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Laurence Miller, PhD, is in independent practice in clinical psychology, neuropsychology, forensic psychology, and business psychology in Boca Raton, Florida, and is Director of Psychological Services at Heartland Rehabilitation Centers in Lantana and Pompano Beach, Florida. Dr. Miller is on the Adjunct Faculty of Florida Atlantic University, and his most recent book is *Shocks to the System: Psychotherapy of Traumatic Disability Syndromes*.

JERRY R. DeVORE, PhD, ABPP

APPLIED PSYCHOPHYSIOLOGY: STATE OF THE ART

From Good Samaritan Hospital Rehabilitation Center

Reprint requests to:
Jerry R. DeVore, PhD, ABPP
Clinical Psychologist
Good Samaritan Hospital
Rehabilitation Center
407 14th Avenue SE / POB 190
Puyallup, WA 98371-0192

SCOPE AND DEFINITION

Applied psychophysiology and biofeedback have a broad scope ranging from the clinical settings of psychotherapy and health care to a number of areas including performance enhancement[21] and ergonomic applications to increase work efficiency and worker productivity and to decrease injury.[72] More esoteric applications include psychophysiological polygraphs in forensic and employment screening for deception detection.[59] There is some promise and application of biofeedback devices in transpersonal and psychospiritual realms.[49] In the consideration of functional aspects of physical symptoms, psychophyisiological assessment can have very important roles because: (1) aspects of autonomic nervous system functioning can be assessed, (2) surface electromyography (SEMG) can provide data about muscle recruitment and activation patterns inaccessible to palpation or needle electromyography, and (3) monitoring brain wave functioning in various activation states provides one of the least expensive means of visualizing brain functioning.

Nearly everyone has read something about biofeedback, as the term became a household word in the late 1960s and early 1970s. In the wake of such successful name recognition, the major professional organization of providers of biofeedback changed its name and its journal to a more expansive and less familiar title of "applied psychophysiology and biofeedback." The question of "what's in a name" has developed, and an entire journal issue[2] has been devoted to attempting to clarify what is meant by "applied psychophysiology and biofeedback." From a practical standpoint, biofeedback refers to a learning protocol in which the behavior of the organism is altered by information from some aspect of its physiological functioning that is presented in a conspicuous manner to the senses of that organism. Some of the impetus to broaden the label to a larger realm of applied psychophsiology comes from the recognition that the clinician might benefit from information about the participant's physiology independent of whether the participant learns anything. For example, applications reviewed below include assessment and monitoring in addition to learning through psycholophysiological feedback. While there is some debate about the domain of applied psychophysiology, one way to define the field is to refer to the blueprint of knowledge statement published by Biofeecdback Certification Institute of America (BCIA) for general biofeedback[16] and for the specialty area of electroencephalography (EEG).[16]

HISTORY

Biofeedback and applied psychophysiology today reflect the confluence of developments in a number of number of areas:[94]

1. **Instrumental conditioning of autonomic nervous system (ANS) responses**—Neil Miller electrified the research and clinical community with a series of elegant investigations demonstrating learned autonomic changes in laboratory animals.[79] At the time he was initially writing, there was a thought that the autonomic system was autonomous and not subject to learning in contrast to motor behavior. In curarized preparations, Miller demonstrated autonomic leaning in the absence of motor behavior. Subsequent research has developed many practical applications of learned changes in autonomic functioning.[10]

2. **Psychophysiology**—David Shapiro taught the first course in psychophysiology at Harvard in 1965. Now there are a number of textbooks available and courses at most major universities with graduate study in psychology.

3. **Behavior therapy and behavioral medicine**—Behavior therapy developed in the 1950s as treatment for a number of behavioral problems. Behavioral medicine developed the application of learning theory to aspects of treating medical conditions in the 1970s.

4. **Stress research and stress management strategies**—Walter Cannon[22,23] formulated a model of fight and flight associated with hypothetical sympathetic nervous system pathways. Selye[96] developed this model further with reference to stress and the general adaptation syndrome model of stress reaction in particular. This model implied that many events would produce a generalized stress reaction with psychophysiological consequences. Treatment via reduction of the stress response was also implied. Meditation[11] and relaxation[62] procedures were developed in the 1970s to assist people in reducing stress reactions.

5. **Biomedical engineering**—Technology available after World War II has dramatically improved the ability and practicality of signal detection. We have advanced from vacuum tubes to transistors to microchips. Now we have sophisticated sensors and computerized systems to analyze and display data in real time. Systems that previously required a research wing in a building are now housed in a laptop computer.

