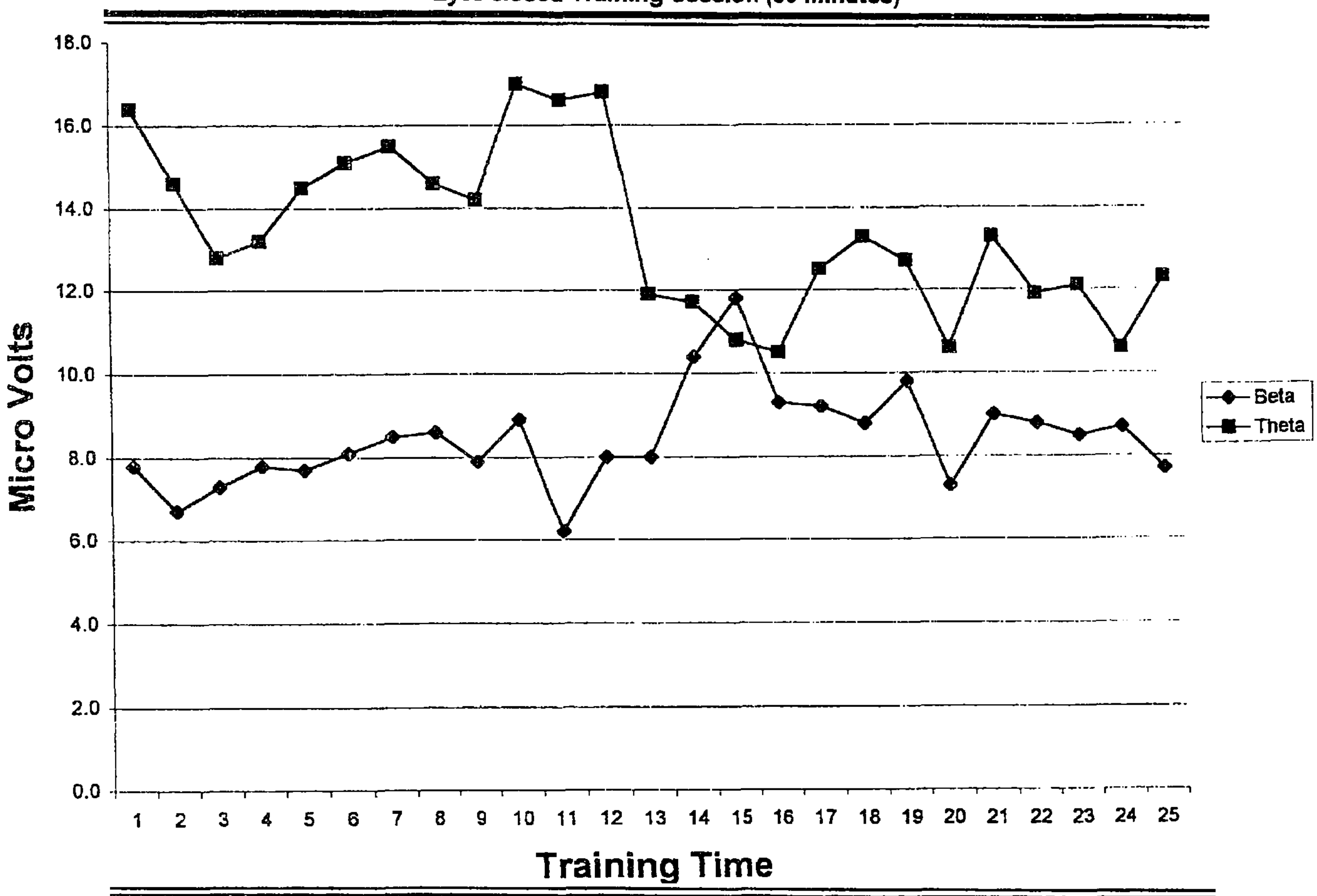
Two other control conditions were tested on the naive 19 year old male college student. He was given three sessions of F3 beta theta training to see if prior Cz alpha training was necessary for the major training effects at F3. He was also tested to see if auditory feedback was sufficient to produce the training effect at F3. The adult female who received training earlier was also given this condition. Finally, the naive post-surgical patient was given three sessions at Cz and monitored at F3. This was done to see if the training sequence had an effect on the interaction between the two sites.

