# NEUROFEEDBACK: AT THE JUNCTURE OF PSYCHOLOGY AND PHYSIOLOGY

A Doctoral Project

Presented to the Faculty

School of Behavioral Sciences

California Southern University

In partial fulfillment of

the requirements for the

Degree of

DOCTOR

OF

PSYCHOLOGY

By

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June 2012

**CALIFORNIA SOUTHERN UNIVERSITY**

**APPROVAL**

We, the undersigned, certify that we have read this doctoral project and approve it as adequate in scope and quality for the degree of Doctor of Psychology.

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**Acknowledgements**

I am deeply grateful for the warm and confident support of my wife, Janie, and for the understanding of my son, Kaelan; and my daughter, Kaylee. The culmination of four years of graduate study in this doctoral project has been preceded by no small amount of time away from family activities. I know that this endeavor has had a positive effect in modeling perseverance and academic pursuit to my children.

Thank you to Dr. Benton Allen for his nudge in this direction and for putting up with my need for reassurance. Thank you to Dr. Toby Spiegel for her assistance and support. Thank you to Dr. Grimes for anticipating good work from me. Thank you to Dr. McKiernan for guiding me through this process.

**Doctoral Project Abstract**

**Title:** Neurofeedback: At the Juncture of Psychology and Physiology

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**Degree:** Doctor of Psychology

**Institution:** California Southern University

**Scope of Study:** Is neurofeedback (NFB) unique in meshing with findings from the new science of interpersonal neurobiology that are blurring the lines between psychology and physiology? Does NFB have an evidence base?

**Findings and Conclusions:** NFB is unique in its ability to interface with the findings of interpersonal neurobiology. Research has demonstrated specific instances of NFB inducing neuroplasticity. Neurofeedback (NFB) training is effective in the enhancement of meditative states, focus training for sports and the amelioration of specific symptoms of some disorders. NFB can be used to allay sympathetic nervous system arousal therefore bolstering the empathic therapeutic alliance. Research paradigms that satisfy the strictest of traditional scientific rigor are problematic, however enough data has been accumulated to say that NFB can be a possibly efficacious form of therapy as well as a tool for increasing the subjective experience of well-being and for the support of peak performance in sports.

**Chair Approval for Publication and Date:**_____

**Keywords:** neurofeedback, neuroplasticity, interpersonal neurobiology

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# Chapter One-Introduction

## Background of the Problem

From the inception of biofeedback researchers have been swimming upstream. As late as the 1950's it was not thought possible to bring autonomic functions under voluntary control. Neal Miller, however, demonstrated the contrary (Miller, 1969, 1978; Miller, & DiCara, 1967; Miller, & Dworkin, 1974). Early researchers went against the grain of prevailing thought and biofeedback has now become an accepted science. Neurofeedback (NFB) is a branch of biofeedback. NFB has achieved success in ameliorating the symptoms of ADHD, yet the generally accepted wisdom prefers medication treatment of ADHD (Arns, de Ridder, Strehl, et al. 2009). Often pharmacotherapy is the only insurance reimbursable form of treatment. Cultural pressures have come into play. The momentum of the multi-billion dollar pharmaceutical industry which manufactures and supplies such medication is not easily deflected. There is a reticence to accept that which does not line up with accepted practice. Anything "outside of the box" that purports success faces the juggernaut of conventional wisdom, and lastly the consolidation of varied disciplines with respect to behavior is disconcerting for those who have a compartmentalized viewpoint.

## Statement of the Problem

The discovery of life-long neuroplasticity and the relationship between experience and physiology are redefining approaches to psychotherapy. The fascinating dance between the mind-body totalities of the therapist and client is now under the scrutiny of highly evolved, non-invasive neuroimaging techniques. The revelations of this new science of interpersonal

neurobiology hold significant therapeutic implications. The interplay between physiology and psychology can no longer be ignored.

NFB is a unique therapy that enables the brain to change itself in response to feedback through sensory pathways. If the underutilization of NFB and lack of insurance reimbursement for NFB are not consonant with research findings then mental health clients may be unreasonably deterred in their access to a potential symptom relieving or performance enhancing therapy.

**Theoretical Backdrop**

The study of psychology, the science of human behavior, and the therapeutic interventions derived from it have sought to change behavior for the better through manipulating cognitions and emotions. Most psychotherapy is commonly referred to as "talk" therapy. The nature of the therapy is dependent upon the basic assumptions behind it. Skinnerian behavioral management, for example, assumes that the likelihood of a behavior to reoccur depends upon its environmental consequences (Schultz & Schultz, 2008). In other words the environment is key to understanding and changing behavior (Schultz & Schultz, 2008). Rogerian counseling assumes that an internal force that drives the individual toward self actualization can be activated by an empathic relationship with a congruent therapist who shows unconditional positive regard for his client (Schultz & Schultz, 2008). Freud intuited that the infant's relationship with its mother inculcated unconscious mechanisms that result in adult pathology and that the task of therapy was to make the unconscious conscious (Schultz & Schultz, 2008). While certainly not all inclusive and highly simplified, these three approaches do exemplify how psychology has spawned therapies that attempt to change the individual's condition by therapeutic application of external changes typical of "talk" therapy working from the outside-in so to speak. While the subjective experience of therapy

involves an inner, mental role for the client, in talk therapy this role is mediated by the therapist's talk.

For millennia there has been an alternative that involves changing physiology to change behavior. Psychopharmacology assumes that making chemically mediated internal modifications will result in therapeutic benefits. Dietary therapies proceed from the same assumption. In a manner of speaking these therapies work from the inside-out. The point of action is in the body and is decidedly more physiological or biological than psychological. NFB is unique in that it acts from the outside-in through its use of sensory input as feedback and from the inside-out by its manipulation of brain wave patterns.

**Theoretical Framework: A Paradigm Shift**

The science of interpersonal neurobiology is blurring the lines between psychology and physiology (Schore, 2009). Exclusivistic narrow concepts about human behavior that proceed within the traditional boundaries of unique disciplines are not only becoming outmoded, they are at a minimum incomplete (Cozolino, 2006). Alan Schore (2009) speculated that the new science of interpersonal neurobiology has created a paradigm shift in how behavior is viewed. The demonstration of neuroplasticity throughout the life span demands that behavioral therapy take into account the physiological changes that result from both trauma and therapy. An unconscious implicit memory can no longer be construed as solely a construct of the mind (Cozolino, 2006). Neurogenisis, synaptogenisis, and neural integration are physiological changes measureable in response to talk therapy (Cozolino, 2006; Linden, 2006). This paper will attempt to show from peer reviewed literature that neurofeedback is uniquely suited to a therapeutic role in the light of this recently demonstrated relationship between psychology and physiology.

## The Mind-Body Connection and Interpersonal Neurobiology

Regardless of therapeutic approach all of the above converge at the point that is the anatomical location most commonly associated with the mind-body connection, the synapse. The mind-body connection is an elusive concept that continually stimulates no small amount of debate. The synapse is the site of inhibition or perpetuation of the chemically mediated electrical potentials that collectively are commonly believed to somehow produce cognition, emotion, and behavior. "If the answer to the issue of brain and mind were as unidirectional as the common statement, "the mind is just the activity of the brain," then there wouldn't be much to talk about. Your brain will take care of everything. The natural implication would be that we are slaves to the brain. But findings from science now confirm the notion that the mind can activate the brain's circuitry in ways that change the brain's structural connections. In other words, you can use the subjective inner aspect of reality to alter the objective physical structure of the brain (Siegel, 2010)." Siegel is stating that psychology influences physiology and that this influence is bi-directional.

**Importance of this Study**

If physiology influences behavior, cognition, and emotion then physiologically based interventions may produce therapeutic changes. This is most obvious with psychopharmacology. Because the molecular action at the synapse is one of the most basic physiological processes in the production of behavior it is a logical target for a physiologically based therapy. Clearly Siegel (2010) is not advocating a purely physiological approach. The new science of interpersonal neurobiology, of which he is a pioneer, draws upon evidence of the physiological changes in the brain that result from its interaction with the external environment through sensory input, and significantly, with metacognition, its own ruminations about itself. Interpersonal relationships are a crucial part of that interaction in what now demands to be called the social brain, and attachment theory now has physiological correlates to its propositions (Badenoch, 2008). The clarion call is to

modify therapy in the direction that hard science from advanced neuroimaging techniques has revealed is effective. The salient finding is one that does not surprise anyone with experience in psychotherapy. For a long time it had been commonly accepted that perceived level of empathy had been shown to be the best predictor of success in therapy regardless of modality (Norcross, Beutler & Levant, 2005; Norcross, 2002). Beyond simple correlation science has recently demonstrated how empathy results in physiological changes (Cozolino, 2006). We are living in an exciting time. The relationship between experience, therapy, and changes in the brain has been demonstrated (Cozolino, 2006).

The empathic therapeutic alliance has been scientifically demonstrated to be the heart of effective therapy. Empathy engenders neuroplasticity (Cozolino, 2006). Since the influence between psychology and physiology is bi-directional what if a physiologically based therapy, couched in an empathic alliance, could influence the action at the synapse in a way that bolsters the alliance and produces changes in behavior? Neurofeedback (NFB) has been demonstrated to modify electroencephalographic patterns that are produced by synaptic firing (Demos, 2005). Does NFB uniquely fit into the mind-body juncture in light of the paradigm shift suggested by Alan Schore (2009)? Psychopharmacology has been an accepted, evidence based therapy for millennia that also acts directly at the synapse. Does NFB which changes synaptic activity have an evidence base?

**Hypothesis**

NFB is hypothesized to be uniquely suited to a role in psychotherapy in the light of demonstrable relationships between psychology and physiology. NFB acts at the synapse which is sometimes thought of as the anatomical locus of the mind-body connection at the juncture of physiology and psychology. NFB is hypothesized to have an evidence base for the treatment of some specific symptoms and disorders.

**Scope of this Study**

While it may seem difficult to avoid a discussion of philosophy when dealing with the mind-body connection no consideration of various viewpoints of the nature of this mystery are presented. While cognition and emotion are subjectively experienced and behavior may be observed the relationship between our personal experience and what others can see is at best only partially understood. This is the frontier of a science of human behavior. In the literature review articles are examined that present physiological correlates of observable and/or subjectively reportable behavior through the use of neuroimaging techniques that are a revolution in themselves. Implications and applications for psychotherapy are the heart of this paper. The literature review will present articles that demonstrate relationships between psychology- the mind, and physiology- the body, with an eye toward the fit of NFB in the therapeutic milieu.

Specific attention will be directed to the evidence base for NFB and reasons why it might be preferred to pharmacotherapy. Mention will be included of some possible cultural influences that may have worked against the more general acceptance of NFB. The preference of NFB over pharmacotherapy and mitigating cultural influences both help place NFB on the proper rung of the acceptance ladder of the mental health community.

**Purpose of the study**

The role of non-invasive neuroimaging in demonstrating the interplay between psychology and physiology is highlighted in attempting to reveal what is scientifically known about this interaction. This paper examines NFB to determine whether or not NFB is unique in its ability to interface with the findings of interpersonal neurobiology, and whether or not NFB is effective for many symptoms of mental disorders as well as

performance enhancement. Does the research support that NFB engenders neuroplasticity reflected in changed behavior?

**Definition of Terms**

- **Bandwidths** are segments of the measured scale of recurring oscillations in electrical potentials. Bandwidth is measured in Hz or cycles/second. In the human brain these oscillations begin at 0 Hz and continue up to about 100 Hz. Most work in NFB is done in the range of 0 Hz to 60 Hz.
- **Electroencephalogram** (EEG) is a polygraph recording of the varying electrical potentials measured by electrodes attached to the scalp (Carlson, 2010). In NFB applications the recording is usually presented on a monitor and saved for later analysis (Demos, 2005).
- **Fast Fourier Transformation** is a mathematical tool to distill the presence of waves of a particular bandwidth from the raw EEG activity.
- **Herz** (Hz) means cycles per second. It is the number of times an oscillation repeats each second (Demos, 2005).
- **Impedance**, measured in ohms, is a measure of the resistance to electrical transmission through a material. In NFB the impedance at the electrode should be less than 5,000 ohms in order to have sufficient electrical signal for the amplifier to work effectively.
- **International 10-20 system** is an agreed upon conventional method of placing electrodes on the scalp and earlobes. It yields 19 sites on the scalp that are identified according to hemisphere and cortical lobe. Left hemisphere sites are identified by odd numbers, right hemisphere sites by even numbers. A letter denotes the location over the cerebral cortex, i.e. T7 is over the left hemisphere temporal lobe.

