Chapter 11
Neurofeedback

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11 Introduction

Despite its birth in the halls of academia, neurofeedback as a discipline largely developed outside of the academy as a tool in clinical practice. Many of the early adopters of this intervention were not traditional mental health or medical practitioners. Some became developers and vendors of equipment and software as a bulwark against the lack of a wider community. In this way, vendors often became leaders of the field. In many instances these individuals filled traditional roles as therapists, teachers, and leaders of professional organizations inhabited by clinicians, academicians, and scientists in other health related disciplines.

This early history contributed to the synergy between developers and clinicians; allowing for the rapid development of clinical tools. Where there has been an interaction between clinical requirements and a manufacturer's capacity, rapid advancement has been the result. This environment has historically contributed to the field being less focused on scientific proof and more on clinical demands and market forces, adding to the field's vulnerability to criticism by traditional medicine and science.

With the production of more methodologically sound research; the field of neurofeedback is on the precipice of a much broader acceptance. The tumultuous birth of the field is inevitably giving way to the order imposed by professional standards, the demands of the growing influence of mainstream science, and the desire for a wider service delivery. The practice of neurofeedback is now commonly executed by healthcare professionals worldwide. Professional guilds for neurofeedback and biofeedback, have firmly taken root and a nascent Quantitative Electroencephalogram (qEEG) guild is developing. EEG-biofeedback is increasingly being implemented in university programs, especially in Europe.

Neurofeedback is a form of brain wave training that makes use of the principle of learning, defined as the general process by which an organism alters its behavior according to certain goals. By measuring and providing feedback related to brain wave activities, the process of neurofeedback provides an additional channel of information that increases awareness of brain behavior by creating subjective experiences that are derived from the EEG.

Neurofeedback has been commonly referred to as training rather than treatment due to similarities to physical fitness training including non-specific intervention stratagems applied to specific disorders and the need for multiple repetitions to produce positive results. Clinicians may apply a variety of interventions that produce symptom remission for the same disorder. EEG-Biofeedback has proved to be useful with an array of psychological and medical conditions. A diversity of protocols has been used to accomplish this result. It can be argued that neurofeedback does not treat anything specific but rather EEG-biofeedback optimizes the central nervous system, thereby improving general function in a variety of cognitive, emotional, and homeostatic domains. It accomplishes this task by conditioning brain electrical activity through repetitive application and so is more aptly referred to as training.

This chapter is intended as a general survey of neurofeedback. It will give a short history of the field and offer an introductory description of the existing clinical modalities that has developed as a result. It will describe basic clinical processes and neurofeedback interventions, including biological, technical, and scientific considerations. This chapter is not intended to be exhaustive. There are some areas of neurofeedback that will not be included. Rather, this chapter was written to help the reader understand neurofeeback in a general way and provide a starting place for deeper investigation.

11.1 Early History of the Field

11.1.1 Joe Kamiya and Alpha Training

The roots of modern neurofeedback began with the work of Joe Kamiya at the University of Chicago circa 1962. Kamiya discovered that human subjects could be taught to consciously control alpha burst activities. Initially, this was done through verbal prompts each time an alpha burst spontaneously appeared. Later, Kamiya used a simple electronic device that would sound a tone when alpha was present in the recording. This early work suggested that feedback could be used to teach subjects what it felt like to generate increased levels of alpha[1, 2]. Because this "felt state" was most typically associated with calm and relaxation, some of the earliest neurofeedback involved teaching a client to increase alpha activity as a treatment for anxiety [3].

11.1.2 Barry Sterman and SMR Training

At approximately the same time as Joe Kamiya's experiments, Barry Sterman began examining the ability of animals to control EEG activity. Sterman, a professor of neurobiology and psychiatry at the University of California, Los Angeles, taught cats to increase the sensorimotor rhythm (SMR) over the motor cortex [4]. In fact, he found that directly rewarding increases in SMR activity which was accompanied by decreased motoric activity while remaining alert was more successful than directly rewarding bodily stillness.

Sterman later found that the cats trained to increase SMR activity were also resistant to seizures when exposed to seizure-causing chemical agents. This finding was later replicated with monkeys and used to develop an early neurofeedback protocol for seizure disorders in human[5].

These early experiments helped lay the groundwork for the understanding that brainwave patterns were connected to states of consciousness and behavior. It was not long before the pioneers in this field began applying the basic methods of neurofeedback to conditions such as anxiety and seizure disorders.

11.1.3 Eugene Penniston and Elmer Green: Alpha/Theta Training

In the early 1960's Elmer and Alyce Green began working with the Menninger Foundation on the development of simple biofeedback tools and autogenic training, primarily to help patients to ease muscular tension. In 1965 at a meeting of the Psychophysiological Research Society, Elmer was exposed to the work of Joe Kamiya. This, in addition to other research tying brainwaves to states of consciousness, eventually led the Green's to begin experimenting with theta training to enhance creativity [6]. Much of this early work was based on the observations of EEG signatures in experienced meditators, healers, and yogis. The use of neurofeedback to enhance alpha and theta brainwaves was an attempt to develop some of the exceptional abilities observed in these individuals.

After taking a seminar with the Greens, Eugene Penniston began exploring specific training protocols with alcoholics in treatment at the VA Medical Center in Fort Lyon, Colorado [7]. Penniston observed that for many alcoholics, there was a decreased level of theta brainwave activity in the posterior region of the brain that was at times accompanied by a decrease in alpha activity. In conjunction with Paul Kulkosky, Penniston developed what became known as the alpha/theta protocol. This form of neurofeedback involves rewarding both alpha and theta frequencies, typically in the parietal or occipital regions of the brain. As the training session progresses, the alpha eventually decreases and becomes lower than theta wave activity. This process is referred to as a "crossover" and is associated with the resolution of traumatic memories and the integration of previously suppressed psychodynamic material [7]. The alpha/theta protocol was found to have very positive outcomes with substance dependence and PTSD [8, 9].

11.1.4 Fehmi, Hardt, Crane: Multi-Channel Alpha Synchrony Training

Les Fehmi had a prominent role in the early days of biofeedback, helping to found what is now known as the Association for Applied Psychophysiology and Biofeedback (AAPB). Fehmi was initially interested in studying alpha brainwave synchrony as this state was associated with autonomic nervous system balance and increased efficiency in brain performance [10] .

Fehmi discovered that synchronous alpha band activity increased dramatically when a person was able to be attentive and surrender control simultaneously [11] . After experimenting with this type of training, Fehmi and his students reportedly felt a deep state of relaxation and focus that was often described as "transcendent" or "in the zone." It was noted that the subjective quality of attention seemed to change after engaging in alpha synchrony training. Attention became more open and capable of taking in the gestalt of a situation. This was qualitatively different than the more typical narrow focus which is common during a stress response.

By utilizing multiple EEG channels, Fehmi helped establish a new kind of neurofeedback that focused on the impact of shaping a global alpha state[12]. Other early innovators including Jim Hardt and Adam Crane also utilized multi-channel synchrony training, advancing the notion that such a protocol strengthened access to deeper states of consciousness and improved self-regulation when compared to single-channel training [3].

Clients trained with EEG synchrony and/or verbally guided "open focus" techniques report significant changes in perception and behaviors [13]. This work has led to the development of protocols and applications used for conditions including pain, depression, anxiety and ADHD [14].

11.1.5 Lubar: Theta/Beta training

Joel Lubar, a professor at the University of Tennessee published the first article describing the use of neurofeedback to address hyperactivity [15]. Lubar expanded on Sterman's earlier work that reported on the successful use of SMR neurofeedback to reduce hyperactivity [16]. Lubar helped establish an arousal model of brain activity. The model recognized that decreases in vigilance are associated with increases in theta activity and increases in beta activity are associated with increases in cognitive processing [7, 17]. Along with his wife Judy Lubar, Dr. Lubar began systematically using neurofeedback designed to decrease theta and increase beta as a treatment for ADHD. His protocols have been refined over the years and have become a standard [18] helping to establish validity and credibility in the field.