Results

F3 beta theta condition

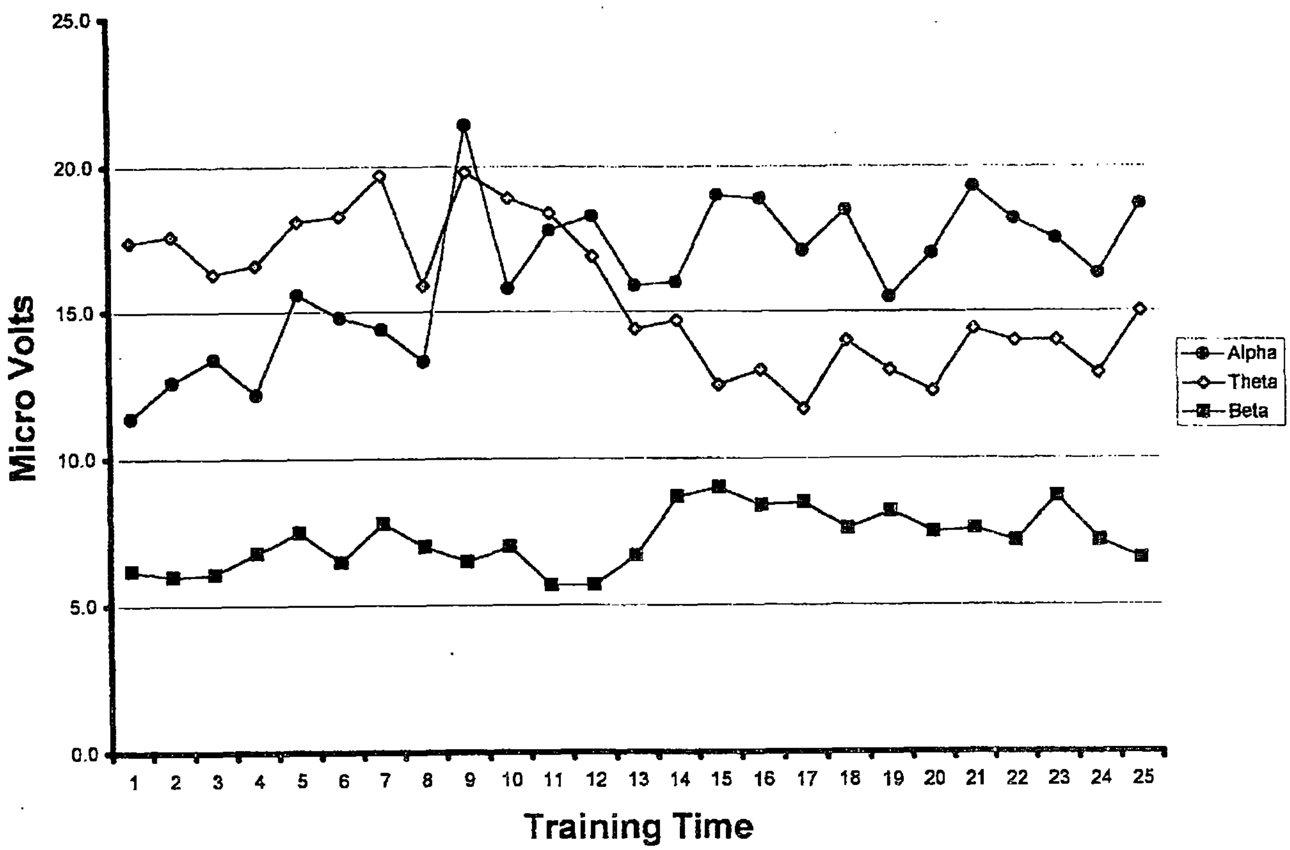
The major effect of this protocol was to produce deep relaxation and calm. At the end of training in this condition, the adult female subject reported achieving this very result. The state is described as very pleasant and one in which she would rather remain and not be disturbed. Figure 1 depicts this subject's 30 minute record. It shows the 30 minute session divided into 25 equal time segments. Her training record shows increases early on of both beta and theta as might be expected on the basis of the reward contingencies. About half way through the 30 minute training session, theta starts to fall and beta starts to rise until they meet. They fall away again slightly then remain this way for the rest of the session.