- **Microvolts** (uv) is the measure used to quantify the amplitude of each wavelength. Amplitude readings range from near 0 uv to 100 uv (Demos, 2005).
- **Montages** are methods of placing electrodes on the scalp. There are two basic montages commonly used in NFB: referential and monopolar.
- **Morphology** with reference to the EEG is the study of wave form. It is crucial for NFB practitioners to recognize the morphology of epileptic spikes. The presence of epileptic spikes requires that the client be referred to a neurologist for evaluation.
- **Motor-evoked potentials** (MEP) are neuroelectrical signals between the spinal cord and peripheral muscles that result when the motor cortex is stimulated magnetically by a non-invasive device that touches the scalp. The process is known as transcranial magnetic stimulation (TMS).
- **Neurofeedback** (NFB) is also referred to as electroencephalographic (EEG) feedback or EEG biofeedback. The process of using NFB is a form of neurotherapy. NFB is a modality of biofeedback (Demos, 2005). "Biofeedback is the process of recording and sending biological data back to a trainee (Criswell, 1995 find in Demos)." During NFB the trainee receives auditory or graphic signals each time brain wave activity approximates the targeted patterns. The brain learns to produce the desired changes through operant conditioning.
- **Neuroplasticity** is the demonstrable ability of the brain to develop and integrate new neural pathways throughout the lifespan. Both synaptogenisis, the creations of new synapses; and neurogeniss, the growth of new neurons, are involved.
- **Normative Databases** are collections of thousands of QEEGs that serve as a comparative measure assisting in the interpretation of individual EEGs.

- **Operant conditioning** is also known as instrumental conditioning and is the process wherein the consequence of behavior increases or decreases the probability of its reoccurrence (Carlson, 2010). In NFB the graphic or auditory feedback makes the trainee aware of approximations of targeted brain wave activity (Demos, 2005). The presentation of feedback is the reinforcing consequence that increases the likelihood of the reoccurrence of the immediately preceding behavioral event.
- **Sensorimotor Rhythm** (SMR) is from 12 to 15 Hz. SMR is the bandwidth increased over the sensorimotor cortex in cats by Sterman in his seminal research that resulted in a serendipitous discovery of a therapy that reduces the frequencies of epileptic seizures.
- **Thresholds** are points in the bandwidth continuum above or below which a reward is presented.
- **Quantitative electroencephalogram** (QEEG) is an electroencephalogram simultaneously measured at all 19 sites of the international 10-20 system. The QEEG yields a map of activity over the entire scalp.

**Summary and Organization**

The literature review that follows, Chapter Two, attempts to show that given the fact that the science of interpersonal neurobiology has demonstrated the experience dependent neuroplasticity of the brain throughout the lifespan that NFB, which engenders lasting changes reflecting neuroplasticity, is a uniquely suitable therapy. The relationship between psychological interventions and changes in physiology is presented with the goal of highlighting NFB's unique place in the mind-body dyad. Evidence follows for the congruent effects of "talk therapy" and more biologically oriented therapies. The

evidentiary base of NFB is examined for multiple applications. The limitations of this study are delineated.

Chapter Three summarizes this paper and presents this author's conclusions and recommendations for future research.

# Chapter Two: Literature Review

"Whenever a new discovery is reported to the scientific world, they say first, "It is probably not true." Thereafter, when the truth of the new proposition has been demonstrated beyond question, they say, "Yes, it may be true, but it is not important." Finally, when sufficient time has elapsed to fully evidence its importance, they say, "Yes, surely it is important, but it is no longer new (Hill & Castro, 2009. Prologue)."
*-Michel de Montaigne (1533-1592)*

## Research Methods

A review of the literature regarding interpersonal neurobiology, physiological correlates of behavior, and the evidentiary basis for NFB is the foundation for this project. Most research articles were located with California Southern University's library database from EbscoHost entitled *Psychology and Behavioral Sciences Collection.* Keywords were: EEG feedback, neurofeedback, neuroplasticity, interpersonal neurobiology, PTSD, ADHD, performance enhancement, and biofeedback. Some articles were discovered through citations to the articles discovered above.

## Methodology

There is a tremendous contrast between the method of this paper, a literature review, and the methods of the researchers whose work is reviewed. It is of value to note how these researchers derived their data because the very tools that have allowed them to do this are a significant part of the revolution that is overtaking behavioral science. The evolution of non-invasive, computer-enhanced, neuroimaging techniques has enabled the discovery of life-long neuroplasticity. The combination of tools available, allowing both spatial and temporal resolution of minute physiological changes in the brain, has ushered in a new era of discoveries of how the psychological relates to the physiological. fMRI and EEG, individually and collaboratively, have been used to examine the physiological effects of psychotherapy and pharmacotherapy.

In an interesting twist all that is being discovered, or verified, is not unfamiliar with mental health clinicians. For example Freud's (1865) intuition regarding the mother-infant dyad has been dynamically reinvigorated by the discovery of the physiological correlates of attachment. More than a century later Freud's theories mesh very well with the cutting edge of interpersonal neurobiology.

It is truly a privilege to have access to so much research. This paper attempts to point out areas where research results corroborate, or in some cases, appear diametrically opposite to each other. In complex systems wherein the relationships are not completely understood diverse results can be expected.

The underpinnings of neurofeedback (NFB) need explanation in order to be understood. Therefore a portion of this paper is expository regarding the history of NFB.

**Historical Perspective**

The information that follows in this section will enable an understanding of the development and basic principles of NFB. The information will provide perspective in judging the contributions of relevant research. Some aspects of NFB's history also impinge on cultural acceptance as will be noted below.

Neurofeedback (NFB), which is also called encephalographic (EEG) feedback training or EEG biofeedback, has been applied to a spectrum of human behaviors. NFB is used to sharpen the focus of athletes, to hone meditative states, and to treat some specific mental disorders. Almost from its inception NFB has seen utility in positive psychology as well as in the treatment of symptoms.

## Measurement of electrical activity in the brain

NFB is dependent on detection of the changing electrical potentials in the cerebral cortex. Richard Caton (1875) was the first to discover that the electrical activity of the brain changed following mental activity (Demos, 2005). "In the 1920s Hans Berger measured the electroencephalographic activity detectable on the human scalp. He was the first to record raw EEG on paper (electroencephalogram). Later he would discover two different filtered waves, alpha and beta (Demos, 2005. p.16)."

> What exactly generates the voltage fluctuations recorded outside the head? We operate under a working hypothesis that appears to account for a number of observations. Early electrophysiologists hypothesized that the EEG and intracranially recorded field potentials (localfield potentials) were due to postsynaptic activity of neural ensembles (Adrian & Yamagiwa, 1935; Li, McLennan, & Jasper, 1952). This view is widely accepted today (Logothetis, Pauls, Augath, Trinath, &Oeltermann, 2001; Luck, 2005; Nunez &Srinivasan, 2006), although the biological basis of the EEG and ERPs has been periodically debated (e.g., Fox &O'Brien, 1965; Galambos &Jahasz, 1997). This means that instead of recording a summation of the action potentials generated by individual neurons, we believe that the EEG and averaged ERPs measure electrical potentials generated in the extracellular fluid as ions flow across cell membranes and neurons talk to one another via neurotransmitters. (Woodman, G. 2010).

## Manipulation of ANS functions through feedback

Up until the 1950s many metabolic activities, such as heart rate variability, blood pressure, and skin temperature, were thought to be under the involuntary control of the autonomic nervous system (ANS). Neal Miller's research in the 1960s demonstrated that ANS functions could be altered with feedback through operant conditioning (Robbins, 2000; Schwartz & Olsen, 1995). Neal Miller's work went against the grain of thought at the time. Extrapolating this discovery to EEG activity Joseph Kamiya trained a volunteer to recognize bursts of alpha (8-12 hz) brain wave activity by verbally reinforcing the appearance of these waves in the EEG enabling the achievement of deep meditative states

without the normally prerequisite long period of training (Peper, E. & Shaffer, F., 2010). NFB had been shown to effect changes in brain wave patterns through operant conditioning. "Alpha biofeedback fit an emerging zeitgeist of self exploration. American culture in the 1960s and 1970s was shaped by a confluence of forces: exploration of consciousness through drugs such as LSD (Timothy Leary and Richard Alpert) and Eastern meditative practices such as transcendental meditation (TM) (Peper, E. & Shaffer, F., 2010)." There is a residue of this association with altered states in the evaluation of NFB that prompts some to dismiss NFB, relegating it to what is referred to as "pop psychology."

**Sterman's cats**

An understanding of Barry Sterman's (1968) seminal research findings provides assurances that the phenomenon to be examined is not the result of placebo effect nor the result of expectancies of the researcher thus diffusing from the inception of this presentation some persistent criticism of NFB.

Taking a completely different tack than Kamiya, Barry Sterman, working with cats, was able to up-train the sensorimotor rhythm (SMR) of 12 to 15 Hz (Wyricka & Sterman, 1968). Increased amplitude of this bandwidth is associated with docility and lack of movement. A serendipitous request by NASA that Sterman study the effect of hydrazine, a fuel that causes seizures, resulted in the first symptom ameliorating application of NFB. Sterman had 50 cats. He injected them all with hydrazine. All but ten developed seizures within one hour. Unexpectedly those cats that had up-trained their SMR were resistant to seizures. A member of Sterman's staff, Mary Fairbanks, was a sufferer of epilepsy. She had been unable to obtain her driver's license because of the frequency of epileptic seizures. In 1971 Sterman began NFB training with Mary to up-train the SMR in the left

hemisphere over the sensorimotor cortex. “The incidence of seizure activity was greatly reduced after 3 months of neurofeedback training. Fairbanks was well enough to obtain a driver’s license (Robbins, 2000a in Demos, 2005. p.19).” “There was no other treatment known to her or her doctors that could have effected this change (Demos, 2005. p.11).” NFB is now an accepted form of treatment for medication resistant epilepsy. (While the treatment of drug resistant epilepsy with NFB has a concrete supporting evidence base, research concerning epilepsy will not be discussed further in this paper because treatment of epilepsy is beyond the scope of ordinary psychological practice. Standard procedure for NFB practitioners who observe the morphology of epileptic spikes in the EEG of a client is referral to a neurologist (Demos, 2005).) The fact that cats do not respond to placebo treatment is all too conveniently overlooked by critics of more recent NFB research. It is doubtful that perceived level of empathy or expectations of the felines contaminated the results. “The most immaculate experiment ever done in neurofeedback was that of Barry Sterman with the cats that were injected with monomethylhydrazine. This was for the best of reasons, namely that neither Sterman nor the cats were aware at the time of the grander experiment in which they were playing a role. Hence neither was in a position to put a spin on events: no placebo response on the part of the cats; and no intention on the part of the researcher to end up with divergent results. This early experiment already punctured the placebo balloon, and it did so for all time (Othmer, 2012).”

## Operant conditioning and NFB

“With appropriate EEG feedback using EEG operant conditioning techniques first developed by Sterman, a person can train his or her brain to shift the EEG patterns,

becoming more flexible in his or her ability to find the correct mental state to fit the task demands of the moment (Lehrer, Woolfolk & Sime, 2007. p.284)."

The principles of operant conditioning explain NFB training. Changes in brain wave activity are measureable. The same rapid evolution of electronic devices that facilitated the development of interpersonal neurobiology and the discovery of life-long neuroplasticity through improved neuroimaging techniques has provided the computerized tools to fine tune the use of NFB. In many ways advanced NFB and interpersonal neurobiology have been co-fostered by this same electronic evolution. These last few paragraphs of NFB basics that follow below will facilitate understanding of the information presented in the literature review.

A computer monitor provides the trainee with feedback. When the EEG activity is on-target a game continues or other reinforcing scenarios are presented. Computer software manipulates the *thresholds* of response making success likely at the start and is capable of progressively resetting the *thresholds* according to the level of success if considered appropriate. The brain changes activity according to the feedback. The changes are considered endogenous because they are made by the brain itself. No electrical energy is delivered to the scalp by the equipment. NFB electrodes simply receive the subtle changes in electrical potentials that can be measured at the scalp. In principle there is no difference in the scenario of NFB from the interaction of brain and environment that resulted in its evolutionary development, except of course, for the occasional genetic mutation. The input to the brain in both cases is through the senses.