6. **Electromyography**—Gasser and Newcomer used a newly invented cathode ray oscilloscope to show signals from muscles and won a Nobel prize in 1940. Prior to that, Edmund Jacobson used EMG extensively to study the effects of imagination and emotion on a variety of muscles. He also used surface EMG (SEMG) to study the effects of relaxation training.[61,62] From those humble beginnings, SEMG has

developed to the point at which many companies now market multi-channel SEMG systems suitable for static and dynamic evaluations. At least one professional organization devoted to surface EMG has been developed—Surface EMG Society of North America (SEMG). (Further aspects of SEMG will be found in the chapter authored by Gabriel Sella in this volume.)

7. **Electroencephalography**—The history of electroencephalography revolves first around the discovery and practical measurement of electrical activity in the brain. Additional historic landmarks include the development of the quantitative EEG and the development of protocols to modify brain wave functioning. Hans Berger is credited as the first person to systematically observe and report oscillating electrical waves from the surface of the human scalp in 1929. In his first report, he identified "waves of the first order" that he designated the alpha rhythm. He also noted a background of higher frequency and smaller amplitude that he called "waves of the second order" or beta waves.[13,14,88] He made pioneering discoveries noting alpha blocking, which is an abrupt suspension of alpha waves when a person with eyes closed in a relaxed state opens his or her eyes. He noted that alpha blocking doesn't occur if the eyes are opened in a darkened room but it does occur even with eyes closed if the person is attending to stimulation or solving mental tasks. Over the subsequent decades, research with human subjects blossomed. The importance of the EEG and QEEG in applied psychophysiology may be suggested by the observation of Hughes and John[39] that "the greatest body of replicated evidence regarding pathophysiological concomitants of psychiatric and developmental disorders has been provided by EEG and QEEG studies."

Nuwar distinguished the EEG, the digital EEG, and the quantitative EEG (QEEG).[82] He was very encouraging about the digital EEG, as it could store EEG readings electronically rather than rely on a pen and ink strip chart. The QEEG as the second major impact on electroencephalography is further distinguished from the digital EEG by a variety of transformations of the raw EEG wave patterns into other variables. The Fast Fourier Transform (FFT) is the chief quantitative transformation. It analyzes the raw EEG into component frequencies, and those components can then be plotted as a frequency spectrum, averaged over a recording period (an epoch) and tabulated as spectral magnitudes. Such data can also be subjected to a variety of multivariate analysis techniques resulting in a variety of complex variables. Tables of data have been developed to provide normative values for populations,[38,66,102,105] and basic psychometric properties have been explored.[59,103] Such quantitative data has been called "neurometrics" by E. Roy John.[66] These data provide a basis for quantitative analysis of brain function.

The third major development in electroencephalography has been the discovery that brain electrical activity can be modified via principles of learning and those changes can have a number of practical psychological effects. Thomas Budzynski has provided a personal account of the transition from EEG to neurofeedback.[20] The research of Joseph Kamiya is credited with the dawn of neurofeedback. While conducting research at the University of Chicago in 1962, Dr. Kamiya discovered that subjects could learn to increase alpha wave parameters.[68] The subsequent literature has documented the application of alpha states to clinical problems.[52] In the mid to late 1960s, Dr. Barry Sterman discovered serendipitously that conditioning 12–15 hz brain frequencies in the sensory motor strip protected cats from the seizure-inducing effects of certain rocket fuels.[101] Subsequent studies showed that operant conditioning of this band (that came to be called the sensory motor rhythm, SMR) reduced seizure activity in humans.[94,101] Further developments have documented the

EEG biofeedback to facilitate attention, imagery, and relaxation.[10,39,94] Additional features of the history of electroencephalography in the realm of applied psychophysiology include the publication of *Introduction to Quantitative EEG and Neurofeedback* in 1999.[39] It is the first book published to review the field for professionals.

8. **Evidence-supported practice**—has developed dialogue in a number of disciplines to identify clinical practices that can be empirically shown to work. In the field of neurology, a complex system of three classes of information and five levels of evaluative recommendations have been proposed:[82] Class I reflects expert opinion and single case study data, class II reflects more cases and some controls, while class III reflects randomized assignment and double-blinded rating. In psychology, a series of papers have culminated in a three class system[24] as well for evaluating empirical support of efficacy. For all classes, some control group comparison is necessary and the treatment must be specified in a manual or equivalent and provided to a well-defined population. Outcome must be measured with reliable and valid measures. For the lowest level of designation, "possibly efficacious," a sample size of a least three in one study and no conflicting evidence are required. For the designation of "efficacious," at least two independent research settings using sample sizes greater than three must report superiority over wait-list or no-treatment controls. For the designation of "efficacious and specific," two or more independent research settings must report all of the preceding with superiority over placebo or alternate credible treatment. Any contradictory findings must be outweighed by the favorable findings. AAPB has published four criteria[97] that include: demonstrated efficacy in comparison with appropriate control groups, replication studies reporting similar efficacy, efficacy reported in long-term follow-up, and the therapy has no counter indications.