Figure 1
Eyes closed Training Session (30 minutes)



At Cz, in the meantime, there appears to be activity related to the activity at F3 despite that fact that no feedback was being provided to this site (Fig. 2). Alpha was noted to increase early into the training session and peaks at about 10 minutes. At about that time theta decreases over the next 10 minutes then levels off. Beta has been level up to now, but starts to increase just before theta levels off. Beta levels off when theta does and they both remain that way for the rest of the session. In the meantime, alpha continued its increase to a level beyond the original level of theta just before theta began its descent. All three frequency bands hold these positions relative to each other until the end of the training session. This procedure was repeated twice more with the same subject and once with the experienced adult male subject. In all four observations, the same results were obtained.

Figure 2
Concurrent Record of Activity at CZ



The naive male subject produced similar results at F3. There were some apparent differences, however. On his first session, (Fig. 3) his band profile was not well organized during the first 10 minutes. Alpha, theta, and delta seemed to meander and criss-cross. After about 10 minutes, the profile began to change. Delta, theta and alpha began to separate and maintain separate courses with delta greater than theta and theta greater than alpha. Beta remained at the bottom throughout. This result was obtained in the second and the third sessions as well except that the frequency band separation came a little sooner.

Interestingly, there were no indications of related profile changes at Cz as noted with the experienced subjects at least in the first training session. The monitoring record at Cz showed no obvious patterns or trends among alpha, theta and delta during the first training session. Beta remained at the bottom as it did at the F3 training site. This record appeared disorganized throughout the entire session (Fig. 4). In the second session, the frequency bands begin to separate and begin to look like the patterns showing at F3 with the exception that the intensity values were twice as great for the slower frequencies.

Figure 3
Initial Training Session at F3 Beta Theta With a Naive Inexperienced Subject