Brain wave activity is measured by frequency, expressed in herz (Hz) or cycles per second, and amplitude or strength of the pulse is expressed in microvolts (μv). The raw

EEG signal is filtered by a computer to reveal the bandwidths of electrical activity that can be measured at the scalp (Demos, 2005). Electrodes are pasted to the skin and clipped onto the ear lobes in accordance with the International 10-20 System of placement (Demos. 2005). The hair is simply parted. There is no need to shave the area. In order to understand the utility of NFB protocols it is helpful to have some knowledge of the various bandwidths, brain states that are associated with these bandwidths, and normative databases. Very simply put, EEG patterns are associated with varying brain states subjectively experienced as drowsiness, alertness, anxiousness etc. Changing the EEG patterns changes the brain state.

> During the last thirty years, a powerful scientific movement has developed to explore the connection between the brain and the mind. Many studies have discovered the ways in which psychological states affect brain function, or are affected by it. In this field neurophysiological examinations have clarified the relationship between the surface electroencephalography (EEG) and underlying thalamocortical mechanisms and psychological temperaments. These studies have shown that optimal modulations in rhythms and frequency of the electroencephalographic brain activities can make positive changes in psychological states (Arani, Rostrami, & Nostrabadi, 2010. P. 170).

A Fast Fourier Transformation (FFT) is used by a computer to mathematically separate the raw EEG into graphic representations of all occurring bandwidths. If there is no activity, or "O μv," at any bandwidth the brain is dead. The lack of an EEG response is a common denotation of brain death. Starting at the low end of the spectrum the *delta* bandwidth occupies from 1 to 4 Hz and is characteristic of sleep. *Theta* occupies from 4 to 8 Hz and is dominant in creativity and meditative states. *Alpha* occupies from 8 to 12 Hz and reflects peaceful alertness and meditative states. The *alpha* bandwidth was uptrained by Kamiya in 1963 without the benefit of computerized feedback. *Beta* occupies from 13 to 21 Hz and is characteristic of sustained attention and focus. The *SMR* or *sensory motor*

*rhythm* occupies from 12 to 15 Hz and is characteristic of mental alertness with physical relaxation. The *SMR* is the bandwidth uptrained by Sterman over the sensorimoror cortex in cats. *High Beta* occupies from 20 to 32 Hz and is characteristic of hyperalertness and/or anxiety. *Gamma* occupies from 38 to 42 or higher Hz and reflects cognitive processing and learning. All of the bandwidths occur simultaneously. Dominance, or increased amplitude, measured in μv, in a particular bandwidth is associated with the various states mentioned above. By convention activity below 10 Hz is referred to as *slow wave* activity and activity above 13 Hz is referred to as *fast wave* activity (Demos, 2005).

### Normative databases

Several data bases have been collected that are available for comparison of a specific client's EEG to a "normal" group. Much of the research that will be discussed cites normative data bases. EEG signatures of specific disorders have been identified, however the correlation of these EEG patterns with the existence of symptomolgy in individual clients is not strong enough for diagnostic purposes (Demos, 2005). It is likely that some individuals will exhibit EEG patterns for a disorder without experiencing any of the symptoms. The converse is true as well. Nevertheless such databases serve an adjunctive role in determining protocols for each client.

## Data Analysis

### Physiological correlates of empathic resonance

In speaking of the resonance of the empathic alliance Dan Siegel (2010) said:

> Our job is not to be the one who knows everything, but the one who is present, attuned and open for resonance with what is. As we join in this moment in the physical realm—making appointments to be in the same place at a given interval of the clock—our nervous systems align their firing patterns as two sets of electrochemical entities phase shift into resonant couplings. What this means is that at times our heart rates align, breathing becomes in-sync, nonverbal signals emerge

> in waves that parallel each other, and in some cases shifts in EEG (electroencephalograms) and heart rate variability co-occur. The functions of our autonomic nervous system, balancing brake and accelerator in the coordination of heart and brain, become aligned as we resonate with each other. These changes represent concrete physical and quantifiable ways in which two states become as one (p.57).

There is an open doorway between psychology and physiology. In one room sits the empathic therapeutic alliance that engenders neuroplasticity with the goal of changing behavior and in the other room sits the brain recreating itself through synaptogenisis, neurogenisis, and neural integration and all the physiological aspects of behavior. The interplay may have always been acknowledged but has never been as scientifically understood as it is in the light of interpersonal neurobiology.

**Endogenous control of waking brain rhythms induces neuroplasticity in humans**

Ros et al. (2010) have demonstrated that training to inhibit alpha at C3 results in neuroplasticity as measured in increased excitability of the motor cortex that lasts for at least 20 minutes. Motor-evoked potentials (MEP) whose amplitude is representative of the strength of neurotransmission from motor cortex to muscle are increased after one session of NFB training (Ros et al., 2010). Ros et al. (2010) use the term *endogenous* to emphasize that the agent of change is the brain itself guided by NFB. Their article is entitled: *Endogenous control of waking brain rhythms induces neuroplasticity in humans.* No behavioral correlates to the increase were measured or observed, however the results may have utility for therapeutic application. If increased strength of MEPs results in more efficiency in translating thought into action then down training alpha at C3 may improve certain aspects of athletic or artistic expression that involve neuromuscular coordination. This speculation was not mentioned by Ros et al. (2010) but certainly has implications for Vernon (2005) and Perry, Shaw, and Zaichkowsky (2011)

presented below in the discussion of performance enhancement. The results support the use of NFB to increase neuroplasticity and cause the authors to speculate: " EEG-based neurofeedback may be a promising technique to modulate cerebral plasticity in a non-invasive, painless, natural way (Ros et al., 2020)." The correlation of NFB to increased neuroplasticity in at least this one measure of MEPs is no longer a matter of conjecture (Ros et al., 2010).

Siegel's (2010) mention of so many physiological correlates to resonance in therapy, including EEG, invites attention to the efficacy of utilizing modalities that directly affect these measures. NFB is one such modality.

## Neurofeedback and PTSD

Examination of the converse of Siegel's (2010) list of physiological correlates to resonance in therapy seems to indicate that physiological arousal could impede the therapeutic alliance. It seems only common sense that continual activation of the hippocampal, pituitary, adrenal axis (HPA) would make progress difficult. Hypervigilance, which involves the continual activation of the SNS, is one diagnostic criterion for PTSD (DSM-IV, 2004). The physical correlates of vasoconstriction, increased heart rate and respiration, decreased skin temperature, and cessation of digestion, are diminished with successful SMR/beta and alpha/theta NFB training (Lehrer, Woolfolk, & Sime, 2007). NFB has been shown to address at least this one symptom of PTSD (Othmer, 2009).

Siegfried Othmer was president of the neurofeedback division of the Association for Applied Psychophysiology and Biofeedback (AAPB) at the time of this writing. Othmer has headed the EEG Institute in Woodland Hills, CA since 1987. He is innovative and respected in the field of neurofeedback and has published many research articles in peer reviewed journals. In reference to the aforementioned PTSD symptom of hypervigilance Othmer (2009) stated: "The

remedy lies in giving the body-mind the visceral experience of calmness to which it no longer has access, and in reinforcing that state to the point where the body can once again live there in the steady state. Cognitively based methods don't accomplish this task very well. A psychophysiological approach is called for (p. 25)." Othmer's ideas place NFB squarely at the juncture of psychology and physiology.

Othmer (2009) describes the effect of trauma on the *body-mind* in his article *Post traumatic stress: The neurofeedback remedy.* (His terminology focuses attention on the mind-body connection. I have suggested that the synapse may be a candidate as the locus of this juncture.) What other researchers have referred to as implicit memory, Othmer (2009) refers to as *state memory.* "Subsequent recall of the event then involves the whole memory, including not only the specific, explicit "event memory" but also the accompanying implicit "state memory" that is diffusely registered throughout the body (Othmer, 2009. p.24)." This reexperiencing leads to a perpetual activation of the fight or flight response that can be countered directly by NFB in reinforcing the state that Othmer (2009) calls *visceral calmness.* Othmer (2009) recognizes that NFB is only one avenue for allaying SNS arousal. Other peripheral biofeedback procedures have traditionally been employed for autonomic dysregulation, however Othmer (2009) states that NFB provides an advantage. "It may be argued that neurofeedback impinges on entire regulatory systems, and these now include not only the domain of cognitive and executive function but of emotional control, autonomic control, and interoception as well (Othmer, 2009. p.24)." NFB may act in a more global fashion because of the integration of neural circuits (Othmer, 2009). (It is interesting to note here that neural integration is one of the processes of neuroplasticity (Cozolino, 2006). Siegel (2010) states that the brain is a complex structure that has the inherent

tendency to integrate itself. It is not illogical to conclude that changes in one brain function might be integrated into the whole.)

The selection of initial training sites on the scalp in Othmer's (2009) treatment for PTSD is biased toward the right hemisphere which is associated with the affective domain. Electrode placement over the right parietal lobe assuages physical arousal (Othmer, 2009). Placement over the right prefrontal cortex targets emotional calming and stability (Othmer, 2009). The reward frequencies are adjusted in accordance with verbal feedback from the client reporting on his subjective experience of calm alertness. Othmer (2009) has found that in PTSD treatment these frequencies tend to be very low extending down to .01 Hz. Establishing the optimal reward frequency in this manner is done during the first session and continued as indicated by client response, in this reported study, for eight sessions. Training at such low frequencies brings into question exactly what is being trained (Othmer, 2009). Othmer (2009) speculates that this infra-low training frequency might be targeting a resonant quality of the EEG. More concerning this follows below.

The second phase of Othmer's approach to NFB training for PTSD is essentially the alpha/theta protocol first developed by Eugene Peniston (Peniston & Kulkosky, 1999). "In our implementation we employ two-channel sum training at P3 and P4 to promote global synchrony in the parietal and occipital region. The nominal theta band is centered on 7 Hz and the alpha band is centered on 10Hz for most individuals (Othmer, 2009. p. 26)." Alpha/theta training with eyes closed and auditory feedback creates a calm, almost pre-sleep state in which the cognitive processes are very quiet. Trauma related imagery that arises in this state typically does so without emotional dysregulation (Othmer, 2009). Othmer (2009) reports lack of abreaction and

clinical success with this NFB treatment for PTSD. “The benign experience of the trauma event essentially reprograms the memory as a merely historical one (Othmer, 2009. p.26).”

**Conditions that engender neuroplasticity**

In his book *Mindsight,* Siegel (2010) describes the resonance and empathy of the therapeutic relationship that engender neuroplasticity and the formation of a coherent narrative of trauma events that releases a client from the symptoms of PTSD. One might speculate that alpha/theta NFB creates the same physiological correlates characteristic of the empathic relationship. That is research that begs doing. The therapist cannot be removed from the therapy and the empathy between the client and therapist is a key, now proven scientifically, to success with any modality. Siegel (2010) states: “My old mentor-one of my greatest teachers- had a powerful saying: ‘Memory retrieval is a memory modifier.’ (p.162).” Siegel’s (2010) mentor is alluding to making the implicit explicit in the presence of an attuned therapist within an empathic therapeutic alliance. Othmer (2009) is speaking about memory retrieval during a calm, hypoaroused state resulting from alpha/theta NFB. Considering the blurring of the lines between psychology and physiology in light of the new science of interpersonal neurobiology could these two approaches be complimentary to each other?

Othmer (2009) speculates that infra-low frequencies, which are the first to develop in the infant brain, may be foundational in the brain’s ability to regulate its state. “If early attachment does not develop as nature intended, the adverse consequences involve not only our emotional regulation but also the arousal regulation system, and from thence autonomic regulation and the whole orchestration of brain function (Othmer, 2009. p.30).” In a similar vein Alan Schore (2009) refers to the physical correlates of behavior, one of which is the EEG, in his article *Relational trauma and the developing right brain: an interface of psychoanalytic self psychology*

*and neuroscience.* "Because of the common interest in the essential, rapid, bodily based, affective processes that lie beneath conscious awareness, a productive dialogue is now occurring between psychoanalysis and neuroscience (Schore, 2009. p. 191)." Schore is referring to those physiological, *bodily based*, processes in the brain that can be observed through sophisticated neuroimaging. (Electroencephalography (EEG) is one of those techniques.) Schore (2009) and Othmer (2009) appear to agree: "A large body of clinical observations and psychiatric research strongly suggests that the most significant consequence of early relational trauma is the child's failure to develop the capacity to self-regulate the intensity and duration of emotional states (Schore, 2009. p.11)." Alan Schore is a respected author with numerous publications in the field of psychoanalysis. In the aforementioned article Schore (2009) discusses early relational trauma and its pathogenic effect on the self. It would appear that Schore (2009) and Othmer (2009) are talking about different aspects of the same process. Both Schore (2009) and Othmer (2009) are connecting dysfunctional early attachment with later pathology. Remediation for Schore (2009) would proceed through the empathic therapeutic alliance while for Othmer (2009) it would be based on neurofeedback. Could the two proceed together?