11.2 Description of the Neurofeedback Process

The process of neurofeedback consists of recording a brain-related signal, typically the electroencephalogram (EEG), and using electronics and/or computers to create a representation of that signal to teach the brain to change. Neurofeedback provides another channel of information for the brain to understand its own process.

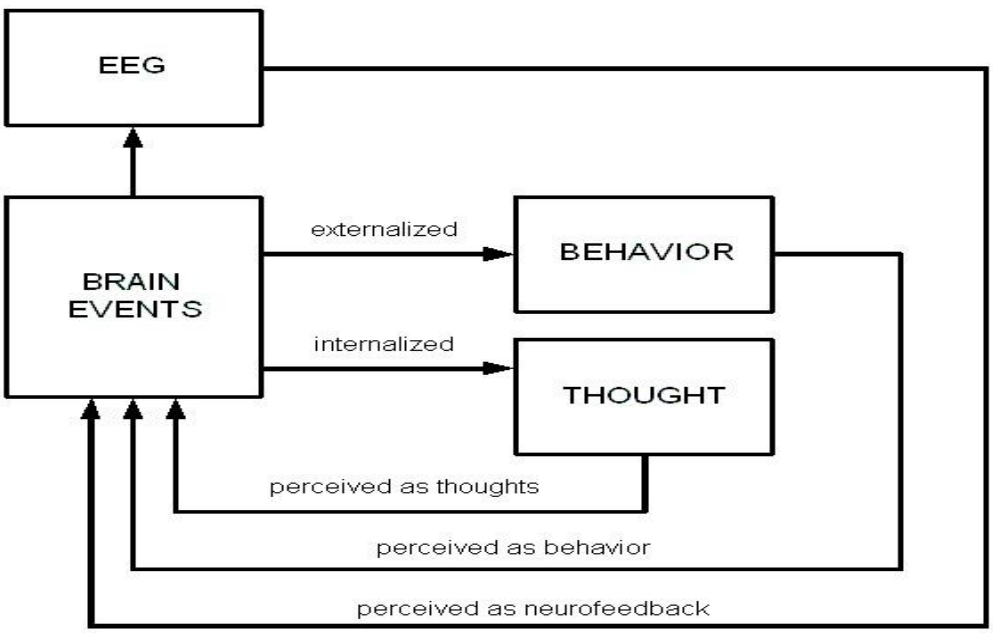

Figure 11.1 The process of neurofeedback

The following figure shows a view of the various tissues, bone, scalp, and hair that comprise the human head. Because of the intervening tissue and bone, the signal on the scalp is thousands of times smaller than the potential if it were measured inside the head.

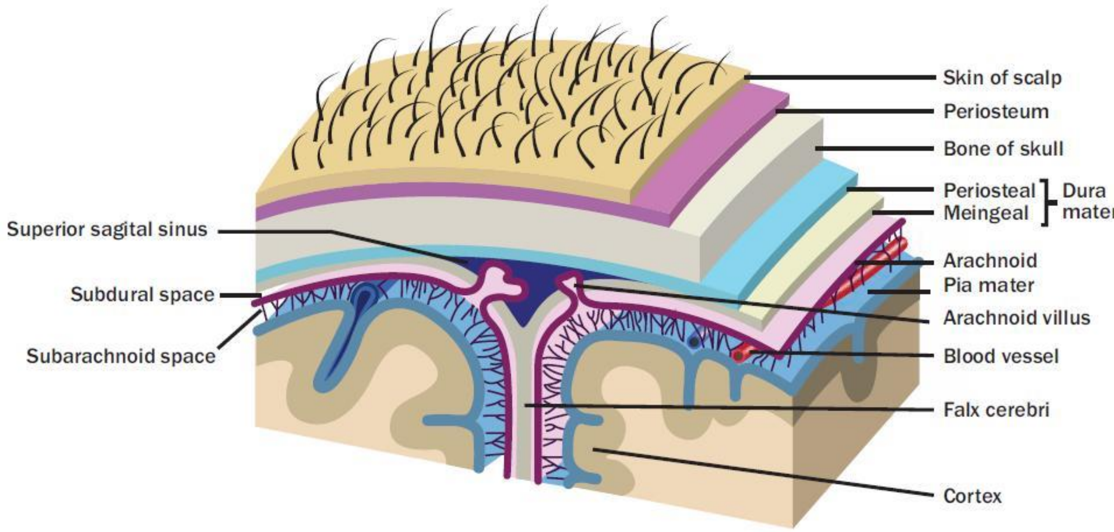

Figure 11.2 The anatomical view of the brain, skull, and scalp

In order to record EEG, sensors must be attached firmly to the skin of the scalp, so that an accurate reading of the electrical potentials on the surface can be recorded.

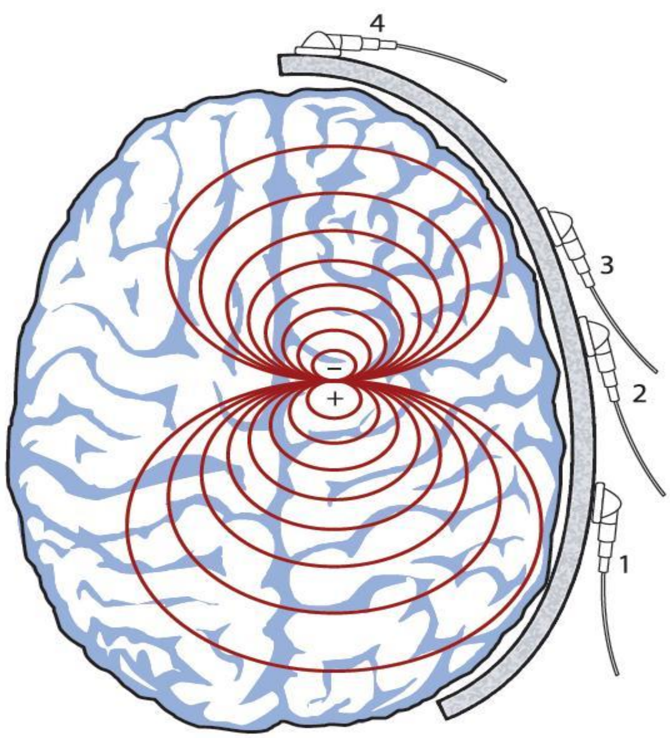

Figure 11.3 An EEG electrical source and the resulting electrical field in the brain

The representation of brain electrical activity is known as feedback, hence the name neurofeedback. In practice, neurofeedback requires a practitioner to apply EEG sensors to the client's scalp, and to then use the equipment to acquire a live EEG signal. This signal must be inspected to ensure that it is free of artifacts and thus suitable for neurofeedback. Once a quality EEG signal has been achieved, the system is operated in such a manner as to provide feedback in the form of visual, auditory, or vibrotactile stimulation.