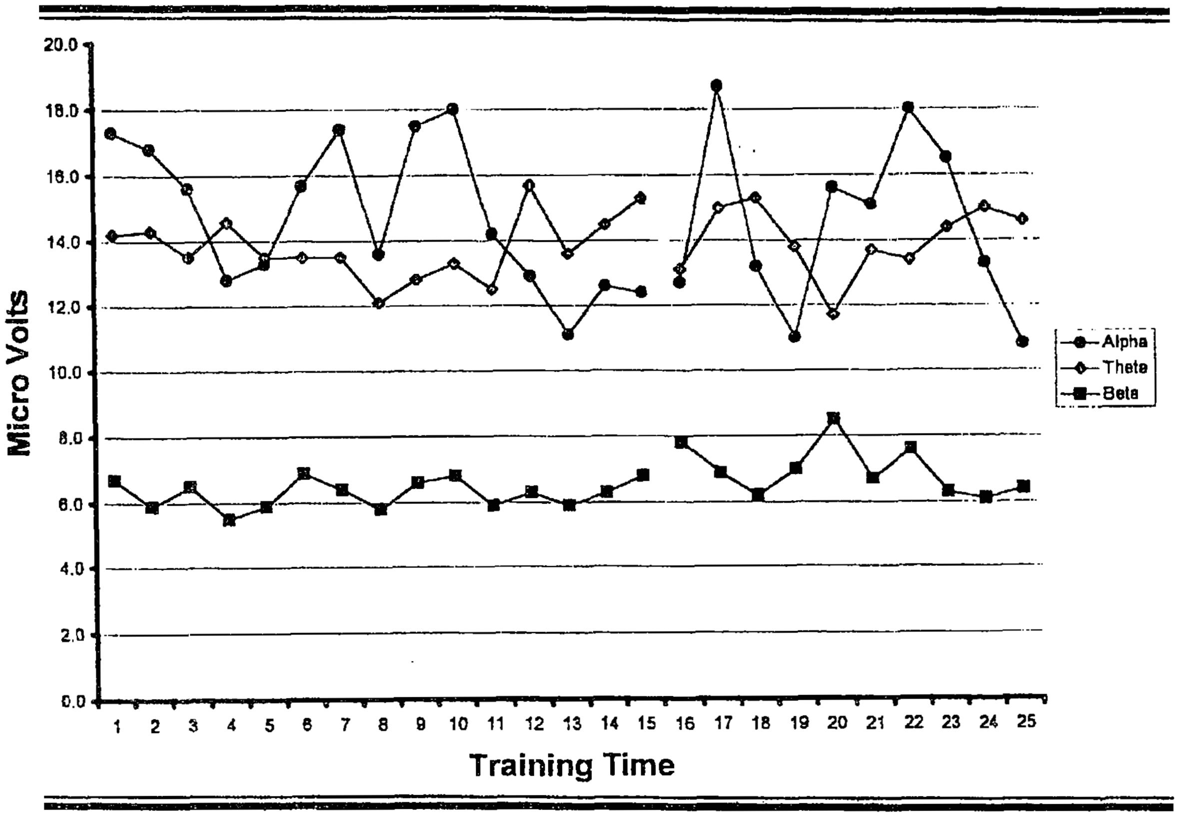
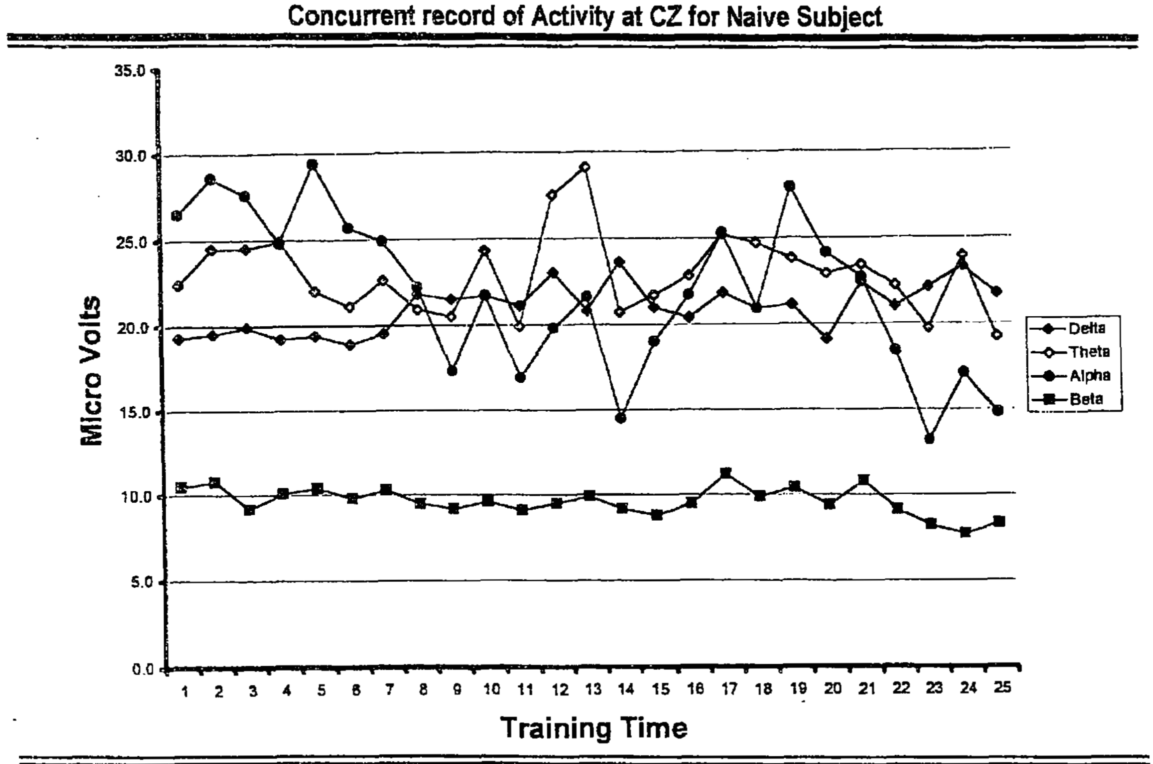