Othmer (2009) presented two fascinating case studies in this article working with NFB for PTSD. While two reports of clinical success offer only anecdotal support, the article does reflect the excitement of therapists utilizing NFB, and offers an invitation to more thorough research. Othmer's (2009) procedures can not be duplicated from this research article because no specificity in making infra-low frequencies available for feedback is presented. Exactly why Othmer (2009) is having success with his procedures cannot be determined from this research. One obvious confounding factor is the nature of the clinician's relationship to the client. Is success due to the empathic TA or to NFB? Or have the two processes contributed

simultaneously? The obvious viewpoint of this paper is that the empathic alliance co-contributes to therapeutic success. The correlations between the ideas of Siegel (2010), Schore (2009), and Othmer (2009) highlight the convergence of psychology and physiology. Alan Schore's (2009) reference to the same pathogenisis of early relational trauma as Othmer (2009) seems to invite an exploration of the synergism of psychoanalysis and physiologically based modalities one of which is NFB.

## Hypervigilance and NFB

As William James put it, ‘‘The greatest thing in all education is to make our nervous system our ally instead of our enemy (James, 1899).’’ In PTSD the survival value of remembering traumatic events puts our nervous system on continuous high alert. An adaptive ANS response becomes an enemy. Neuroplasticity can proceed in obviously maladaptive directions. While NFB alone is not a sufficient approach to PTSD, it can address the persistent symptom of increased arousal to facilitate trauma resolution through the formation of a coherent narrative as utilized by Othmer (2009) in the aforementioned article.

## Guidelines for efficacy of therapy

A set of standards based upon American Psychological Association (APA) guidelines will be used in this paper to indicate the present state of NFB research with regards to therapy. "The Guidelines for Evaluation of Clinical Efficacy of Psychophysiological Interventions jointly accepted by the International Society for Neurofeedback and Research (ISNR) and the Association for Applied Psychophysiology and Biofeedback (AAPB) and similar to those of the American Psychological Association (APA) specify five types of classifications ranging from "Not empirically supported" to "Efficacious and specific" (Arns et al. 2009. p.180)."

- **Level 1: Not Empirically Supported.** Supported only through anecdotal evidence or non-peer reviewed journals.
- **Level 2: Possibly Efficacious.** Shown to have a significant impact in at least one study, but the study lacked a randomized assignment between controls.
- **Level 3: Probably Efficacious.** Shown to produce positive effects in more than one clinical, observational wait list or within-subject or between-subject study.
- **Level 4: Efficacious**. Shown to be more effective than a no-treatment or placebo control group. The study must contain valid, clearly specified outcome measures. The study must be replicable by at least two independent researchers demonstrating the same results.
- **Level 5: Efficacious and Specific:** Shown to be statistically superior to credible placebo therapies or bona fide treatments in at least two independent studies.

This rubric will be applied to the research that has therapeutic implications. In regards to Othmer's (2009) article reported above NFB would be considered level 2, possibly efficacious, for amelioration of symptoms of hypervigilance in PTSD. Lack of corroborating research and controls limit this application to this level of efficacy at this time.

**The power of focused attention and attention deficit hyperactivity disorder**

"One of the key practical lessons of modern neuroscience is that the power to direct our attention has within it the power to shape our brain's firing patterns, as well as the power to shape the architecture of the brain itself (Siegel, 2010. p. 39)." Siegel (2010) touts the ability of mindfulness to engender neuroplasticty throughout his book, *The Mindful Therapist*. Van der Ord et al. (2012) utilized mindfulness techniques, which entail inward focus, with 22 parents of children with ADHD and concurrently with their children as well. The approach is interesting

because mindfulness requires focused attention and one major symptom of ADHD is the inability to stay focused. ADHD is a double edged sword in that these children not only have difficulty engaging in academic tasks, but also have an impediment to utilizing therapeutic techniques that require attention. The authors reported some success as measured by subjective self reports of the parents. Teachers, however, who were blind to the study, reported no changes in behavior. Van der Ord et al.'s (2012) techniques would be considered level 1, not empirically supported at this time.

## ADHD

In 2007 the Center for Disease Control and Prevention (CDC) reported that approximately 4.5 million children from age 3-17 years had a history of an ADHD diagnosis. More than half of these children were taking medication to ease their symptoms (CDC, 2007). Ryan et al. (2012) in their article *Medication Treatment for Attention Deficit Hyperactivity Disorder* voice the widely accepted conclusion that ADHD is a biologically based disorder. However they do not look beyond pharmaceuticals for any other physiologically oriented therapy. Ryan et al. concede that medication does not cure ADHD, rather it ameliorates some of the symptoms that return upon discontinuance. The list of common side effects includes: blurred vision, constipation, diarrhea, dizziness, dry mouth, fever, headache, irritability, lightheadedness, loss of appetite, nausea/vomiting, nervousness, stomach pain, trouble sleeping, and weight loss (Ryan et al., 2012). In addition Ryan et al. (2012) present lists of more serious and rare side effects. Perhaps an alternative is available with almost no reported unpleasant side effects. Is NFB an evidence based treatment for ADHD without the side effects of medication? Fox, Tharp, & Fox, (2005) based on a review of 6 studies, one of which had over 200 participants, conclude

that NFB is efficacious in reducing symptoms of ADHD without side effects and that the behavioral changes persist from 1 – 10 years post treatment.

Neurofeedback (NFB) has had a long relationship with attention deficit hyperactivity disorder (ADHD). In 1976 Lubar & Shouse targeted the same frequency band as did Sterman in his seminal research up training the sensory motor rhythm (SMR) in cats that lead to his serendipitous discovery of a treatment for epilepsy. As mentioned above, by Othmer (2012) an aspect of Sterman's research is under appreciated by many who tout the confounding factors of the quality and quantity of the clinical relationship and the perceived level of empathy by the subjects. Sterman's subjects were felines and Sterman himself was blind to the unexpected results. As colorfully expressed by Othmer (2012) this was truly an immaculate paradigm forever putting to rest the confounding placebo factor.

Lubar & Shouse (1976) used an ABA design demonstrating that up training the SMR lead to a diminution of hyperactivity symptoms with the converse true as well. The primary behavioral correlate of up trained SMR is docility. Increased SMR can be noted in the EEG of paraplegics. SMR would seem to be a likely target for amelioration of hyperactivity symptoms. "Several variations of this training protocol have been developed and tested over the years such as enhancing beta and inhibiting theta, enhancing SMR and inhibiting theta etc. For a detailed explanation of these different protocols also see Monastra (2005) (Arns et al., 2009. p. 180)."

Arns et al. (2009) in their meta-analysis of 15 studies investigating the use of NFB for ADHD concluded that according to the rubric presented above NFB treatment for ADHD could be considered Level 5, efficacious and specific, with large effect sizes (ES) for inattention and impulsivity, and a medium ES for hyperactivity.

Monastra et al. (2005) in an earlier analysis of 5 studies that included control groups concluded that NFB was considered to be Level 3, probably efficacious, in the treatment of ADHD. In refutation Loo & Barkley (2005) published a critical review of Monastra et al. (2005) stating that "…the promise of EEG biofeedback as a legitimate treatment cannot be fulfilled without studies that are scientifically rigorous (Loo & Barkley, 2005. p.73)." Loo & Barkley (2005) pointed out small group sizes, lack of randomized assignment, and confounding factors such as cognitive training and additional time spent with the therapist. In regards to these criticisms one might point out that the playing field is skewed in favor of demonstrating efficacy according to accepted guidelines in favor of pharmacotherapy. It is a relatively easy task for well funded pharmaceutical companies to enlist hundreds of physicians armed with a valid and reliable pre and post survey of ADHD symptoms in a randomized, double blind study of the effects of medication with placebo controls. On the contrary NFB has no such monetary backing, requires significant amounts of skill to administer, and is almost impossible to double blind (although an attempt at double blind research is presented below). In addition there are varied protocols employed by independent clinicians. NFB can not simply be encapsulated and prescribed. The amount of client-therapist interaction involved in receiving a prescription is minimal whereas NFB client-therapist interaction is significant, often requiring 10, 20 or even 60 sessions of about 45 minutes each including prepping , feedback training, and debriefing. NFB studies require much more client participation and commitment than pharmaceutical studies that concern themselves mainly with compliance.

It is highly unlikely that NFB research will be conducted with the same clarity of process and findings that can be achieved with research into medication for ADHD. Criticism regarding lack of specificity in isolating NFB as the effective agent of change will be revisited in the

discussion section below. It may suffice to say that research concerning the efficacy of NFB for ADHD treatment has mixed reviews.

Contributing to the mixed reception of NFB for ADHD Lansbergen et al. (2010) published an article entitled *ADHD and EEG-neurofeedback: a double-blind randomized placebo-controlled study.* This feasibility study sought to ascertain whether rigorous double-blind, placebo-controlled, randomized placement research could be implemented for NFB treatment of ADHD. The small N=14 of children diagnosed with ADHD and a mean age of about 10 plus or minus about 2 years was randomly broken into an EEG feedback (N=8) and a placebo-feedback group (N=6). All children completed 30 sessions of uninterrupted EEG or placebo feedback training. Significantly thresholding was done automatically by computer every 30 seconds so that reward levels were positive 80% of the time for the EEG feedback group. The placebo feedback group received a random signal similar in experience to a real EEG. Clinicians, parents, and subjects were blind to group placement. Only the clinical director knew which children were in the placebo group and he was not involved in collection or evaluation of data.

Severity of ADHD symptoms was rated based on the DSM-IV ADHD scale at baseline, upon completion of the training, and six months after training. In this study 3 of the 6 children receiving placebo feedback thought they had received real feedback. This would seem to indicate that placebo feedback is feasible. The statistical analysis of the results revealed no difference in either condition. Both groups improved somewhat. The authors conclude that this improvement was due to unspecified factors such as therapist-child interaction or simply time passed. They suggest that NFB for ADHD treatment may be ineffective noting that there was not even a trend toward more improvement in the EEG group. The authors modified their stance somewhat in regard to the blinding of clinicians to group assignment recognizing that manual thresholding

may be more effective than automated thresholding therefore losing the double blind in their continuing research. In their ongoing study they also decided to add explicit attention training strategies to the NFB for both conditions postulating that practice in such strategies may be an integral part of NFB's reported successes. The authors had estimated that for a statistically strong study they would have needed an N of 120. The preliminary findings do not support previous uncontrolled research into the effectiveness of NFB for ADHD.

Arruda et al. (2007) have demonstrated an EEG pattern that correlates with sustained attention through the simultaneous use of qEEG and a continuous performance test (CPT). Such tests are often used in the diagnosis of ADHD so the identification of an EEG pattern measured at specific points on the scalp that correlates with good performance may provide a target for future NFB research. Arruda et al. (2007) enlisted 65 right handed college students (20 male, 45 female) to participate in a qEEG study. This research dove tales with previous work by Arruda et al. in 1997 that identified an EEG correlate to sustained attention that was, however, limited by the equipment available at the time. In this more recent work Arruda et al. (2007) utilized a skull cap with electrodes placed over the entire scalp according to the international 10-20 system. In addition electromyographic signals were recorded from eye-blinks and masseter muscles to allow efficient artifacting of the results. A computer delivered the auditory stimuli for the continuous performance test (CPT) which involved the subject making a response each time a paired letter was heard in a voiced list. The qEEG was recorded simultaneously with the CPT. Measures of beta wavelength from four right hemisphere sites proved able to predict hits and misses in the CPT performance with an accuracy of 65%. Right frontal, central, and temporal regions were measured at F8, C6, C6a, and F6 according to the international 10-20 system.

The association of increased beta activity with sustained attention has influenced the rationale of ADHD protocols since Lubar & Shouse (1976). Evidence of this beta activity being a marker for sustained performance adds to evidence confirming protocols that up train this activity.

In 2009 Arruda et al. followed up with research to determine if cyclical changes in performance during a CPT would be correlated with synchronous changes in beta activity. The subjects were 62 undergraduate students ( 17 male, 45 female) who were all right handed (Arruda et al., 2009). EEG is particularly appropriate to ascertain any ongoing brain activity. Whereas most neuroimaging techniques provide good spatial resolution they are usually a snapshot measuring activity at one point in time. EEG, on the other hand, provides temporal resolution allowing measurement over an extended period of time.