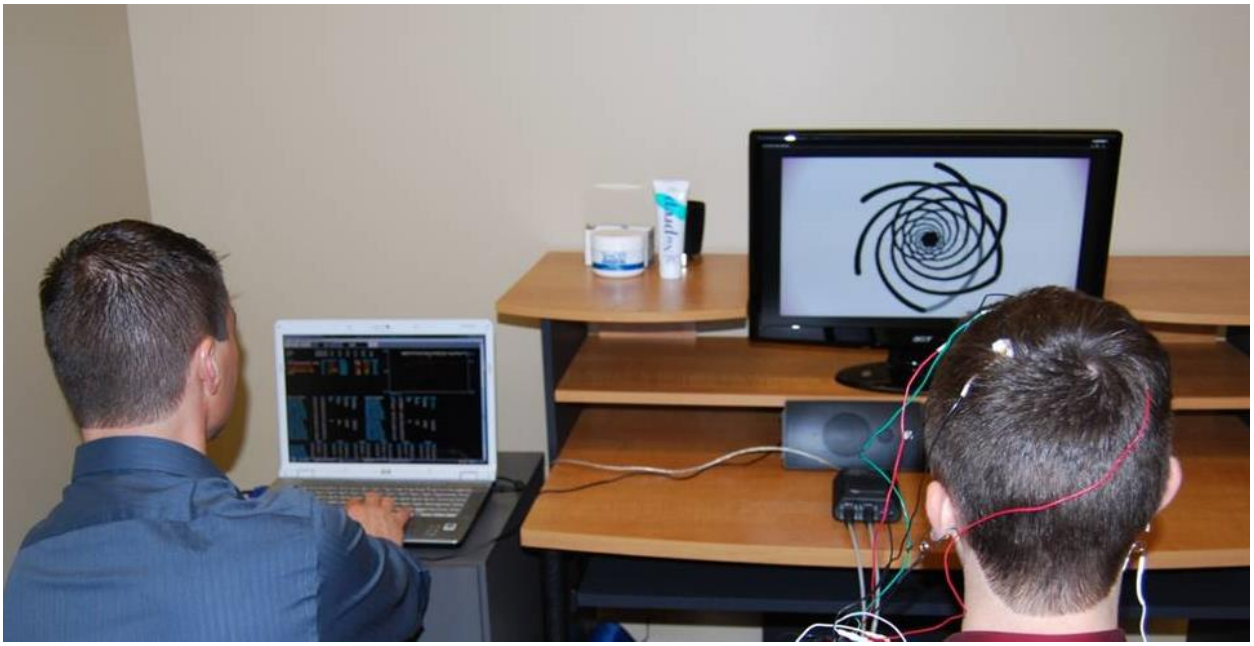

Figure 11.4 A subject being trained with Z-score neurofeedback

11.2.1 Signal Processing

In order to derive useful feedback information from the raw EEG signal, it is necessary to subject it to some signal processing. This consists of mathematical operations that are implemented either in hardware or in software, and which provide a suitable measure of the relevant EEG parameters. It is important that the signal processing be done in "real-time," which means that the derived information must be computed and made available quickly (typically within less than 1/10 of a second). The most common transform of the signal in neurofeedback training is the Fourier transform. Others employ a Joint Time Frequency analysis and fewer still apply the Hilbert transform.

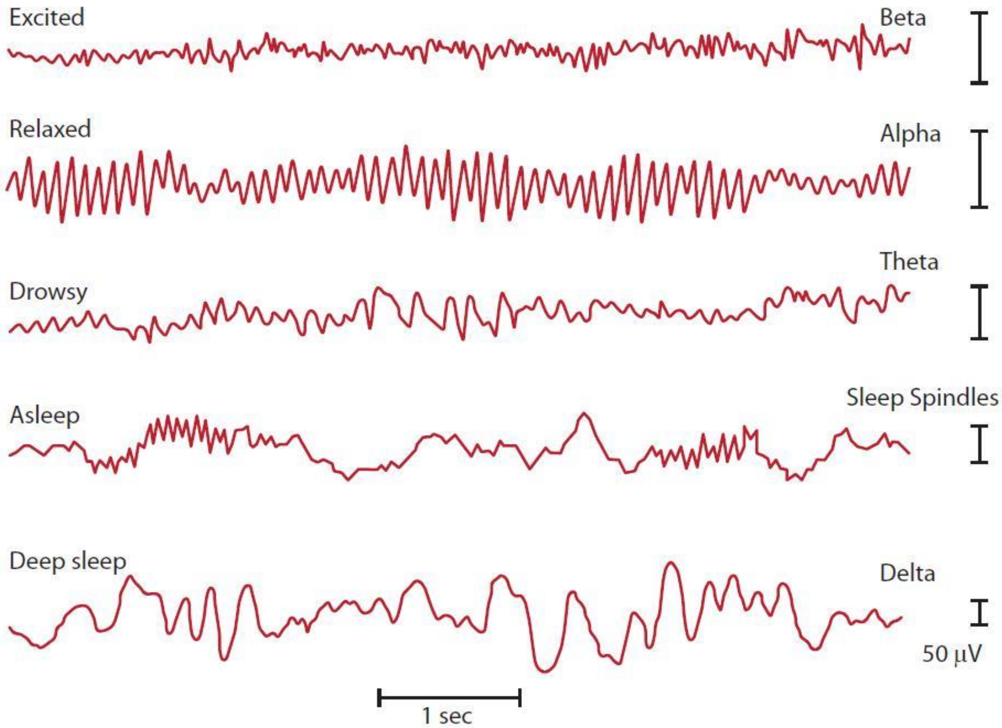

Figure 11.5 The Basic Types of EEG bands and their behavioral correlate

Signal processing for neurofeedback is most often based upon a mathematical analysis of the EEG, producing estimates of the amount of energy (or connectivity) in the EEG, for particular frequency ranges. For historical as well as physiological reasons, the EEG bands are generally divided into certain standard bands shown in Table 11.1.

Typical EEG Component Band Ranges

- Delta 1 – 3 Hz
- Theta 4 – 7 Hz
- Alpha 8 – 12 Hz
- Lo Beta 12 – 15 Hz (SMR)
- Beta 15 – 20 Hz
- High Beta 20 – 35 Hz
- Gamma 40 Hz (35-45 Hz)

Table 11.1 Band pass filters used for neurofeedback

While neurologists and other EEG analysts view these waveforms directly, neurofeedback requires the reduction of these patterns to some type of number, so that the software can produce feedback signals related to quantitative patterns. It is beyond the scope of this chapter to detail the signal processing used for neurofeedback. However, the basic operations yield estimates of important parameters such as the amount of power in a certain frequency band. More elaborate computations provide information such as the speed of each EEG signal, the presence or absence of signals, and how the signals reflect the quality of connections between brain regions.

11.2.2 Operant Conditioning

There is a variety of mechanisms involved in the process of any learned behavioral change, and neurofeedback employs more than one. Of these, the most often cited, and one of the most basic, is operant conditioning. This occurs whenever an organism is provided with feedback in the form of a reward (or punishment), and consequently learns to perform a desired behavior. In the case of neurofeedback, the "behavior" is the production of a particular type of EEG wave or waves.

Neurofeedback Learning Mechanisms
• Classical Conditioning
• Concurrent Learning
• Habituation
• Self-Efficacy
• Generalization
• Transference
• Nonlinear Dynamic Adaptation
•

Table 11.2 Neurofeedback learning mechanisms

It is important to view neurofeedback within the broader context of brain self-regulation mechanisms [19]. The brain undergoes normal cycles of activation, separated by periods of de-activation or relaxation [16]. Figure 11.6 shows the range that the brain may work within, as it moves from a state of concentration (activation) to a state of relaxation (de-activation).

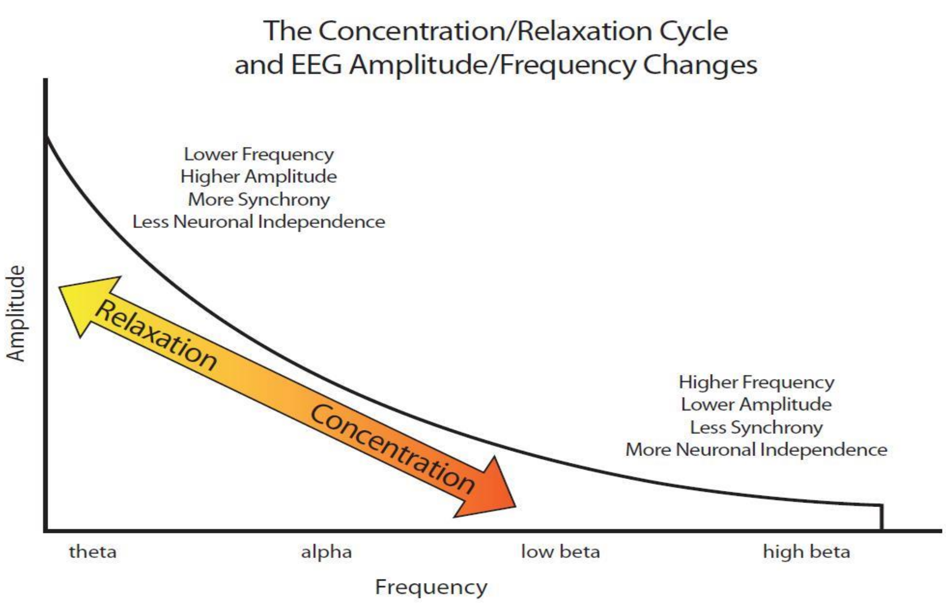

Figure 11.6 The synchronization/desynchronization cycle

While it might appear that the objective of neurofeedback is to increase brain waves that are deficient or decrease brain waves that are excessive, the goal is much broader and often involves attempts to encourage the brain into a more efficient and flexible state.