Figure 4
Concurrent record of Activity at CZ for Naive Subject



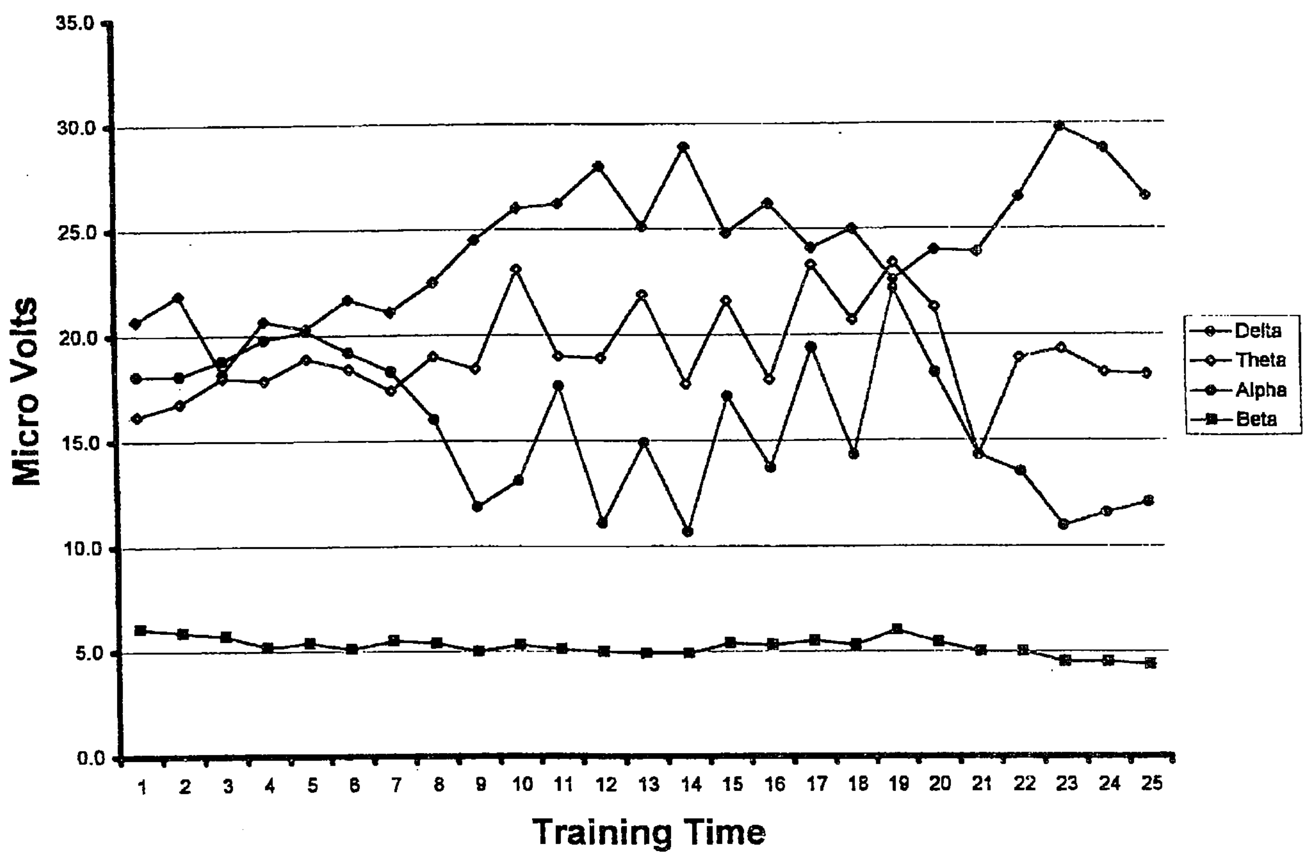
F3 theta control condition

As a control condition, the same procedure was set up again. This time, at F3, only theta was rewarded and the effects were monitored at Cz. The data at Cz in the first 20 minutes showed a gradual and definite decline in alpha. Beta and theta showed little or no change in intensity over the 20 minute recording period. When asked, the subject complained of feeling lethargic and unpleasant. She didn't like the training session and wondered what protocol she was training on. Thus theta training was terminated, and the beta theta protocol restored. The record at Cz then showed a change in alpha, rising to a level above that of theta very similar to that shown in Fig 2. This change in the record was accompanied by a return of the pleasant mood associated with this protocol.

F3 beta control condition

The other control condition was for rewarding beta at F3. The female subject was set up with the two POD trainers, and theeffects were observed on the profile at Cz. The record at F3 for theta and beta during beta training stayed relatively flat throughout the training period, alpha meandered with no particular direction or trend. At Cz, (Fig. 5) the record showed that beta and theta were relatively flat throughout. Alpha also showed no particular direction similar to what happened at F3 during the same time.

Figure 5
Concurrent Record of Activity at CZ



After 19 minutes of training (between time segments 15 and 16), the subject was asked how she was feeling. She stated that she was not comfortable, she didn't like this program, it was not relaxing, and she felt irritated. The program was modified to F3 beta theta.