A qEEG skull cap was used with electrode placement according to the international 10-20 system. Electromyographic sensors were placed near the eyes to monitor eye blinks. The same four right hemisphere sites from Arruda (2007) were chosen for analysis of correlating beta activity during the CPT. In addition four homologous sites were chosen in the left hemisphere to be able to contrast left and right hemisphere contribution to sustained attention.

Arruda et al. (2009) speculated from previous research (Smith et al., 2003) that attention would be modulated during the 1 minute to 2 minute interval and again subsequent to 5 minutes during the 30 minute CPT task. The results verified the variations within the 1 to 2 minute interval as covarying with beta activity but although there were variations in performance in the later interval these were not seen to be covarying with beta activity in the right hemisphere. “A possible explanation for the observed cyclic variations may be that human performance is modulated by an endogenous arousal system that either restricts or expands the focus of attention

across time (Tucker and Williamson 1984) (Arruda, 2009. p. 14)." Changes in attention from a tightly circumscribed locus to one expanded to the wider environment may have survival value. The authors speculate that the variation in performance found between 1 and 2 minutes may represent an endogenous system that regulates focus (Arruda, 2009). Children diagnosed with ADHD have been observed to have lower levels of beta activity. The authors speculate that a decline in beta activity at the 1 to 2 minute interval during task may indicate cortical immaturity associated with ADHD (Arruda, 2009). The study highlights changes in electrical activity in the brain that have been observed since Richard Caton did his first work in 1875. The psychological activity involved in the CPT task influences physiological activity in a predictable way.

Pharmacotherapy with stimulant medication and NFB treatment of ADHD both modify activity at the synapse. Pharmacotherapy does so by invasively modifying the molecular content of the interstitial fluid and has significant side effects. NFB does so by noninvasively providing the brain with feedback that results in changes in the EEG through operant conditioning and has minimal side effects. Research paradigms for pharmacotherapy in ADHD treatment are straightforward and there is a large body of research to conclude that it is efficacious. Research paradigms for NFB are inherently more complex and the research to date has received considerable criticism limiting the acceptance of its evidence base. In the light of new findings from interpersonal neurobiology it is straightforward to say that NFB mimics the process that resulted in the brain's evolution as mentioned above. Stimulant medication introduces elements that are foreign to the brain's natural processes. In either approach interpersonal neurobiology has convincingly demonstrated that the empathic therapeutic alliance (TA) is a sine non qua for success. Mental health clinicians often refer clients to psychiatrists or medical doctor general

practitioners for medication trials. What is the common amount of time spent in intake, diagnosis, and prescription? Is it sufficiently long to establish resonance and attunement?

**Evidence of a convergence of psychology and physiology from fMRI**

Linden (2006) in an article published in *Molecular Psychology* entitled: *How psychotherapy changes the brain – the contribution of functional neuroimaging*, provided evidence for a conjuncture of "talk" therapy and pharmacotherapy from a review of 11 fMRI studies. Linden (2006) noted the emerging interest in biological substrates for changes in patients' beliefs, cognitions, emotional states and behavior. He posited first that psychotherapists should have a clear understanding of the biological portion of the therapeutic equation. "Second, a better understanding of these biological mechanisms might aid in the improvement of therapeutic interventions or even in the utilization of these very mechanisms, as in the case of neurofeedback (Linden, 2006. p. 528)." There is a tantalizing invitation implied that might provide a research avenue demonstrating the efficacy of NFB. Would the demonstration that NFB results in changes in the EEG that are congruent with those produced by an accepted therapy help validate its use? "… the tools of non- invasive functional brain imaging can now reliably detect training- and learning-related changes in brain activation patterns in healthy volunteers and there is no reason why this should not be possible in those affected by mental disorders as well (Linden, 2006. p.528)." The reliable induction of the symptoms of a disorder in the imaging environment is a prerequisite to neuroimaging research (Linden, 2006). Symptom provocation during imaging produces neural changes. In the case of OCD stimuli that evoked compulsive behavior were presented (Linden, 2006). For PTSD narratives of the trauma were read during imaging (Linden, 2006). In a similar manner sadness was induced in those diagnosed with depression (Linden, 2006). Induction of symptoms allows the study of neural substrates

with non-invasive imaging techniques (Linden, 2006).Such studies have demonstrated that both CBT and pharmacotherapy (selective serotonin reuptake inhibitors), for OCD and phobia result in the same neural substrates. In other words the same changes in the brain were noted after "talk" therapy and after pharmacotherapy for OCD and phobia. A psychological and a physiological therapy produced congruent results (Linden, 2006). "The similarity of the functional imaging findings indicates a convergence of the neural pathways that mediate pharmacotherapy and psychotherapy effects, at least for phobia and OCD (Linden, 2006. p. 535)." Resulting brain changes observed for major depressive disorder (MDD) varied, possibly indicating a greater divergence in results of CBT versus pharmacotherapy for MDD (Linden, 2006). Linden's (2006) work is a demonstration of similar neuroplasticity engendered by both a psychological and a physiological therapy. Could the EEG of clients undergoing an evidenced based therapy for a particular disorder be compared with the EEG of clients undergoing NFB? The demonstration of similar changes in the EEG would point to a convergence of effects.

Beauregard & Lévesque (2006) demonstrated that neural substrates for attention and response inhibition show increased activity after 40 sessions of NFB. A group of 20 children with a DSM diagnosis of ADHD were randomly assigned to a control group of 5 and to an experimental group of 15. None of the children were medicated during the research. The NFB was done in two phases of 20 sessions each with three sessions per week. During phase one SMR (12-15 Hz) was up trained. During the second phase Theta (4-7) was down trained and Beta 1 (15 – 18 Hz) was up trained. At the start of the study an fMRI was done during the Counting Stroop task and during a Go/No Go task on all 20 subjects. The EEG was recorded from Cz with reference at A1 and the ground at A2. Several tests were used at the start of the study that indicated no significant differences between the control and experimental group. Tests included

the Digit Span subtest of the Wechsler Intelligence Scale for Children—Revised (WISC-R) (Wechsler, 1981), the Integrated Visual and Auditory Continuous Performance Test (IVA, version 4.3), and the Conner's Parent Rating Scale–Revised (CPRS-R) (Full Scale Attention Quotient and Full Scale ResponseControlQuotient) (Conners et al., 1997). The scores of the children in the experimental group on the Digit Span and the IVA increased significantly after NFB training. Scores of those in the control group remained the same measured before and after the duration of the study. Scores on the Inattention and Hyperactivity measures of the CPRS-R decreased significantly for the experimental group.

Neural substrates as measured by fMRI reflected changes in results of neuropsychological testing. Beauregard & Levesque (2006) predicted that the dorsal division of the anterior cingulate cortex (ACcd) would be activated in the experimental group. "As for the ACcd, a large corpus of functional brain imaging data reveals that this brain region exerts a pivotal role in the cognitive processes involved in the Stroop task (Bush et al., 1998; Bush et al., 2000), being critically implicated in selective attention, the selection of an appropriate response, and the suppression of inappropriate behavioral responses (Carter et al., 1998; Corbetta, Miezin, Dobmeyer, Schulman & Petersen, 1991; Pardo, Pardo, Janer & Raichle, 1990; Paus, Petrides, Evans & Meyer, 1993; Petersen et al., 1999) (Beauregard & Levesque, 2006. p. 15)." Significant loci of activation were observed in the experimental group in the ACcd post NFB treatment during the Stroop task. No activation was noted in this area in the post fMRI of the control group during the Stroop task. The researchers posit that the better performance on the neuropsychological tests post treatment was related to improved neuronal activity of the ACcd which is a central component of the pre-frontal attentional system (Beauregard & Levesque,

2006). The research is significant in that it demonstrates through fMRI subcortical changes as a result of NFB which draws measurements of electrical potentials only at the cortex.

Beauregard & Levesque (2006) also noted significant activations of the left caudate and left substantia nigra in the experimental group post NFB that were not present in the control group. These changes were observed during both the Stroop and the Go/No Go task (Beauregard & Levesque, 2006). The researchers suggest that these activations point to dopamine as a possible mediator of the beneficial effects observed post NFB. The activity of methylphenidate that successfully ameliorates ADHD symptoms by blocking the reuptake of dopamine increases the amount of this amine in the interstitial space providing one possible explanation for the similarity of effect of NFB and stimulant medication (Beauregard & Levesque, 2006).

Linden (2006), a meta-analysis discussed above, provided evidence from fMRI that "talk" therapy and pharmacotherapy result in congruent physiological changes in neural substrates for OCD and phobia. Beauregard and Levesque (2006) have demonstrated through fMRI that NFB results in physiological changes in neural substrates for attention and task suppression both of which are aspects of ADHD symptomology. Neuropsychological measures confirm that behavioral improvements correlate with these physiological changes (Beauregard & Levesque, 2006). In both studies the relationship of experience with changes in neuronal activity as measured by fMRI has been demonstrated. Linden (2006) suggested that his research implies a therapeutic role for NFB. The results of symptom abatement correlating with physiological changes resulting from NFB in Beauregard & Levesque's (2006) research add evidence to the effectiveness of NFB for ADHD. While the small N of 20 in Beauregard & Levesque (2006) is weak statistically an attempt was made to have a control group (N=5) increasing the value of this study. The level of detail in describing methods should allow for duplication.

In 2008, Mulert et al., in an article entitled *Simultaneous EEG-fMRI: perspectives in psychiatry,* noted that fMRI can be used to identify underlying neural generators for EEG and ERP. The articles immediately above by Linden (2006) and Beauregard & Levesque (2006) demonstrated the synergistic capability of combining the spatial resolution of fMRI with the temporal resolution of EEG. fMRI detects the contrast of blood oxygenation levels, which is referred to as BOLD (Blood oxygenation level dependent). fMRI is a snapshot in time, but with spatial resolution to the millimeter. EEG detects the changes in electrical potentials that are measureable at the scalp that result from the synchronous firing of neural ensembles over a span of time but reveals very little about location of the generator of those potentials. The inability to localize the source of EEG is known as the "Inverse Problem," and was described by Helmholtz, a pioneer of electrophysiology, more than 150 years ago (Mulert, 2008). Various combinations of signals from different locations can result in the same potentials at the scalp therefore making EEG incapable of determining the source (Mulert, 2008). The combination of EEG with fMRI is a component of the rapid technical evolution that has allowed the science of interpersonal neurobiology to emerge through sophisticated noninvasive computerized neuroimaging.

**Self medication: Substance Use Disorder (SUD)**

Recreational psychotropic drugs have a long history. Altering subjective states with various substances is a clear example of manipulating physiology to make a psychological change. Pathological dependence on a substance to sustain its effects is a societal as well as an individual nemesis. NFB may provide a way to modify EEG patterns conducive to successful SUD therapy.

Arani, Rostrani & Nostratabadi (2010) utilized quantitative electroencephalograpy (qEEG) to measure the brain activity of 20 patients addicted to opioids in addition to the

Symptom Checklist-90-Revised (SCL-90-R) and the Heroin Craving Questionnaire (HCQ). All 20 were undergoing pharmacotherapy. One half of the patients received 30 sessions of NFB as well as the pharmacotherapy. The authors speculated that those receiving the NFB would demonstrate a greater reduction in comorbid symptoms. "Until recently, substance abuse and comorbid psychiatric/medical problems were typically treated independently (Arani, Rostrani & Nostratabadi, 2010. p. 170)." However the authors note that compartmentalization is giving way to coordinated treatment. This makes sense from the viewpoint of interpersonal neurobiology considering the interplay of psychology (mind) and physiology (body). NFB is based on the accepted scientific idea that the mind and the body are interconnected (Arani, Rostrani & Nostratabadi, 2010.). Arani, Rostrani & Nostratabadi (2010) suggest that substance abuse disorder requires a combination of neurophysiological and psychological modalities. The authors cite reduced dependence symptoms and improved psychological variables in NFB research studies beginning with Peniston's work in 1989 and 1990 that demonstrated positive results with alcoholic patients. The Peniston's Protocol of alpha-theta training has been utilized successfully in the subsequent research of Scott et al., 2005 & Fahnon et al., 1997 (Arani, Rostrani & Nostratabadi, 2010.).

As in Peniston's (1989, 1990) original protocol the therapeutic intervention employed by Arani et al. (2010) entailed the use of scripted guided imagery that dealt with the essential aspects of maintaining abstinence for 3-5 minutes before NFB. "The initial sessions were used to train patients to decrease alpha levels that were above 12 mV (peak to peak), while augmenting theta, until there was "crossover." This was defined as the point at which the alpha amplitude drops below the level of theta (Arani, Rostrani & Nostratabadi, 2010. p. 172)." Sessions were done with eyes closed with auditory feedback. After "crossover" both alpha and theta were

uptrained. Delta was downtrained as well to discourage sleep (Arani, Rostrani & Nostratabadi, 2010.).