Goals of neurofeedback

- Improve Self-Regulation
- Achieve Flexible & Appropriate Brain States
- Normalize Connectivity
- Address Functionality, not Symptoms
- Provide Lasting Change

Table 11.3 Goals of neurofeedback

11.3 Neurofeedback Modalities-QEEG Guided Neurofeedback

The field of neurofeeback can be loosely separated into two categories: clinicians that employ a symptom based approach and a treatment approach guided by a pre-treatment Quantitative Electroencephalogram (qEEG). Clinicians that apply neurofeedback to present complaints without a quantitative analysis are symptom based practitioners and those that utilize age normed data in assessment and training are said to be qEEG based. Quantitative analysis is based on the use of a reference database.

One dominant theme in the analysis of EEG, and in the design of neurofeedback protocols, is the application of reference databases. These consist of EEG data in various reduced forms that provide nominal or target values for key parameters. Databases employed for this purpose contain what are considered "normal" or "typical" EEG's, used to create statistical references or "norms," for comparison. In addition, a database may contain a number of abnormal or disordered subjects, used for comparison purposes. When abnormal, as well as, normal EEG is available it is further possible to create "discriminant" functions that provide statistical estimates of the likelihood that a subject comes from one of the clinical populations.

There is a variety of ways to employ qEEG when planning and performing neurofeedback training. The traditional approach uses a qEEG analysis to determine which deviations from "normal" are relevant to presenting symptom expression, and designs a neurofeedback protocol that encourages the brain towards a more normative state. This approach seeks to make "large things small" and "small things larger." While this approach makes sense, training decisions should be made combining client complaint with functional neuroanatomy. Simple linear decisions may not be consistent with the complexity of brain function. qEEG deviations may be coping or compensatory mechanisms and facilitate normal function. In order to determine whether an observed deviation is pathological or compensatory, it is important that the neurofeedback practitioner has an understanding of functional neuroanatomy.

Despite the common observation that qEEG maps may become more normal or typical after treatment, it is not necessary for this to occur for the client to experience benefits. The brain is not a simple, linear mechanism that always responds in a predictable or consistent manner. Clients may have various ingrained tendencies or patterns, coping mechanisms, compensating strategies, or other behavioral or physiological mechanisms at play, that can interact with the brain and the neurofeedback process in complex ways.

11.3.1 Description of qEEG metrics

The particular computed values that are derived from the EEG are referred to as "metrics." This simply means that something is being measured. As with any phenomenon or object, there are various ways to compute and use different metrics. When we ask "how large" an EEG signal is, we refer to its magnitude in microvolts. The metrics related to signal amplitude (or power) in a single channel include Absolute Power (value in microvolts), Relative Power (percentage of total band), and Ratios (between bands). These values are descriptors for the activation processes in the cortex. These metrics reflect the quality of a response to a stimulus or the ease of shifting behavioral states. As absolute power increases or decreases, it reflects the activation dynamics of groups of cortical neurons to meet a behavioral demand. For instance, when one moves from actively reading to a drowsy state before sleep, groups of cortical neurons move from a low amplitude desynchronized fast activity to a higher amplitude slow-wave synchronous activity.

In addition to evaluating the activation processes, qEEG metrics allow the clinician to evaluate network dynamics. This is done through metrics that relate to the relationships between pairs of channels. These indices most often include amplitude asymmetry (a measure of the ratio of energy from one site to another), coherence (a measure of the amount of shared energy between network pairs), and phase (the metric used to determine the speed of information transfer). These metrics fall under the rubric of connectivity. Other connectivity metrics include Comodulation and Spectral Correlation Coefficient that reflect the magnitude consistency between two signals and correlation between amplitude spectra respectively. Connectivity metrics are described in detail by Collura [20]. These metrics are generally computed for a given band, so that one generally refers to them for example, as "coherence between C3 and C4 in beta or the phase lag at T4 and P4 in theta."

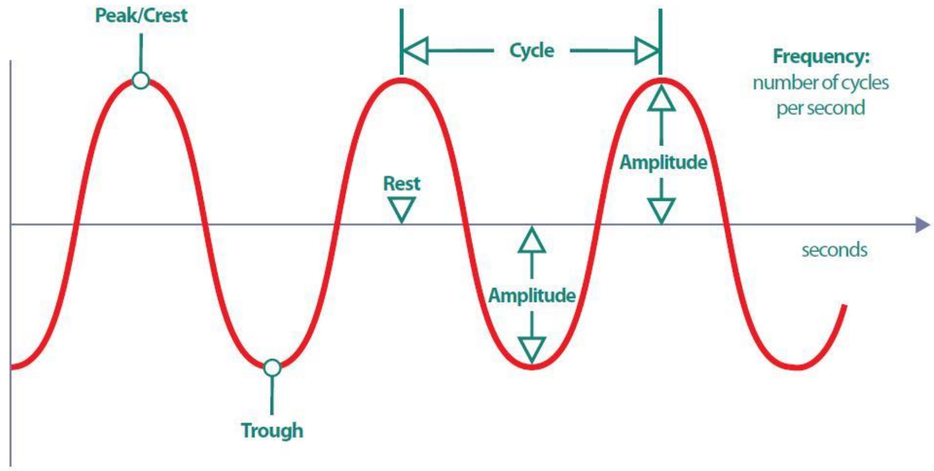

Figure 11.7 Basic EEG metrics

11.3.2 Databases

11.3.2.1 BrainDX

BrainDX is a database that is derived from the original NXLink database created and reported by E. Roy John and his laboratory at the Brain Research Laboratory of New York University [21-24]. Originally, it largely consisted of eyes-closed data from over 700 normal subjects, and also included a large number of clinical (abnormal) cases. It has recently been supplemented with adult eyes-open data, with plans to add child eyes-open data in 2014. There is also an associated software system that includes the ability to conduct EEG analyses and reports. This system provides a complement of discriminant functions, sLORETA z-score images, and other report capabilities. The BrainDX database is incorporated into neurofeedback products by one vendor: Brainmaster Technologies, Inc.

11.3.2.2 Applied Neuroscience / Neuroguide

The Neuroguide database was created at the University of Maryland, as the Lifespan Database, and is currently provided by the Applied Neuroscience Institute (ANI) [25]. It contains approximately 625 subjects, and spans the age range from birth to 80, with both eyes-open and eyes-closed data. The Neuroguide application includes artifacting, as well as, optional discriminant functions, LORETA analysis, and other capabilities.

The ANI database is also used for z-score neurofeedback, by a number of providers, who incorporate the database into their own neurofeedback products. The consistency between the Neuroguide and the NXLink (now BrainDX) database has been established and documented, showing that essentially identical results can be expected, regardless of which database is used [25].

11.3.2.3 SKIL

The SKIL database was created by Barry Sterman and David Kaiser [26] and is primarily an adult database. It contains eyes-open, eyes-closed, and task conditions. There is also a SKIL application that can read in EEG files from various providers, and provide analysis functions. SKIL also provides neurofeedback software that operates on several types of EEG equipment.