At F3 (not shown) after the change to rewarding beta and theta, the record is not clear about the changes in beta and theta. There was a clear drop in the level of alpha from 18 to about 11 micro volts which was maintained until the end of the session after 10 minutes of this regimen, however, the subject noted that she felt much better and more comfortable despite that fact that she was blind to the manipulations in the protocol.

At Cz during F3 beta training, the action of alpha was not as dramatic as it were when training started off with beta theta (Fig. 5). Alpha appears to increase in strength overall, but not clearly different than prior to the change in the protocol. Beta, however, appears to increase overall during this time.

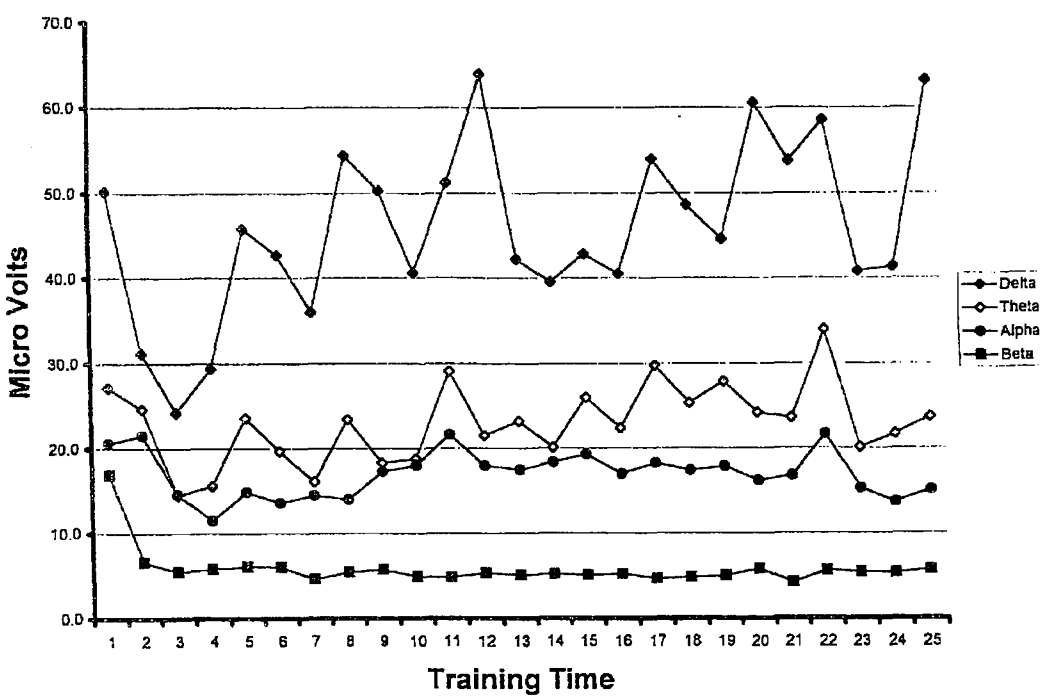
F3 beta theta training and no auditory feedback condition

The naive male college student was trained on F3 beta theta for three sessions. His responses on the first two sessions were described above. On the third session, this subject was again trained on F3 beta theta for 15 minutes. At the start of the next 15 minutes, the thresholds were manipulated so that it was not possible for him to produce auditory feedback. This was done without informing the subject. The results were monitored at Cz.

At F3 during the first 15 minutes, the subject showed a coherent profile ranging between 5 and 20 microvolts; very similar to Fig. 3. When the sound feedback was turned off, the intensity (microvolts) values especially for delta practically doubled and appeared to be increasing at the end of the recording period. Theta appeared to be increasing as well, but less so; alpha maintained the same levels as before when there was sound feedback (Fig. 6).

Figure 6

Concurrent Activity at Cz while F3. Trained with Beta Reward (Experienced Subject)



The frequency bands did retain their relative positions, but with no feedback, the training profile across the 15 minute period appeared to have expanded or "spaced out".

The power values now ranged from a little over 10 to 70 microvolts.

At Cz, in the meantime, the change from auditory feedback to no feedback resulted in little or no changes in the appearance of the profiles. It was as if nothing happened. The cumulative average values for both 15-minute periods were virtually identical. It appeared that there were no demonstrable connections between F3 and Cz that were affected by the change in feedback conditions.