Statistical analysis of the results on pre and post SCL-90-R, HCQ, and qEEG "…showed that the independent variable (NF training) was associated with a significant difference between the experimental and control groups in some neuropsychological scales (Arani, Rostrani & Nostratabadi, 2010. p. 174)." Positive results included improved measures on the subscales of somatization, obsession, interpersonal sensitivity, psychosis, hostility as well as in the total score for those receiving NFB and pharmacotherapy. There was no significant improvement in the subscales for anxiety, phobic anxiety, depression, or paranoia. The authors concluded that NFB improves comorbid symptoms of opioid dependence in the aforementioned areas which confirmed their hypothesis.

NFB resulted in decreased craving and improved withdrawal symptoms as indicated on post treatment SCL-90-R subscales. Several explanations were offered by the authors to explain the mechanism through which NFB may cause these changes. "A number of investigators are in essential agreement that ongoing direct experience that evokes persistent neuronal activation alters brain structure and brain functioning (Praag et al., 2000; Rosenzweig, 2003). A possible linkage between steady-state stimulation induced neuronal activation and neuronal plasticity is the increasing evidence that brain electrical activity regulates the synthesis, secretion, and actions of neurotrophins which promote synaptogenisis (Arani, Rostrani & Nostratabadi, 2010. p. 176)." The authors speculation regarding the relationship between NFB and neuroplasticity is supported by the results of Ros et al. (2010), previously discussed, which demonstrated increased strength in evoked motor potentials (EMP) subsequent to NFB.

## Aplysia and neuroplasticity

The relationship between neuronal stimulation and neuroplasticity just mentioned above was demonstrated by Eric Kandel (2003) as described by Norman Doidge (2007) in his book *The Brain that Changes Itself.* Kandel worked with a giant marine snail, aplysia, that has uniquely large 1 mm thick neurons that can be seen without magnification. The conservative nature of evolution which builds upon primitive neural systems allows extrapolation to the more complex brain of modern homo sapiens (Doidge, 2007). Lasting learning requires the formation of long term memories. Kandel (2006) showed that for a short term memory to become long term a protein called kinase A moves from the intracellular fluid into the cell nucleus. "The protein turns on a gene to make a protein that alters the structure of the nerve ending , so that it grows new connections between the neurons (Doidge, 2006. p.220)." This process of synaptogenisis follows the sequence of:

1. Learning through experience that produces a short term memory.
2. The migration of kinase A into the cell nucleus.
3. Kinase A turns on a transcription gene.
4. The gene causes the production of a new protein.
5. The new protein causes the cell to grow new connections between neurons.

Operant training in NFB results in learned changes in the regulation of brain state through self regulation of EEG rhythms. The learning in this case is an example of the brain turning on transcriptor genes in response to feedback driven mechanisms. The brain is changing itself in response to external stimulation through the sensory receptors.

One neuron developing a long term memory can increase synaptic connections from 1,300 to 2,700 (Doidge, 2007). Turning on transcription genes is a portion of the process of

therapy that influences physiological changes. Transcription gene actuation alters synaptic connectivity and deserves consideration as a physiological conjuncture of mind and body.

## Efficacy of NFB for SUD

Sokhadze et al. (2008) conclude that based on the criterion of efficacy discussed above NFB alpha/theta training for alcoholism is probably efficacious. Beta training combined with alpha/theta training for stimulant or mixed substance abuse in a residential program is probably efficacious (Sokhadze, 2008). Sokhadze et al. (2008) point out that the bench marks for assessing efficacy in SUD treatment with any therapeutic modality are not clearly established. Abstinence for a specified amount of time, improved function, and improved quality of life are all outcome considerations that need to be specified and clearly defined. Because EEG abnormalities vary according to the substance used efficacy must be defined in a substance specific manner. Comorbidity and mixing substances also complicates evaluation. Studies published to date are of the adjunctive use of NFB combined with cognitive or twelve step therapies (Sokhadze, 2008). Therefore it must be acknowledged that NFB is not stand alone therapy. As in Othmer's (2009) use of NFB to calm the SNS in PTSD treatment, NFB serves an adjunctive roll. Peniston's (1989, 1990, 1991) protocol utilized suggestive imagery in combination with alpha/theta training. Hand warming, skin temperature, biofeedback was used as a preliminary relaxation exercise (Sokhadze, 2008). Scott & Kaiser (1998) and Scott et al. (2002, 2005) successfully utilized protocols for ADHD followed by the Peniston Protocol in the treatment of stimulant abusing patients. Their method is referred to as the Scott-Kaiser modification (of the Penniston Protocol) (Sokhadze, 2008).

Early studies that have supported Peniston & Kulkosky's (1989, 1990, 1991) results have received criticism regarding comorbid conditions, among other concerns, that may not have been

accurately reported. Peniston (1998) stated that it ‘‘remains unknown whether the temperature training, the visualizations, the ATBWNT (alpha-theta brain wave neurotherapy), the therapist, the placebo, or the Hawthorne effects are responsible for the beneficial results.(Sokhadze, 2008. p.12)’’ The level of detail in Peniston’s (1989, 19990, 1991) original research is insufficient for duplication. Criterion for successful intervention varied between attempts at replication (Sokhadze, 2008).

Substances that are abused produce unique EEG changes. Cocaine dependent users who are abstinent exhibit diminished high beta (Roemer et al., 1995). Alcoholics may exhibit lowered alpha in specific regions (Kaplan et al., 1985). NFB protocols need to be substance specific. The use of NFB for SUD is decidedly not “one size fits all.” The most widely abused substances are: alcohol, marijuana, heroin, cocaine, and methamphetamine (Sokhadze, 2008). EEG signatures of use and treatment protocols necessarily differ for each substance.

Speaking very generally alpha activity may be viewed as inhibitory and faster beta activity may be viewed as excitatory (Saletu-Zyhlarz et al., 2004). The decreased alpha power observed in alcoholics may indicate brain atrophy (Sokhadze, 2008). Individuals coming from families with a history of alcoholism exhibited lower alpha power in the occipital and frontal areas and an increase in relative beta in these areas in comparison to individuals coming from families without a history of alcoholism (Sokhadze, 2008). Such results may be associated with a higher risk for alcoholism. It is interesting to note that non-alcohol dependent relatives of alcoholics exhibit these same patterns illustrating both the inheritability of these patterns and the complexity of etiology in alcoholism. The up training of alpha/theta frequencies in alcoholism treatment may be seen as an attempt to normalize the EEG. It may also be true that self

medication with alcohol may be the users attempt to augment deficient alpha power. An individual's choice of drug may reveal some characteristics of their EEG.

## NFB for Fibromyalgia

Fibromyalgia syndrome (FMS) is a systemic disorder characterized by pervasive muskuloskeletal pain and other symptoms most commonly affecting women (Kayiran et al., 2010). fMRI studies indicate a possibly enhanced sensory processing that results in low tolerance for pain (Mountz et al., 1995; Gracely et al., 2002; Guedj et al., 2007 in Kayiran et al., 2010). The increased sensitivity to pain was suspected to be related to disinhibitory processes that lead Kayiran et al. (2010) to suggest that NFB up training of SMR might be palliative for FMS. Up training of SMR had been shown to reduce impulsivity in ADHD by Monastra et al., (2005); Arns rt al., (2009); and Lubar & Shouse, (1976) discussed above.

Kayiran et al. (2010) studied 40 FMS female patients who were randomly paced in an experimental NFB group of 20 or a control group of 20 that received pharmacotherapy with escitalopram, an accepted SSRI with proven clinical efficacy. EEG was recorded at C4 with reference and ground placed at A1 and A2 according to the International 10-20 system (Kayiran et al., 2010). FMS symptomology was assessed at baseline, the $2^{nd}$, $4^{th}$, $8^{th}$, $16^{th}$, and $24^{th}$ week for both groups using the Visual Analogue Scale (VAS) for pain, VAS for fatigue, the Fibromyalgia Impact Questionnaire (FIQ), and the Short Form 36 (SF-36). Additional neuropsychological scales were applied and mean amplitudes of EEG frequencies were recorded for the NFB group.

Both groups showed significant improvement at the conclusion of the study. Improvements for the NFB group peaked at the $4^{th}$ week while improvements in the control group peaked at week 8. Interestingly no significant changes were noted in mean amplitudes of

EEG frequencies, however a decrease in the theta/SMR ratio was observed in week 4 for the NFB group. This is consonant with the protocol of up training SMR and it coincides with maximum improvements in FMS symptoms for the NFB group. This result would seem to indicate that the NFB training was the efficacious variable. While both therapies resulted in significant positive changes the NFB reached maximum effectiveness sooner which the authors speculate may indicate faster brain plasticity.

Linden (2006) discussed above demonstrated congruent physiological effects in neurological substrates as a result of "talk" therapy and pharmacotherapy in the treatment of OCD and phobia. In this research by Kayiran et al. (2010) congruent results as measured by neuropsychological scales in the treatment of FMS were demonstrated for NFB and pharmacotherapy. Kayirna et al. hypothesized that thalamic inhibitory mechanisms might be one factor in the hypersensitivity of FMS patients to pain. Beauregard & Levesque (2006) discussed above used fMRI to demonstrate subcortical changes resulting from NFB. The research of Beauregard & Levesque (2006) could serve to bolster Kayiran et al's (2010) hypothesis that SMR up training improves inhibitory function associated with this region. While their research demonstrates improvement in FMS through NFB training the research does not delineate the mechanism of action.

Frank et al. (2010) in an article concerning the effectiveness of NFB (termed EEG biofeedback in their study) for FMS rated this therapy as Level 2, Possibly Efficacious. "Keep in mind that if a condition has a lower efficacy rating, this does not suggest that biofeedback is not helpful in that condition, but rather that relevant research has not yet been conducted. Also, when combined with conventional medical management, an individual may very much benefit from a 'possibly efficacious' biofeedback application (Frank et al., 2010. p. 88)."

## NFB for Asperger's and Autism Spectrum Disorders

Few conditions highlight the interaction of mind and body as do Asperger's and Autism Spectrum Disorders (ASD). Physiological conditions in the brain temper or completely dilute the ability to discern emotional tone in another's behavior depriving the sufferer of the human experience of resonance with others. Complete attunement with another is prerequisite in therapy and an almost universally sought after quality in at least one significant relationship. The depth of subjective experience in such relationships is often described in spiritual terms emphasizing a quality normally considered distinct from biological processes. Yet research is yielding clues to physiological remediation and NFB may be pivotal.

Thompson et al. (2009) in their research and clinical observations of the functional neuroanatomy of Asperger's Syndrome postulate that biofeedback, especially Heart Rate Variability (HRV), as well as other treatments need to be integrated with NFB. This echoes the fact that NFB is not considered a stand alone therapy as mentioned beforehand. Thompson et al. (2009) term this "emerging understanding" the Systems Theory of Neural Synergy. "The name underscores the fact that NFB and BFB influence dynamic circuits and emphasizes that, no matter where we enter the nervous system with an intervention, it will seek its own new balance and equilibrium (Thompson et al. 2009. p. 39)." This idea was verbalized by Othmer (2009), Cozolino (2006), and Siegel (2010) in articles and books discussed above. All agree that the brain is a complex system that seeks integration. Changes in one area will be integrated into the whole system. Neural integration is one of the lifelong processes of neuroplasticity (Cozolino, 2006).

While there is no indicated pharmacotherapy for Asperger's Syndrome some medications are used to treat symptoms (Thompson et al. 2009). Children with Asperger's may exhibit hyperactivity resulting in a prescription for stimulants or amphetamines. Weight loss and insomnia are common side effects. Medication is often resorted to when symptoms impinge on others as in school situations. "In the authors' experience, the results of medications used with children who have Asperger's syndrome are usually a lack of significant improvement and an array of unfortunate side effects (Thompson et al. 2009. p.46)." In some cases where beta spindling is present stimulant medication may worsen behavior in the child with Asperger's who also has symptoms of ADHD (Thompson et al. 2009).