11.3.2.4 HBI / WinEEG

The Human Brain Institute (HBI) database was developed by a team in Russia, led by Dr. Juri Kropotov [27]. The database is comprised of 885 healthy subjects of both sexes aged 7 to 89 years. The subjects were divided into 20 age groups. It is incorporated into the WinEEG system, and can be used to create maps and reports of EEG's read in from standard EEG files.

11.3.2.5 BRID

The Brain Resource International Database (BRID) is very extensive, and includes a wide range of abnormal as well as normal EEG's. The database consists of more than 5,000 subjects that range in age from 6 to 100 years. BRID provides a report service for subscribers, and primarily uses equipment that is provided by the company to affiliated practitioners.

11.4 qEEG Based Neurofeedback-Inhibit/Enhance training

Inhibit or enhance training, also known as "traditional" neurofeedback, is based on providing rewards when particular frequency bands are either present in excess and so are "inhibited" or when they are insufficient and so are "enhanced." This type of training is commonly done using the traditional bands for training, such as theta, alpha, low beta, beta, or high beta. For example, after consulting a brain map, a protocol for relaxation may include enhancing when alpha absolute power is insufficient compared to the age-normed population mean, but inhibiting when theta or high beta are large. The rewarding or reinforcing is commonly done when the chosen EEG band is above a specified threshold during enhance training and below a specified threshold during inhibit training. The following table shows some common protocols based on enhancing or inhibiting components. Enhance training is also sometimes called "uptraining," while inhibit training is known as "downtraining."

Standard Enhance/Inhibit Type Protocols
• Alert C3 – beta up; theta, hibeta down • Deep Pz – (Penniston) alpha up, theta up

• Focus C4 – SMR up; theta, hibeta down • Peak2 C3-C4 – alert and focus combined • Relax Oz – alpha up; theta, hibeta down • Sharp Cz – broadband squash

Table 11.4 Standard inhibit/enhance protocols

11.4.1 Z-Score training

Z-score training was created by the collaboration between two software and equipment vendors: Applied Neuroscience, Inc and Brainmaster Technologies, Inc with the contributions of several clinicians [28-30]. The training is based on the principle of using statistical z-scores in real time, rather than using raw signal amplitudes or other variables. In order to do z-score training, it is necessary to select a suitable database for the reference (see above), as well as to have software that can compute z scores in real time. By using z-score parameters during the process of training, it is possible to inform the brain whenever any of one or more (often many more) variables are within a certain range of normal (e.g., +/- 1.0 Standard Deviation). This type of training allows for the training of large numbers of variables across multiple brain sites simultaneously.

A typical set of pre-treatment and post-treatment qEEG maps collected before and after z-score training is shown below in Figure 11.8, as an example. It illustrates that there may be particular deviations from normal (excesses or deficits) in the initial map, and that these deviations may be partially or wholly resolved (normalized) in the post-treatment assessment [28]. In order to aid in understanding statistical deviance in the brain maps, an illustration of the relationship between color and standard deviations is provided in Figure 11.8. The qEEG and neurofeedback community accepts two standard deviations and greater as a representation of abnormal activity.

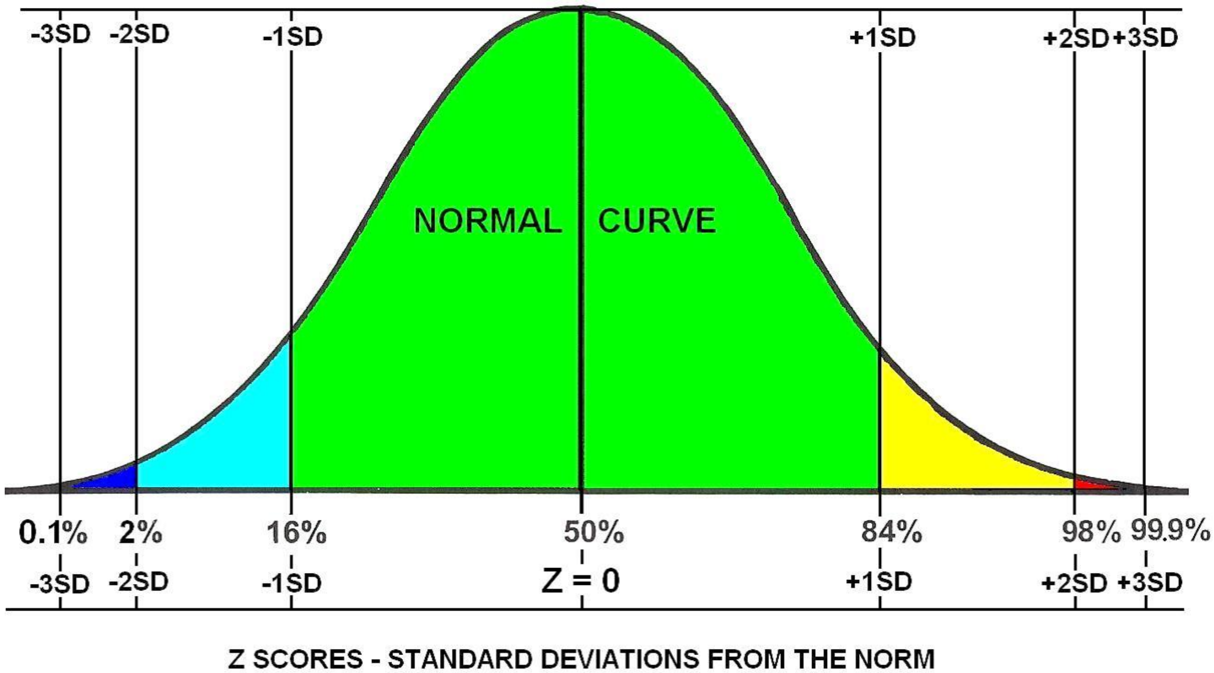

Figure 11.8 Bell Curve

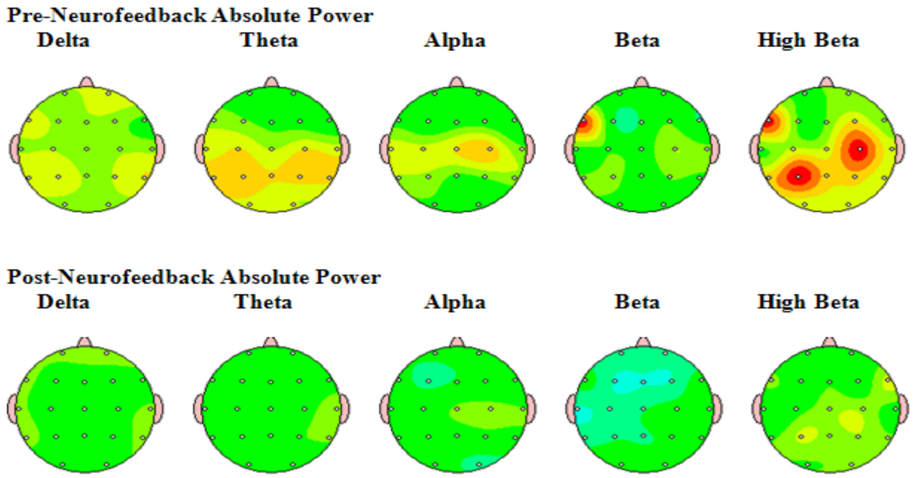

Figure 11.9 Pre/Post Neurofeedback training brain mapping

The following coherence maps taken pre-treatment and post-treatment show a clear normalization of coherence, indicating that brain connectivity is more typical of normal, following the treatment.