Cz alpha control condition

The final control condition was to see if F3 is affected by alpha training at Cz. The present protocol suggests that Cz is a foundation procedure that provides a sort of preparation for therapy. This may be thought of as exercising the arousal circuitry to facilitate their participation in therapy. Thus, through its rich projection system, the brainstem alpha and theta mechanisms should be able to influence distant sites.

A naive post surgical (left parieto-occipital arachnoid cystectomy) patient was trained at Cz with alpha. His training was monitored at F3. The training record at Cz showed growth in delta, theta, and alpha bands. There was definite waxing and waning of these frequency bands over the 30 minute training session. There was also some growth in beta toward the last third of the session. This is a common finding even on the first session.

The record at the F3 no-feedback site showed a qualitatively different result. Delta, theta and beta started out all mixed together between 15 and 20 microvolts with alpha riding on top between 20 and 30 microvolts. The same rhythms were maintained throughout the entire training session. These results are similar in many respects to Fig. 4 in that there seemed to be an independence between these two sites at this early stage of therapy. By the third session, one can note a resemblance between the training pattern at Cz with that at F3.

Discussion

The approach described in this paper suggests that ADD/ADHD can be readily treated within 20 sessions. The strategy adopted was to stimulate Cz and F3 in an attempt to restore the normal profile at Cz. These are powerful sites for this purpose, and much of the symptoms of ADD/ADHD can be ameliorated in a relatively short time. Although further improvements in these patients through neurofeedback is still possible, this protocol demonstrates that significant treatment effects may be obtained within the constraints set by many managed-care payers.

While these sites are certainly not new, these training protocols appear different from mainstream neurotherapy in a number of ways. The theta component is rewarded rather than inhibited, and it is combined with beta in training. To reward theta is clearly indicated from a brief review of the recent literature on the neurophysiology of learning and memory. With this protocol, a growing number of ADD/ADHD patients (and patients with other CNS disorders) have been successfully treated in our clinic.

This simple protocol starts off with six sessions of Cz alpha. It is suggested that this component conditions the circuitry that will be involved in the therapy. In the training of naive subjects in the present study, F3 activity (monitored only) did not appear to be related to Cz training during the initial training session at Cz. Similarly, activity at Cz did not appear related to F3 training. Thus in the initial stages of training, whether training started at F3 or at Cz, there seem to be no obvious functional connection between the two sites.

With continued training over three sessions at both sites, F3 activity appeared to respond to training at Cz. However, also over three sessions, Cz activity never appeared to respond to training at F3. With the experienced subjects, on the other hand, effects going both ways could easily be seen. In the early stages of therapy, therefore, it appears easier to establish connections between these two sites if training starts at Cz rather than F3.

These observations may be related to the concept of coherence (Thatcher, et al, 1986, Lubar, 1997) in which a statistic may be computed as a measure of the functional relationship among cortical sites. High coherence indicates high functional relationship, whereas low coherence indicates low functional relationship. In the present case, although coherence was not computed per se, there is a suggestion that initial Cz training improves coherence at least between Cz and F3 and facilitates training overall.

It appears then the six sessions at Cz is sufficient to facilitate connections to F3 and probably to other sites as well. This facilitation may take the form of learned connections under the influence of theta mechanisms in the brainstem that are stimulated along with alpha during Cz training (Klimesch, et al. 1997).

During F3 training, local, i.e., left frontal problems are attended to through beta arousal and theta learning processes. Corrective action takes place at this site for both language-based academic deficits and emotional conditions. At this point, it is only presumed that the signs and symptoms of these disorders are ameliorated based on behavioral reports and tests. The claim of affecting emotional symptoms is based on experience in our clinic since F3 beta theta is a central component of our treatment of anxiety and depression.

Brainstem arousal processes are also stimulated by the beta theta combination as found in the present study. It was demonstrated that F3 beta theta training produces increases in alpha activity at Cz. Brainstem arousal in turn activates the entire cortex through its intricate projection system thereby involving the entire cortex in the ongoing training. Thus this protocol gives the therapist a way of involving arousal in the training which also contributes to the effectiveness of the protocol.

After Cz alpha, the protocol calls for training to shift to F3 beta theta. When the college student was debriefed following F3 beta theta training, he was equivocal about feeling relaxed. All other subjects who had Cz alpha training prior to F3 beta theta uniformly reported deep relaxation, difficulty in remaining awake, and so on. The training data on this subject suggested that the effect of F3 beta theta was local only and did not involve Cz.