In 2010 Thompson et al. published a study of data gained over a 15 year period with 150 clients with Asperger's Syndrome (AS) and 9 clients with Autism Spectrum Disorder (ASD). Their stated objective was to determine if NFB was of any benefit to clients diagnosed with AS. Because these researchers are clinicians their over riding interest is a beneficial outcome for their clients rather than the isolation of a single efficacious variable. NFB was combined with BFB of respiration, electrodermal response, and Heart Rate Variability so it is difficult to assign efficaciousness to any one modality. Clients received 40 to 60 sessions of NFB which down trained slow wave activity (most often 3-7 Hz) and up trained SMR (12-15 or 13-15 Hz). Electrodes were placed at CZ for children and halfway between FZ and CZ for adults with reference to the right ear (Thompson et al. 2010). When the clients EEG revealed calm, focused relaxation metacognitive strategies that touched on social understanding, spatial reasoning, reading comprehension, and math were taught (Thompson et al. 2010).

Many pre and post measures were used. "Significant improvements were found on measures of attention (T.O.V.A. and IVA), core symptoms (Australian Scale for Asperger's

Syndrome, Conners' Global Index, SNAP version of the DSM-IV criteria for ADHD, and the ADD=Q), achievement (Widr Range Achievement Test), and intelligence (Wechsler Intelligence Scales) (Thompson et al. 2010. p. 63)." The authors conclude that there is preliminary support for the use of NFB with AS. Frank et al. (2010) rate NFB as Level 2, possibly efficacious, for use in Autism Spectrum Disorders.

## NFB for Performance Enhancement

The aim of performance enhancement is for an individual to complete a specific function or task with fewer errors and greater efficiency, resulting in a more positive outcome (Vernon, 2005). "Bruno DeMichelis, formerly at the AC Milan soccer team, changed how biofeedback and neurofeedback are perceived by sport scientists after the success of AC Milan in the European Cup and World Cup of Soccer in 2005 and 2006. Recently DeMichelis modeled the AC Milan ''Mind-Room'' at Chelsea Football Club in the U.K. Other professional and Olympic sport organizations throughout the world (as well as the U.S. military) are adopting biofeedback and neurofeedback as the basis of their mental training programs. (Perry, Shaw & Zaichkowsky, 2011)."

Perry, Shaw, and Zaichkowsky (2011) addressed whether psychophysiological interventions with biofeedback and neurofeedback assist athletes with cognitive and emotional self-regulation resulting in improvement in sports performance. Specifically they examined professional ice hockey players ability with penalty shots and Division I college women's gymnastic athlete's balance beam routines. The training intervention with the ice hockey players consisted of heart rate variability (HRV) and skin conductance (SC) feedback. Of interest to this project the training intervention with the gymnasts utilized NFB and HRV. The NFB consisted of increasing the sensory motor rhythm and decreasing theta at Cz. The authors demonstrated improved performance in both sports activities. "One of the authors (LZ) has recently accepted the position as sport psychologist and

Director of Sport Science for the Vancouver Canucks. In this professional hockey context he has developed a bio/neurofeedback laboratory and clinic designed to teach athlete self-regulation skills (Perry, Shar & Zaichkowsky, 2011)". While the evidence provided by this study was sufficient for a professional sports organization to make a monetary investment it contains some flaws from a strictly scientific viewpoint. The lack of a control group prevents assigning efficacy to any one aspect of the training. The authors recommend that a larger subject pool be used to determine optimal training protocols.

David J. Vernon (2005) authored an article entitled "Can Neurofeedback Training Enhance Perfromance? An Evaluation of the Evidence with Implications for Future Research." Vernon (2005) focuses on improvement, either in cognitive tasks, physical activities, or artistic performance, of those individuals whose initial performance falls within a normative baseline. In other words this research is not involved in helping those whose abilities are deficient in certain areas. Vernon (2005) notes that there are observed differences in the EEG patterns of experts at sports that differ from those of amateurs. The identification of these patterns during and before performance may provide a rationale to attempt to train these patterns in those less adept (Vernon, 2005). Vernon (2005) cites findings that alpha activity in the left hemisphere temporal region increases prior to execution of the skill (Hatfield et al., 1984 & Salazar et al., 1990). This is suggestive that the cognitive, verbal, self-talk aspects of the left hemisphere are less active allowing the visual-spatial processes of the right hemisphere to take a more prominent role (Salazar et al., 1990). Research with three groups of pre-elite archers including a control group that did not receive NFB training revealed a clear improvement in those who uptrained alpha in the left temporal region, a decrease in performance in those who uptrained alpha in the right hemisphere, and no improvement for the control group (Landers et al., 1991 in Vernon, 2005). N = 24, 16 of which

were male and 8 of which were female. Improvements as indicated by the difference between pre and post test scores were significant ($p<0.05$). Lander's (1991) results as reported by Vernon (2005) were sufficient for the researcher's to conclude that neurofeedback protocols uptraining alpha in the left temporal region prior to performance were supported as a method to enhance performance in pre-elite archers.

Vernon (2005) states that the direction of change may vary according to the demands of the sport. Crews & Landers (1993) demonstrated a right hemisphere increase in alpha has been associated with decreased errors in skilled golfers (Vernon, 2005). This is the opposite of that which was observed in the pre-elite archers described above. This demonstrates the need for sports specific research into the neurological correlates of peak performance. Vernon's examination of the research prompts him to state: "Given the reported association between specific patterns of cortical activity and particular levels of performance it seems plausible to utilize neurofeedback as a tool to train individuals to re-create patterns of cortical activity in an attempt to enhance performance. However, it seems the plethora of claims regarding the use of neurofeedback training to enhance performance is matched only by the paucity of research showing a clear effect (Vernon, 2005. p.362)." Vernon (2005) cites lack of control groups, lack of demonstrated pre and post changes in the EEG, and a range of methodological flaws as the basis for his conclusion. Vernon does not suggest that NFB cannot enhance performance, only that the evidence to date is equivocal from a scientific viewpoint (Vernon, 2005). The research of NFB for performance enhancement indicates Level 3 efficacy, probably efficacious, because several researchers have demonstrated benefits with a control group.

**Methodological Assumptions and Limitations**

There are several professional organizations in the field of NFB that publish peer reviewed literature. Access to the very latest research requires membership. The International Society for

Neurofeedback and Research (ISNR) and the Association for Applied Psychophysiology and Biofeedback (AAPB) are the most prominent. This writer is not currently a member of either. Many journals limit free public access to issues that are at least one year old and offer the latest at a price. Economic circumstances have limited this writer's access to what is freely available on the internet and through California Southern University's web portals.

The assumption is made that the research upon which this study is based is commonly available to its likely readers.

**Limitations of this Study**

The field of neuroimaging is extremely broad. While neuroimaging is integral to the discoveries that have lead to the new science of interpersonal neurobiology a comprehensive review of all articles that might have impinged upon areas of these discoveries is beyond the scope of this endeavor. Rather articles that have to do with neuroimaging were chosen because they were cited by authors in the field of NFB or interpersonal neurobiology. The selection of research cited this way may have narrowed the selection of authors to those predisposed to demonstrate a positive effect for NFB.

At least one area of research that demonstrates efficacy of NFB has been left out of the data analysis section. The treatment of epilepsy with NFB was mentioned in the historical section because it was Sterman's (1968) serendipitous discovery that lead to the first effective use of NFB to ameliorate symptoms. Epilepsy, however, is normally beyond the scope of practice of psychologists and so has been excluded.

NFB has been used for many other symptoms and disorders. Some success has been reported for anxiety and depression, however the paucity of available research caused this writer to decide to leave it out of the discussion at this time.

# Chapter Three: Summary and Conclusions

## Summary

This paper concurs with Alan Schore's (2009) view that a paradigm shift has taken place in the approach to behavioral science. While Freud (1865) had written an unpublished manuscript entitled *Project for a Scientific Psychology*, the idea that physiology would become an un-ignorable factor in explaining human behavior was largely left dormant until the evolution of highly sophisticated neuro-imaging techniques lead to the new science of interpersonal neurobiology. Answers to the mysteries of human behavior now demand psychophysiological explanations. Life-long neuroplasticity has been demonstrated (Siegel, 2010). The empathic nature of the mother-infant dyad and the tenets of attachment theory are now known to have measurable physiological correlates (Cozolino, 2006). Certainly the interconnectivity of psychology and physiology, of mind and body, had always been recognized but until now it had not yielded much to scientific understanding.

The synapse is a candidate for the physiological locus of the mind-body connection. Neurofeedback, allowing endogenous changes in EEG patterns by making the client aware of his EEG activity, ultimately acts at this juncture. NFB has an accumulating evidence base and is a physiologically based therapy that engenders psychological changes. Clinical reports of success with ADHD, Asperger's Disorder, Autism, SUD, Fibromyalgia, and performance enhancement are accumulating along side of scientific research. Yet NFB is underutilized.

Therapeutic modalities derive their techniques from their underlying assumptions. Skinnerian behavior management techniques examine the environment for clues that sustain or extinguish a behavior (Schultz & Schultz, 2008). Rogerian counseling assumes an inherent force for growth and allows this to manifest within an empathic relationship characterized by unconditional

positive regard (Schultz & Schultz, 2008). Freudian psychoanalysis probes the mother-infant dyad to make the unconscious conscious (Schultz & Schultz, 2008). The science of interpersonal neurobiology has now demonstrated through advanced neuroimaging techniques that empathy results in neurogenisis, synaptogenisis, and neural integration regardless of theoretical approach (Cozolino, 2006). Empathy has proven to be the psychological catalyst igniting therapeutic physiological changes in the brain (Norcross, Beutler & Levant, 2005; Norcross, 2002) and concomitantly changing behavior. Resonance in the therapeutic alliance is accompanied by a parallel synchronicity in many physiological measures (Siegel, 2009). Neurofeedback can allay sympathetic nervous system arousal which mitigates against empathy (Lehrer, Woolfolk, & Sime ( 2007). Interpersonal neurobiology, in revealing the catalyst of the mind-body connection, now indicates that any therapy must consider physiology of the neural substrates. NFB is a physiologically based approach that can serve an adjunctive role within the therapeutic alliance.

NFB operates on the EEG in the same way as all biofeedback modalities providing the client with information thus allowing endogenous learning according to the principles of operant conditioning. NFB has distinctively varied historical roots. Kamiya (1968) up trained the alpha bandwidth associated with meditation. The *zeitgeist* of the American culture at the time was infatuated with altered states. Experimentation with LSD and other substances was viewed by some as a spiritual pursuit. Unfortunately NFB became an unwitting abettor in this agenda and the residue of this perceived collaboration has relegated NFB to what is considered by many as *pop-psychology*.

While Kamiya (1968) worked within an almost spiritual milieu, Sterman (1968) endeavored to up train the SMR bandwidth in cats, thereby contrasting psychology with physiology, and providing a clear demonstration of NFB's unique ability to change both mind

and body. Sterman's (1968) discovery that up training the SMR lead to a diminution of frequency of seizures has been touted by Othmer (2012) as an experiment of immaculate design forever putting to rest the criticisms of placebo effect and bias on the part of the researcher because neither Sterman nor his cats were aware of the serendipitous outcome.

Ros et al. (2010) demonstrated increased neuroplasticity as measured by the strength of MEPs resulting from down training alpha at C3 proving a direct relationship between NFB and neuroplasticity in at least this one narrowly defined measure. Othmer (2009) successfully used NFB to facilitate trauma resolution in an adjunctive role for NFB that allayed SNS arousal facilitating changing implicit traumatic memory into an explicit narrative. Siegel (2010), Schore (2009), and Othmer (2009) agree on the physiological role of neuroplasticity in trauma resolution while having uniquely varying orientations in mindfulness, psychoanalysis, and applied psychophysiology.

NFB has been applied to ADHD since 1976. Many studies have concluded that NFB is efficacious with ADHD, however these studies have received much criticism regarding research design, small N, placebo effect and blinding. At least one study by Lansbergen et al. (2010) showed no effect, however this study, while attempting a double blind, had a small N of 14. Loo & Barkley (2005) have critically reviewed much of this research determining it to be deficient. Barkley has authored a text concerning ADHD with well referenced diagnostic and treatment sections. Barkley concurs with Ryan et al. (2012) that medication is an effective treatment. While NFB for ADHD has not conclusively demonstrated its efficacy, both Ryan (2012) and Barkley (2005, 2006) cite research supporting the efficacy of the physiological approach of pharmacotherapy. NFB is also a physiological approach and some novel work is being done with neuroimaging concerning EEG correlates of ADHD symptomology augmented by fMRI.

Linden (2006) confirmed congruent effects on neural substrates as measured by fMRI for "talk therapy" and pharmacotherapy. Linden (2006) suggests that using NFB might improve clinical outcomes. The simultaneous use of EEG with temporal resolution and fMRI with spatial resolution combines the advantages of both techniques and has revealed the subcortical source of some EEG changes noted in NFB (Mulert et al., 2008).