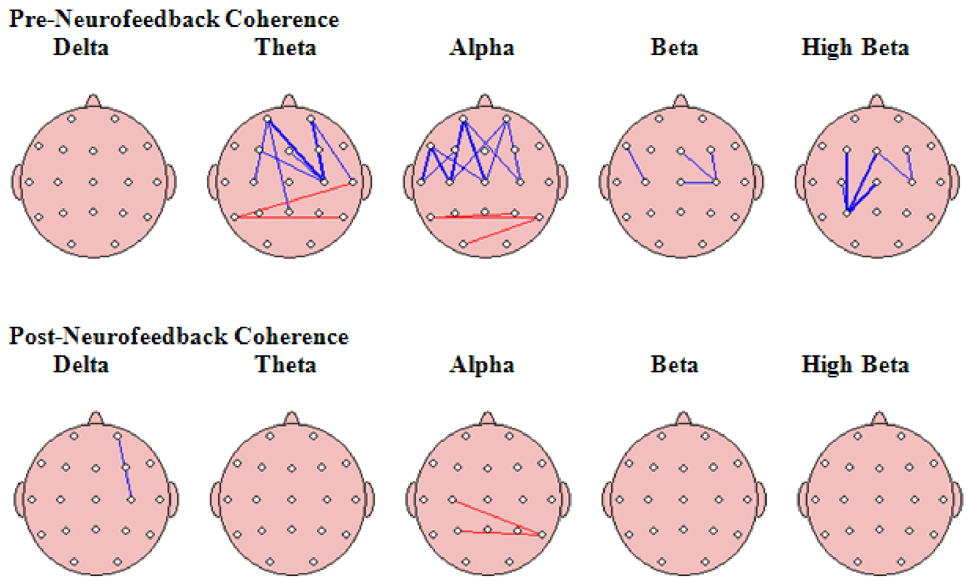

Figure 11.10 Pre/Post Neurofeedback training demonstrating normalization of coherence

11.4.2 sLORETA/LORETA

LORETA and sLORETA are methods that can be used to extrapolate the activity of deeper brain regions from surface EEG data. This has been called the inverse solution as it applies an algorithm that utilizes the surface amplitudes to identify current sources below the outer layer of the cortex. While this generally requires a minimum of 19 sensors, it allows the client to receive feedback that is specific to deeper structures in the brain, such as the Cingulate Gyrus or the right insula. It measures the magnitude of current with Current Source Density (CSD): Nano-amperes per cubic millimeter. In addition, sLORETA/LORETA coherence and phase are currently being calculated and trained in some applications.

LORETA and sLORETA can also be combined with z-scores, so that each brain region is evaluated in comparison with a database of brain activity.

The following figure shows an example of a sLORETA display showing brain activity in specific brain areas. In this image, excess Z-scored CSD activity is visible in the Cingulate Gyrus.

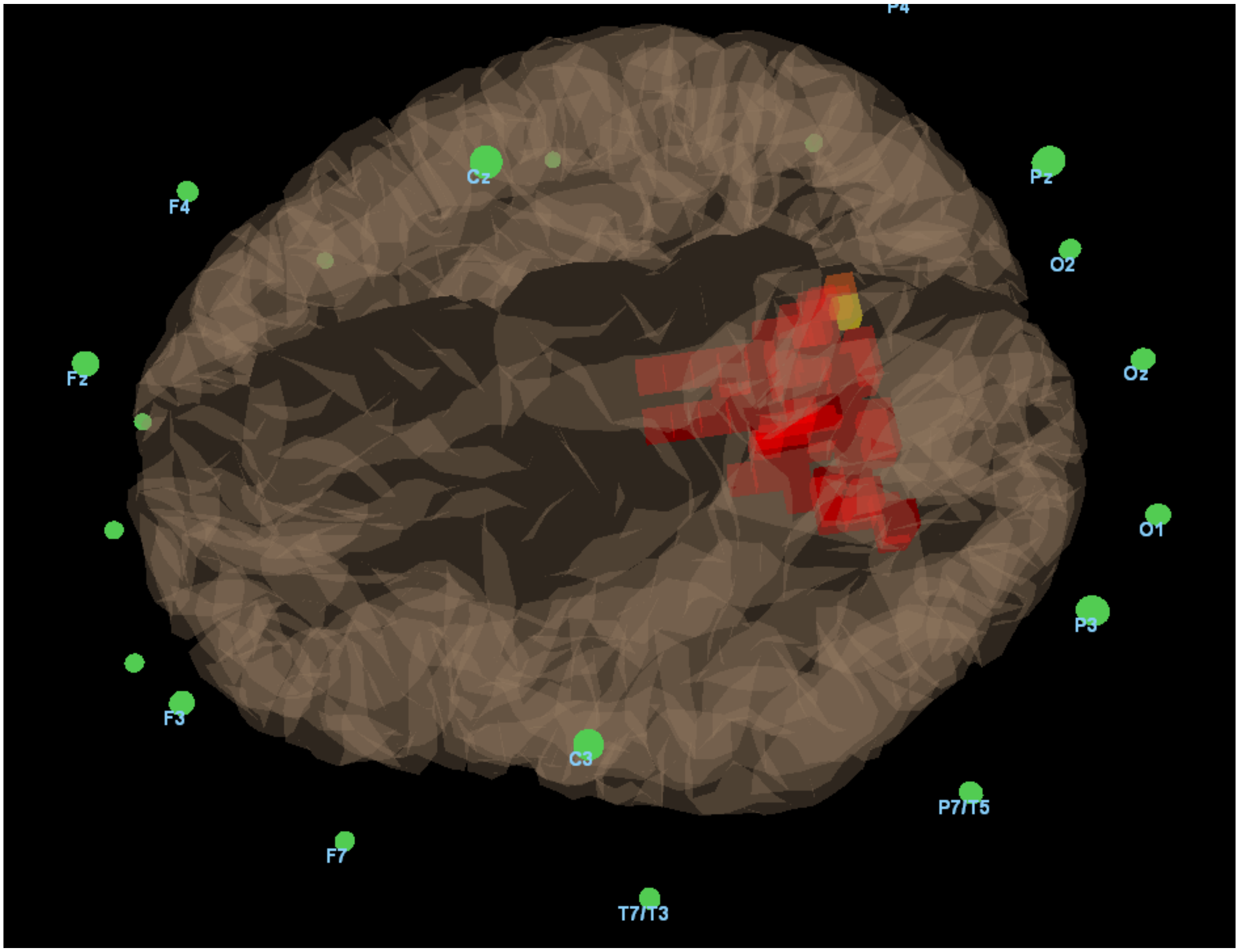

Figure 11.11 A sLORETA display of Z-scored current source density in the Cingulate Gyrus

11.5 Neurofeedback Modalities-Symptom Based Approaches

Symptom based approaches rely on applying the appropriate training protocols to the specific presenting problems. This paradigm was established at the commencement of the field and is applied differentially determined by client complaint, functional location in brain, and clinical experience. The symptom based approach began with alpha band training, followed shortly after by SMR and alpha/theta training. More recently, the symptom based approaches include Slow Cortical Potential (SCP) training Alpha Asymmetry and Infra-slow fluctuation/Infra-low Frequency training. These neurofeedback training protocols are also utilized by qEEG based clinicians.

11.5.1 Alpha Training

Alpha training is most often used for relaxation, peak performance, pain relief, and anxiety. It is performed in an eyes closed condition in one or more channels [13, 31, 32]. The client attempts to increase electrical activity in the 8 to 12 Hz range while simultaneously inhibiting slower frequencies, usually 4-7 Hz and a higher band in the 20 to 30 Hz range. Alpha activity is trained in posterior regions of cortex most frequently in parietal regions. Jim Hardt, Les Fehmi, and others train alpha synchrony in two or more channels. In this form of alpha training, channels are summed together and microvolt increases rewarded under the assumption that synchronous neuronal assemblies firing simultaneously are responsible for amplitude increases.

11.5.2 SMR Training

SMR training was developed by Barry Sterman for seizure disorder [5]. It was later utilized by Joel Lubar and others for ADHD [33]. It has been used for a host of other clinical presentations and may be the most frequently studied and utilized neurofeedback training. The SMR band is commonly defined as 12-15 Hz. This range of frequencies is rewarded for amplitude increases while simultaneously inhibiting lower and higher frequency bands. The protocol is executed on the sensorimotor strip at one site or a combination of sites usually C3, C4 and Cz. Ordinarily; it is performed in a single channel montage. Less frequently, two or more channels or a bipolar montage electrode array is implemented. The result of the training is often improved attention and reduction of restlessness or motoric stillness.