The present study also specifically revealed that F3 beta theta may produce a stimulating effect on the arousal process at Cz. This effect is not produced by either F3 beta alone or F3 theta alone. Neither were any of the training results produced in the absence of sound feedback. These findings suggest that there are functional relationships among the frequency bands probably reflecting the complex processes of learning and memory.

In the learning literature reviewed earlier, it was noted that theta is critically involved in the laying down of memory traces of recently learned material, their consolidation, and retrieval (Klimesch, 1996). It has been suggested that theta functions as a "gate" in directing the flow of information through the hippocampus (Winson and Abzug, 1978). It is noted that in the protocols of others (personal communication since protocols are rarely published or explained) no specific allowance is made either to facilitate memory formation as in rewarding theta, or to try to achieve optimum arousal during training through the use of alpha. This is interesting since most practitioners describe NEUROTHERAPY as some form of learning process. Yet, their protocols reflect little of the major variables thought to affect acquisition as suggested by classical learning theories. In the simple protocol presented here, both processes are included. Specifically, the use of F3 beta theta allows theta learning and memory processes and the alpha arousal processes to be simultaneously active. We will await future research to determine the reliability of these observations and thoughts.

The present studies indicate that the widespread practice of inhibiting theta during neurotraining of ADD/ADHD patients may indeed be counter-productive. This practice which has little basis in research may be at least partly responsible for slow training, extended training sessions, and ineffective protocols.

The present results also suggest that combinations of frequency bands may have influences on functions quite distant from the site of stimulation. This finding should not be surprising since one should not expect that the rest of the brain to go dormant while a site is receiving training. This finding may have implications on the practice of referential and bipolar training in which multiple sites are stimulated simultaneously. Given the reliability of the present findings, one needs to establish what the "natural" responses of one site are when another is being stimulated. Some investigators (e.g. Thatcher et al, 1986) have noted that correlation (coherence) tends to be low among sites particularly as the distance between them increases. One cannot assume, however, that low correlation means these sites are refractory to each other. The web of projection, commissural, and association fibers assures us that every part of the brain can be affected by every other part to some degree; we just need to know how to look.

Summary and Conclusions

A role for theta is proposed in frontal training involved in the treatment of ADD/ADHD. The role is discussed within the context of a training protocol for these conditions in which theta is rewarded. Rather than being a hindrance to rehabilitation, theta with beta at F3 seem to stimulate the effect of alpha at Cz to contribute to a general quieting effect and facilitate the acquisition of mental and behavioral control.

These results suggest that the practice of inhibiting theta during training is probably not conducive to efficient therapy. This practice probably hinders rather than facilitates therapy and may be the reason for extended training sessions. The finding that training at one site can produce changes at distant sites also suggests that therapists proceed with caution when using referential or bipolar protocols. One needs to find out how frequency bands at one site interact to produce effects at other sites. Simultaneous stimulation of multiple sites may interfere with natural responses with yet unknown consequences.

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Figure Captions

Fig. 1. This is a record of a 30 minute training session for an experienced subject. The session was divided into 25 equal segments. The subject was trained with eyes closed at F3 with both beta and theta rewarded with sound feedback.

Fig. 2. This is a concurrent record of activity at Cz of the same subject in Fig. 1. Although no frequency band received reward at Cz, note the increase in alpha.

Fig. 3. This is a record of the initial training session at F3 beta theta with a naive inexperienced subject.

Fig. 4. This is a concurrent record of activity at Cz for the same naive subject in F3 on his first training session. Note the lack of organization among the delta, theta, and alpha bands. Contrast this finding with that of Fig. 2.

Fig. 5. This figure shows the concurrent activity at Cz while F3 was being trained with beta reward only with an experienced subject. Between time segments 15 and 16, the protocol at F3 was changed to F3 beta theta. Although there was an initial rise in alpha, this change was not clearly different than the behavior of alpha prior to the change from reward beta to reward beta-theta.

Fig. 6. This is record was taken from the same subject in Figs. 3 & 4. On his third session, following beta theta training at F3 for 15 minutes, the sound feedback was turned off unbeknownst to him. This record shows the 15 minutes during which he received no auditory feedback. Compare with Fig. 3.

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