9. **Professional developments**—In 1969, the Biofeedback Research Society was founded. It was renamed in 1976 to Biofeedback Society of America and later changed its name to Association of Applied Psychophysiology and Biofeedback. The *Journal of Biofeedback and Self Regulation* started in 1976 and later changed names to *Applied Psychophysiology and Biofeedback*. The Biofeeedback Certification Institute of America (BCIA) was developed as a certifying agency 1981, to indicate basic knowledge and skill in biofeedback. It was sponsored and supported by the then BSA. The *BCIA Knowledge Blueprints*[15,16] provide a significant guideline to the knowledge and skills a clinician should possess prior to treating patients with psychophysiological procedures. Additional specialty organizations have recently been developed including the Society for Surface EMG, and the Society for Neurotherapy.

MODES

SEMG

Surface electromyography "is a technique through which electrophysiological data can be obtained from the surface of the skin, reflecting gross underlying electromyographic and electrophysiological potentials."[30] The electrical signals for surface or percutaneous methods of electromyography result from muscle action potentials. Typically activity in the extrafusal fibers, originating from the activation of the alpha motor nervous system, is the focus of study. While needle electromyography and surface electromyography both provide data based on some of the same underlying physiology, there are significant differences in the kind of information each procedure provides.[30] For example, SEMG can indicate muscle spasm, the impact of posture on muscle activity, and the impact of emotion and it can indicate

disturbance in functional movement. (Please refer to the article by Gabriel Sella in this volume for further information about the SEMG mode.)

EEG

There appears to be some basic agreement about the origins of rhythmic brain activity that can be measured at the scalp.[100] The immediate source of measured electrical activity is from the cortical layer containing the pyramidal cells. Post-synaptic potentials from cell populations create the EEG signal. Projections from the thalamus synapse onto these cells. Pacemaker neurons throughout the thalamus normally oscillate in the 7.5–12.5 range and produce the electrical activity known as the alpha rhythm that dominates the EEG of an alert health person who is awake but resting with eyes closed. The cell membranes of the thalamic neurons can be hyperpolarized by the nucleus reticularis via gamma-aminobutyric acid (GABA) release. This results in slowing the firing rhythm to the 3.5–7.5 Hz or theta range. Delta activity of the brain (1.5–3.5 Hz) is thought to originate in cortical layers and in areas of the thalamus that are typically inhibited by the ascending reticular activating system (RAS) in the midbrain. That helps to explain why delta activity is seen in sleep and coma, conditions in which the RAS is inhibited. Frequencies in the 12.5–20 Hz or beta range are believed to originate at the cortical level and thalamocortical transactions related to specific information processing. In the waking adult, activation of the RAS causes inhibition of the nucleus reticularis via cholinergic and serotinergic pathways, resulting in releasing the thalamic cells from the hyperpolarizing influence of the nucleus reticularis. This allows them to function as relays of information for cortical processing, which is indicated by beta range frequencies in the EEG. Glutamic pathways from the nucleus reticularis can inhibit thalamic pathways directly through hyperpolarization, and dopamine pathways through the striatal projections can inhibit the RAS, also resulting in the inhibition of thalamic neurons and thereby blocking the flow of sensory information through the thalamus to the cortex. These neurotransmitter pathways have been the focus of a great deal of physiological research and attention in the areas of biological psychiatry and psychopharmacology.

Analogue EEG and digitized analogue recordings of brain wave activity are well described in the literature. They typically produce multichannel recordings that are then analyzed for artifact and clinically significant patterns by a trained clinician.[41,59,65] With the QEEG, multichannel recordings of 16–19 electrode sites in a standardized format known as the 10/20 system are collected and edited to remove or control for a variety of artifacts that might contaminate data analysis. The data is then analyzed using the Fast Fourier Transform (FFT) to quantify the power or spectral magnitude at each frequency, averaged across the sample. The result is known as the power spectrum, and it traditionally has been separated into four frequency bands—delta (1.5–3.5 Hz), theta (3.5–7.5 Hz), alpha (7.5–12.5 Hz), and beta (12.5–20 Hz). In summary, the QEEG allows for digitized recordings that can be interpreted in the manner that clinicians have always done, and in addition, the data provides quantitative information not otherwise available.