11.5.3 Alpha-Theta Training

Alpha/Theta training, also known as deep states work, emerged from the work of Elmer Green, Steven Farhion, and Dale Walters at the Menninger Clinic over thirty years ago [6, 34]. Eugene Penniston and Paul Kulkowski later applied the intervention to alcoholics in recovery and Vietnam Veterans with Post Traumatic Stress Disorder [8, 9]. It is executed with the eyes closed, usually with the client in a reclining chair. Alpha/theta training is performed with one or more electrodes, most frequently placed in posterior areas of cortex. Both the alpha and theta bands are enhanced while inhibiting the delta band and a higher frequency band: nominally 20 to 30 Hz. The goal of the training is to enter a “crossover” state wherein the theta band is greater in amplitude than the alpha band. Physiologically, crossover resembles a hypnogogic/hypnopompic state: the state of consciousness entered just before sleep or just before awakening. This crossover state is associated with spontaneous imagery and autobiographical memories and is said to enable individuals to process emotionally salient material. Alpha/theta training is frequently used with a hypnotic induction and/or a scripted guided imagery that addresses the subject’s presenting problem.

11.5.4 Alpha Asymmetry Training

Alpha Asymmetry training was developed by Peter Rosenfeld, and Elsa and Rufus Baehr in the mid 1990’s [35]. They found a strong correlation between asymmetries in alpha absolute power in the frontal lobes and mood disorders. They proposed that right anterior activation is related to increases in withdrawal related emotions and left anterior activation is related to approach related behaviors. Their technique was predicated on the assumption that the alpha rhythm reflected hypo-activation and that greater alpha magnitude in the left frontal area indicated a deficit of approach related behaviors mediated by that area. They did not use normative data but relied on an alpha asymmetry score obtained by calculating the ratio of left and right prefrontal alpha. They used a two channel montage at F3/F4 referenced to Cz.

11.5.5 Slow Cortical Potential

Slow Cortical Potential SCP training has been employed, largely in Europe, for more than thirty years [36]. It has been used to train Epilepsy [37], Brain-Computer Interface [38] and ADHD [39]. As originally applied, SCP training was a “one size fits all protocol” with the majority of the training done at the vertex. In this early manifestation, the client attempted to produce cortical excitation, a negative DC shift, in the case of ADHD; or cortical inhibition, a positive DC shift, in the case of Epilepsy over the course of many short trials [37]. More recently SCP training has evolved to focus on areas other than the vertex and trains both negative and positive gradient shifts in the same session with proportions of negative and positive trials dependent on client presentation [40].

11.5.6 Infra-slow Fluctuation/Infra-low Frequency

Infra-slow Fluctuation (ISF) or Infra-low Frequency (ILF) training is a frequency based training. The frequency bands addressed are different in the two techniques. However both paradigms filter and train the very low frequency band known as the Ultradian Rhythm < .01 hertz [41]. These slow rhythms are influenced by changes in amplitude and polarization of the Direct Current (DC) signal [42]. Infra-slow training owes its lineage to the early Beta/SMR training of Susan Othmer and EEG Spectrum [43]. That intervention was done with a single channel of EEG and an intra-hemispheric bipolar montage on the motor strip and temporal lobes. The technique was modified by replacing a set reward band with a 3 Hzz window that was shifted up or down contingent upon client response.

Infra-slow training produces immediate state shifts in the client. The trainer targets state regulation in real time by discovering an optimum frequency through trial and error for each client. Success is defined by the immediate improvement in affect and arousal regulation in session and ultimately by generalized improvements in behavioral and state regulation in life.

Over time, it became apparent that the vast majority of clients were finding an optimum clinical response at lower and lower frequencies. As the optimum frequencies trained descended below .1 Hz, it became clear that optimum response was more readily achieved when training was executed with a DC coupled amplifier. This technique has begun to incorporate normative data and simultaneous bipolar and referential montages [42].

11.6 Patient Assessment

Neurofeedback clinicians utilize a range of strategies for assessing client symptoms including subjective symptom questionnaires, objective neuropsychological testing, and qEEG. The use of assessment instruments tends to divide along professional boundaries with access to neuropsychological tests often determined by professional practice laws.

The vast majority of neurofeedback clinicians use some form of a subjective symptom questionnaire that is often set up in a Likert Scale format. The Continuous Performance Test is an instrument also in frequent use among practitioners. The use of pre/post qEEGs is becoming a more frequent part of many practices. A smaller group of practitioners, largely psychologists utilize neuropsychological testing.

11.6.1 Symptom Assessment

While a formal assessment or Psychological Evaluation is not always necessary, it can be extremely helpful in the process of developing an efficient treatment plan and tracking symptom change. For example, if a client were seeking neurofeedback for "memory problems," objective testing may reveal differences between auditory and visual memory; or working memory versus long-term memory; or it may reveal that the problem stems more from problems with attention or anxiety. These distinctions may be too subtle for many clients to accurately perceive or articulate. This clarification may be important in relation to electrode placement, protocol selection and any adjunct strategies that may be implemented.

Neurofeedback clinicians utilize a range of strategies for assessing client symptoms including objective neuropsychological testing, subjective symptom questionnaires and qEEG integrated assessments. A sampling of these types of evaluations will be discussed below.

11.6.2 Neuropsychological Assessments

Neuropsychological assessments involve completion of a well-defined set of task(s) known to be linked to a specific brain region(s). These assessments are based on standardized administration procedures and scored in relation to a normative database. Such testing can reveal specific deficits in neuropsychological functioning and help identify brain areas that may be involved in the deficit(s). These tests commonly examine constructs such as memory, intelligence, language skills, sensorimotor, visual/spatial processing and executive function tasks. Traditionally, these assessments consist of a battery of tests that would be administered to the client by a trained Psychologist or Psychometrist. Examples of this type of testing might include the Wechsler Adult Intelligence Scale (WAIS), the Test of Memory and Learning (TOMAL), or the Tower of London Test. Once administered, these tests would require individual scoring and interpretation.

11.6.3 Computerized Neuropsychological Batteries

Programs such as MicroCog, IntegNeuro, and CNS Vital Signs, are specifically designed for clinical use and allow the neurofeedback practitioner to administer the assessment in their office in 30-90 minutes. These programs often have both short and extended versions, include multiple domains of concern, require minimal computer literacy and provide nearly instant scoring and report generation. Among the most commonly used assessments in this category is MicroCog.

MicroCog was the first computerized neuropsychological test battery developed for clinical use. It has measures in 5 domains, including attention/mental control, memory, reasoning/calculation, spatial processing and reaction time. It is modestly priced and has been shown to be an effective screen for early dementia among elderly subjects [44]. It has also been shown to be effective in distinguishing between dementia and depression and measuring cognitive impairment related to drug abuse [45].

11.6.4 Targeted Neuropsychological Tests

An alternative to a battery of tests is to utilize tests specific to one area of concern. Potentially the most popular type of assessment utilized by neurofeedback practitioners is the computerized test of attention or continuous performance test (CPT). These tests present the client with a series of simple target and non-target cues either through visual and/or auditory information. The client's performance is measured by examining variables such as reaction time, reaction time standard error, errors of omission, errors of commission and signal detection to a normative sample. Performance on these tests has repeatedly been shown to differentiate ADHD from non-symptomatic groups [46]. The most commonly used of these tests include the T.O.V.A. (Test of Variables of Attention), Conners' and the IVA (Integrated Visual and Auditory) continuous performance tests. This type of assessment is beneficial for symptom clarification, treatment planning and progress tracking.