Beauregard & Levesque (2006) worked with NFB and fMRI and concluded that the neural substrates for attention and response inhibition changed subsequent to 40 sessions of NFB. Psychoneurological testing confirmed amelioration of ADHD symptomology. The combination of neuroimaging with various modalities is identifying the neural substrates for many symptoms and highlights the convergence of psychology and physiology.

The activity of kinase A in turning on transcriptor genes during conversion of short term into long term memories results in measurable synaptogenisis in Aplysia, a giant sea snail. Extrapolation to the human nervous system is possible because of the conservative nature of evolution building upon more primitive systems rather than shedding them (Cozolino, 2006). The learning taking place in NFB must also involve changing short term into long term memories because of the reported duration of some effects. Therefore NFB not only changes synaptic activity by altering the firing patterns of neuronal ensembles, but also activates transcriptor genes that turn on synaptogenisis.

The implications of research in the new science of interpersonal neurobiology against which the utility of NFB is examined in this paper are indeed causing a paradigm shift. A compartmentalized view of the individual brain examined from narrowly defined disciplines has characterized Western science (Cozolino, 2006). Individualism is cherished, but as Cozolino points out: "We are just beginning to understand that we have evolved as social creatures and

that all of our biologies are interwoven (Cozolino, 2006. p.3).” The realization that no individual has matured in isolation and that the species has evolved socially is the underpinning of interpersonal neurobiology. The core mechanism of neuroplasticity, the empathic relationship, has been verified by neuroimaging.

Lifelong neuroplasticity and the inherent social nature of our brain are novel concepts for many in the field of human behavior. Neurofeedback, despite having been demonstrated in the late ‘60s continues to have an aura of novelty as well. Neurofeedback has an accumulating evidence base and can play an adjunctive role in the therapeutic alliance. Not only can NFB allay SNS arousal thereby enhancing empathic resonance, but NFB can also teach the client to change his EEG patterns thereby changing his subjective experience.

**Conclusions**

The hypothesis that NFB is uniquely suited to a role in psychotherapy in light of findings from interpersonal neurobiology is, at a minimum, partially affirmed by the evidence in the literature. The hypothesis makes three points. Is NFB unique? Is it a suitable therapy? Are these two points supported by the new science of interpersonal neurobiology? The second hypothesis that NFB has an evidence base is also partially affirmed.

Is NFB unique? NFB is the only therapeutic modality that allows the client to change his brainwave patterns with real time feedback (Demos, 2005). NFB operates through the processes of conditioning in a unique manner that is consistent with those processes that resulted in the brain’s evolution (Demos, 2005; Cozolino, 2006).

Is NFB a suitable therapy? Evidence has been presented that suggests at least possible efficacy, level 2, for Autism and Fibromyalgia; probable efficacy, level 3, for Alcoholism and SUD; and level 4 efficacy for ADHD (Frank et al., 2010). Vernon (2005) suggests level 3, probable

efficacy, for the use of NFB in performance enhancement for sports and artistic endeavors such as ballet, gymnastics and musical recitals. Suitability for individual clients must be determined by the clinician. Very hyperactive children might produce too much muscle artifact for the feedback to be effective (Demos, 2005). Those with OCD might be concerned about having electroconductive paste applied to their scalp and earlobes. Autistic clients might exhibit tactile sensitivity to having their hair parted and electrodes placed on their skin. These are incidental concerns that an empathic therapist would be alert to. The evidence presented establishes efficacy for some disorders (Frank et al., 2010). Suitability of NFB for individual clients, as with all modalities, is at the discretion of the clinician. NFB is an adjunctive therapy. It can not be separated from the influence of the relationship with the therapist. This is a confound for all therapies. The empathic quality of the therapeutic relationship is the *sine qua non* for success as has been demonstrated by interpersonal neurobiology. The evidence suggests that NFB is a suitable therapy with many applications.

How does NFB mesh with the findings of the new science of interpersonal neurobiology? Interpersonal neurobiology is blurring the lines between physiology and psychology and between therapies that focus on the mind or the body (Schore, 2009). NFB allows learning a changed physiological state indicated by changes in the EEG pattern (Demos, 2005). These changes are subjectively experienced by the client as a change in his state of mind (Arani, Rostrami, & Nostrabadi, 2010). NFB is a physiologically oriented therapy that produces psychological changes. This is evidence of an interaction between body and mind through changes of firing patterns of neuronal ensembles that emanate at the synapse. Is this the locus of the mind-body connection? While that question cannot be answered the process at least suggests that NFB operates at a juncture of mind and body. This is an *a posteriori* argument that deserves consideration. NFB effects changes in the mind-body interaction

suggesting a good fit in the therapeutic milieu that has undergone a paradigm shift toward consideration of psychophysiological influences.

Emapthy in the therapeutic alliance is the *sine non qua* for success and is a core tenet of interpersonal neurobiology. SNS arousal mitigates against empathic resonance. NFB can be used to allay SNS arousal (Lehrer, Woolfolk & Sime, 2007). Othmer (2009) has utilized NFB to facilitate the recall of trauma memories without emotional dysregulation to help the client transform implicit memories into explicit narratives. NFB can play an adjunctive role in bolstering the empathic alliance and facilitate the state Othmer (2009) refers to as visceral calmness.

A remarkable finding of interpersonal neurobiology is lifelong neuroplasticity (Siegel, 2009). This fact is contrary to commonly accepted notions of complete brain maturity by age 20 or so, followed by a steady decline in function. Ros et al. (2010) have demonstrated increased neuroplasticity as measured by the strength of EMPs after one session of NFB. Ros et al. (2010) speculate that NFB may be a non-invasive way of increasing neuroplasticity. Kandel (2003) working with a giant sea snail, Aplysia, as reported by Doidge (2007) demonstrated that the protein kinase A migrates to the cell nucleus during the transformation of short term into long term memories. The kinase A protein turns on a transcriptor gene that causes synaptogenisis resulting in the number of synapses in the cell increasing on the order of from 1,300 to 2,700. NFB changes in the EEG have been demonstrated to have durations of up to 10 years. NFB establishes long term memory and in so doing NFB learning triggers the action of kinase A resulting in synaptogenisis.

Othmer (2009) in working with infra-low frequencies of the EEG speculated that the very low frequencies might be a resonant quality of the EEG. Very low frequency patterns are the first to be observed in the infant's developing brain and may be foundational in the brain's ability to regulate its state. Othmer (2009) speculates that training at these levels might encourage neural integration. Further, because the brain has an inherent propensity for neural integration, changes in any one area are likely to be integrated into the whole (Othmer, 2009, Siegel, 2009).

The arguments presented above that NFB is uniquely suitable in the light of findings from interpersonal neurobiology are certainly not conclusive. They are suggestive. The first hypothesis while not provable is valuable in that it has provided the opportunity to explore the relationship of NFB to this new science and the appropriateness of NFB as an adjunct to therapy.

The second hypothesis that NFB has an evidence base is affirmed for different levels of efficacy for the disorders mentioned in paragraph 3 above. The interpretation of the research is not, however, universally accepted.

**Discussion**

Much of NFB research has been done with a small number of subjects, no blinding, lack of random assignment, lack of control groups and no control of confounding variables. Many of the reviewed articles were written by therapists more interested in clinical results than in scientific validation of NFB. Loo & Barkley (2005) have highlighted these deficiencies in their article: *Clinical Utility of EEG in Attention Deficit Hyperactivity Disorder*. In reference to scientifically validating the efficacy of NFB for ADHD Loo & Barkley (2005) stated:

> This will require clinical trials that incorporate random assignment to treated and untreated groups, placebo conditions, larger sample sizes, evaluators that are blind to treatment condition,

> clear and comprehensive sample description (particularly with regard to psychiatric and learning disorder comorbidity), appropriate data analytic (statistical) procedures, and documentation of EEG changes that correlate with treatment outcome. These methodological difficulties compromise the internal validity of most of the studies reviewed here, making interpretation of the results and conclusions about the actual effect of treatment impossible (p. 74).

Some researchers view the quality of evidence for NFB more favorably. Othmer (2012) has colorfully described Sterman's (1968) research as having an *immaculate* design. Othmer (2012) notes that neither Sterman (1968) nor his cats were aware of the serendipitous discovery that the up training of the SMR bandwidth over the sensory motor cortex would control seizures. The results generalized to Sterman's epileptic assistant who was able to obtain her driver's license subsequent to 3 months of NFB (Demos, 2005). Frank et al. (2010) rate NFB for epilepsy at level 4, efficacious. Othmer (2012) has pointed out that cats are unlikely to demonstrate placebo effect and of course the cats were blind to their placement in the unintended control or experimental group. Sterman (1968) had no idea that he would inadvertently discover a treatment for epilepsy while working to measure the effect of hydrazine, and being blind to this outcome, had no opportunity to unconsciously skew the results. It is doubtful as well that Sterman's (1968) relationship with the cats tainted their behavior. It is fair to note that Loo & Barkley (2005) are specifically criticizing NFB research that has to do with ADHD. The nature of Sterman's (1968) experiments might not generalize to ADHD, but at least for epilepsy research confounds regarding placebo, random placement, blind evaluation, and relationship with the therapist appear to have been answered emphatically.

Loo & Barkley (2005) state that pharmacotherapy is the gold standard of treatment of ADHD agreeing with Ryan et al. (2012). Both agree, however, that treatment with medication does not cure ADHD. Symptomology returns upon discontinuance. Fox, Tharp & Fox (2005) noted persistent beneficial effects of NFB training for ADHD from 1 to 10 years post treatment with no

side effects. Ryan et al. (2012) list many side effects for ADHD stimulant medication. Consumer Reports (2012) in an updated article evaluating medication for ADHD stated:

> All of the stimulants cause side effects. Very few differences have been found in terms of their safe use. The most common side effects are decreased appetite, headache, insomnia, nervousness, and rapid heart rate. Careful dosing and practical advice can usually reduce or eliminate most of these effects. Children using the patch form of methylphenidate might also experience some mild skin reactions such as redness, itching, or an allergic rash. (p.20)

NFB has minimal reported side effects (Demos, 2005).

NFB is less invasive than pharmacotherapy because it utilizes sensory input in the form of feedback to allow the brain to change itself. Pharmacotherapy introduces complex molecules into the interstitial fluid affecting changes in the activity of the synapse.

While the acceptance by the mental health community of the evidence for NFB's efficacy has been debated its use by sport's organizations to enhance performance has proven a worthwhile investment. The Canadian Olympic organization utilized NFB preparation for its alpine skiers who medaled in several events. The soccer team, AC Milan, which was very successful in the European Cup and World Cup of Soccer in 2005 and 2006, utilized a *mind room* with NFB and biofeedback training equipment (Perry, Shaw & Zaichkowsky, 2011).

Frank et al. (2010) noted that almost 40% of adults in America used some form of *Complementary and Alternative Medicine* (CAM). NFB is considered CAM therapy. Many parents are hesitant to use stimulant medication for children diagnosed with ADHD and are increasingly opting for NFB. Cost for NFB is about $100.00 per session with often 40 to 60 sessions required. Benefits have been reported as long as 10 years post treatment. Stimulant medication can easily cost up to $100.00/month but symptoms return upon discontinuance. The higher initial cost of NFB may be acceptable to many considering that the outlay ends after treatment.

**Direction for Future Research**

Interpersonal neurobiology has reintroduced Freud's ideas of a science of psychology. Freud (1913) stated that psychology needed a point of contact with biology. With renewed interest in psychophysiology more research is needed regarding the physiological correlates of successful therapy. Schore (2009) suggested that progress in therapy might be gauged by some physiological measures. These measures need not be limited to NFB which was a focus of this paper. Rather an entire range of biophysical measures might be employed. Correlations could be noted between measures. The equipment is readily available that simultaneously monitors common biofeedback markers and EEG. It is much less expensive than fMRI equipment and offers temporal resolution which fMRI does not.

However fMRI does offer spatial resolution which NFB does not. Beauregard & Levesque (2006) have demonstrated the utility of pre and post fMRI to establish the neural substrates of EEG activity and pharmacotherapy. Some work has been done that demonstrates congruent effects of pharmacotherapy and "talk" therapy. If congruent effects on neural substrates could be demonstrated for commonly accepted evidenced based therapies and NFB then a whole new genre of corroborating evidence would be available to the scientific community. Physiological correlates might offer more reliable measures than the multitudinous questionnaires and inventories currently in use for pre and post therapy.

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