11.6.5 Subjective Assessment Questionnaires

Subjective assessment questionnaires utilized by neurofeedback practitioners are extremely varied in focus, length and target population. Some are inventories that measure multiple dimensions such as the Minnesota Multiphasic Personality Inventory (MMPI) and The Millon Clinical Multiaxial Inventory (MCMI). Others are very specific to a concern, such as anxiety, depression, or autism spectrum disorders. For adult assessments, these questionnaires are typically self-report. As such, they must be interpreted cautiously, taking into consideration issues such as social desirability, malingering, secondary gain, acquiescence and the capacity for a distressed individual to report accurately. Despite these concerns, self-report questionnaires have consistently been found to be a valuable tool for clinical assessment. Many of the scales designed to assess children, such as the Behavior Assessment System for Children, offer teacher and parent versions of the scale in addition to a self-report. This allows cross-comparison of ratings from different perspectives and from different environments.

11.6.6 qEEG integrated assessments

Several companies offer assessment tools that utilize Quantitative EEG data in conjunction with additional assessments to assist neurofeedback practitioners in protocol selection. Thatcher [47] has developed a symptom checklist with the goal of linking brain structure to neuropsychological function based on fMRI, PET and EEG/MEG research studies. Other systems such as the MiniQ Analysis by New Mind or the CNC 1020 system by Brownback and Mason offer neurofeedback recommendations based on matching reported symptoms to implicated brain regions.

Effective and efficient treatment with neurofeedback is predicated on a clear understanding of the symptoms involved, related brain areas and an analysis of the client's qEEG. As this brief section illustrates, this information can be obtained through many avenues and must be considered alongside issues such as accessibility and cost. For many practitioners, finding the right combination of tools is a trial and error process that evolves with the technology and scope of practice.

11.7 Addressing Conditions with Neurofeedback

From simple ADHD to complex disorders of children on the Autism Spectrum, to those with affective disorders, case reports of the positive effects of EEG-biofeedback are abound. Far fewer controlled studies exist. The dearth of controlled studies has begun to change recently with ADHD being the most thoroughly researched disorder.

11.7.1 ADHD

Lubar and Shouse published the first reports of neurofeedback training for ADHD in 1976. Employing an ABA research design they demonstrated that hyperactive symptoms decreased when SMR was enhanced and increased when SMR was inhibited [15]. The outcomes in this research led to scores of studies employing SMR and several variations of this training to address ADHD. For a more detailed description of these protocols also see Monastra [48]. Since that tim,e attention problems have been the most thoroughly investigated issue to date. Many controlled studies have demonstrated a large effect size for neurofeedback [49].

Slow Cortical Potential and theta/beta ratio training have been studied in the successful treatment of Attention Deficit Hyperactivity Disorder [39, 50]. Both neurofeedback protocols show comparable results on the three features of ADHD: inattention, impulsivity, and hyperactivity [50]. The theta/beta ratio training was actually an inhibit/enhance protocol that encouraged beta and reduced theta. A few of the studies included frontal sites for training, while in the majority of studies the theta/beta training addressed central strip locations (C3, Cz, C4) as did the SCP training.

In 2009, Arns et al published a meta-analysis that concluded that neurofeedback can be considered an efficacious and specific intervention for ADHD with a large effect size for inattention and impulsivity and a medium effect size for hyperactivity [49]. The designation of Efficacious and Specific was determined by guidelines jointly accepted by the International Society for Neurofeedback and Research (ISNR), the Association for Applied Psychophysiology and Biofeedback (AAPB) and is analogous to guidelines accepted by the American Psychological Association (APA).

The American Academy of Pediatrics has recently declared EEG-biofeedback a "Level 1 Best Support" intervention for ADHD. Their October 2012 report on Evidence-based Child and Adolescent Psychosocial Interventions concluded that neurofeedback had the highest level of support based on at least two randomized, placebo controlled studies [51] . The academy's decision was established on three studies [50, 52, 53], two that utilized fMRI to measure the change in the neural substrates of selective attention after neurofeedback training.

Other protocols that have not been systematically investigated have demonstrated promise in the training of this disorder. Recently, several cases involving children with attention problems were treated with Z-score training with positive results [28]. The enhancement of regional cerebral blood oxygenation (Hemoenphalography) in specific cerebral locations has been shown to increase sustained attention [54]. The training of the Infra-low frequency band has produced normalization on the Test of Variable Attention in a recent study[55].

11.7.2 Other Conditions

Other conditions have not yet reached a Best Support level of research. However, there are substantial studies for a variety of complaints that demonstrate the effectiveness of neurofeedback training. From Traumatic Brain Injury to Autism, the list of conditions addressed continues to grow. A variety of neurofeedback protocols have proven their effectiveness with a wide assortment of clinical presentations. These interventions have been applied by providers whose specialties cut across the human service delivery spectrum including mental health practitioners, educators, physical therapists, and medical personnel [56].

Anxiety, the main staple of most psychotherapy practices has been addressed effectively by neurofeeback with dozens of small studies [32, 57, 58], as has depression [59, 60], Obsessive Compulsive Disorder [61], and Post Traumatic Stress Disorder [8]. This effectiveness has led many mental health practitioners to include neurofeedback in their practice making psychologists, social workers, and other mental health professionals the largest group of providers in the field. At the same time, EEG-biofeedback has expanded the typical client base. Many in the mental health professions have utilized neurofeedback for Substance abuse [9, 62], Autism Spectrum Disorders [55, 63-65], and sleep disorders [66]. Promoting Peak performance in athletes, artists, and other professions has become the primary focus of some practices [67-69]. Mental health practitioners have traditionally been involved with educators in eliminating impediments to learning. Neurofeedback has been central to addressing ADHD and more recently has been used to address other learning disabilities. [70-72]

Doctors, nurses, occupational therapists, physical therapists, and other allied health practitioners utilize neurofeedback in their practices, some since the beginning of the field. Each brings a special set of skills that is complemented by neurofeedback. Seizure disorder, possibly the first disorder treated with neurofeedback [5, 73], has recently become an intervention of interest to neurologists and other health professionals [29, 55, 74]. Migraine headaches have been the focus of neurofeedback for over twenty years [75]. Recently, a large study confirmed the early promise of this intervention guided by a neurologist who employed qEEG in the treatment paradigm [76]. Traumatic Brain Injury has been the focus of many in the mental health field who developed neurofeedback for brain injury to supplement the sparse treatment options of traditional medicine. Jonathan Walker, a neurologist and pioneer in the neurofeedback field, has been instrumental in developing neurofeedback strategies for the brain injured [77].

In order to understand the magnitude of the research, a viewing of the Comprehensive Neurofeedback Bibliography amassed by the International Society for Neurofeedback and Research is suggested [56].

11.8 Conclusion

A large body of research spanning several decades contends that neurofeedback has proved useful with a wide variety of psychological and medical conditions. An assortment of protocols has been applied to accomplish these successful outcomes. It is reasonable to propose that neurofeedback does not treat anything specific but rather optimizes the central nervous system thereby improving general function. Recent research recognizes that EEG-biofeedback accomplishes this task by conditioning brain electrical activity and so is more aptly referred to as training rather than treatment.

The idea that central nervous system regulation is the result of neurofeedback training may help to explain the reported positive impact of neurofeedback on a host of disorders. The growing body of research that supports this perception explicates neurofeedback's recent acceptance by mainstream health practitioners and the general public. From its beginnings at the University of Chicago in the latter half of the last century, neurofeedback has become a worldwide phenomenon. The growth of the industry has occurred largely without government or academic support. Kept alive by the efforts of a few pioneers that recognized the efficacy of this intervention, neurofeedback has only recently begun to garnish the popular recognition, professional acceptance, and institutional support equal to its promise.

Frank H. Duffy, M.D., Professor and Pediatric Neurologist at Harvard Medical School, stated in an editorial in the January, 2000 issue of the journal Clinical Electroencephalography that the scientific literature advocates for the application of neurofeedback to address many disorders. "In my opinion, if any medication had demonstrated such a wide spectrum of efficacy it would be universally accepted and widely used….. It is a field to be taken seriously by all" [78].

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