The ability of the QEEG to quantify and store data has allowed significant normative studies to be conducted. Data indicate that there are clear age-related changes in the QEEG but there are no significance differences as a function of ethnicity or culture.[59] A number of databases have been developed already, and Thatcher has provided a detailed and thoughtful discussion of databases and their uses. Three basic purposes are identified for using a QEEG data base:[105] (1) Assessment of pathophysiology is a chief purpose, to identify whether there are data suggesting a neurophysiological basis for the patient's complaints. (2) Therapy planning can be assisted by identifying the strengths and weakness of electrophysiological function in light of potential treatment interventions. (3) Treatment evaluation is a third role of QEEG. Treatment designed to modify the electrophysiological status of the brain should show outcomes reflecting systematic changes in the electroencephalographic profile.

Neurofeedback is one of several terms used to describe training protocols that involve detecting brainwave activity and feeding back indexes of that activity in order to alter subsequent brain activity and psychophysiological processes associated with that activity. Like surface EMG, there are many different protocols and reports of success for a variety of conditions. At this time, there is no empirical evidence to warrant one approach over another. Newer innovations include neurofeedback devices that provide feedback about more than one site simultaneously. Two channel systems are common, and four channel systems are also reported. Just as there is feedback-driven electrical stimulation in the EMG world, there are systems with audio, visual, and/or electromagnetic stimulation driven by EEG parameters. Clinical papers are beginning to be published using these modalities.[21,93]

Surface Temperature

Skin temperature measurement has been approached with varying degrees of technological intricacy. Relatively simple instruments such as liquid crystal bands that change color as a function of temperature or household thermometers have been used for some stress management applications. More sophisticated measures have included digital thermography using a thermistor, which is a heat-sensitive resistor. Such instruments can sample temperature changes very rapidly and are sensitive to minute fluctuations. Such instruments have had many applications in the treatment of migraine headaches[17,19,94] and Raynaud's syndrome,[95] and scattered reports of success have been noted with complex regional pain or reflex sympathetic dystrophy.[94]

Electrodermal Response

Assessment of electrodermal responses has had one of the more colorful histories in applied psychophysiology. The basic response primarily reflects changes in sweat gland activity and is most frequently detected by passing a very low electric current through the body and measuring the skin resistance, or its mathematical reciprocal, skin conductance. Most clinical instruments today report readings in conductance (micro mhos). Sweat gland activity or sudomotor activity is exclusively innervated by the sympathetic nervous system; hence under suitably controlled conditions, the electrodermal response can reflect sympathetic nervous system activity. Historically, the Swiss psychiatrist, Dr. Carl Jung, in 1907, was among the first to use electrodermal responses clinically.[67] He found that people show sympathetic responses to words and ideas causing stress. This finding is one of the bases of the use of polygraphs in deception detection.[60] The measurement of electrodermal responses has been a significant element is some psychospiritual disciplines (e.g., Scientology). It may be used as one measure of regional sympathetic arousal in the assessment of complex regional pain syndrome. It may also be used to facilitate learning and performance enhancement of complex motor skills.[84]

Other modes of medical significance include heart rate, respiration and indexes of heart rate variability, especially in coordination with respiration. These and other modes can be very important for stress management and pulmonary problems.

CLINICAL ARENAS

Neuromuscular Applications

Teaching patients to relax has helped a variety of pain problems[50] including muscle contraction headaches,[3,4,19,94] phantom limb pain,[94,98] and pain from low back injury.[33,36,48] Many of these studies do not fully identify the pathophysiology or the impairment syndromes involved. That limits the application of clinical reasoning. In this section, impairment syndromes will be discussed first followed by a review of a variety of clinical conditions that typically present in physical medicine and rehabilitation settings. (I have omitted a discussion of a number of musculoskeletal conditions because they are discussed in the chapter by Dr. Gabriel Sella in this volume.) Impairment syndromes are patterns of neuromuscular activity that underlie complaints of pain and limitations in functioning. Cram, Kasman, and associates[30,69] have identified several syndromes and have linked assessment protocols and treatment to each syndrome:

1. **Psychophysiological, stress-related hyperactivity**—This syndrome reflects disturbance in muscle functioning (and other monitored systems) that is shown in the assessment phase to be linked to psychological stressors. Stress profiling is the typical assessment protocol, and a number of stress management procedures might be appropriate for treatment.

2. **Postural dysfunction**—Reflects measurable impact of posture on muscle functioning.

3. **Reflex spasm/inhibition**—Hypertonicity or hypotonicity induced by reflex systems that may be activated by inflammation, active trigger points, and cumulative strain or recurrent trauma.

4. **Learned guarding or bracing**—Learned activation on movement or postural loading essentially to mitigate anticipated pain or injury.

5. **Learned inhibition**—More rare than guarding, this syndrome is also operantly learned because avoidance of muscle activation reduces pain or is anticipated to reduce pain or injury.

6. **Chronic compensation for joint hypermobility/hypomobility**—Muscles take over the role of other joint tissue. Damage to the joint is the primary condition, though abnormal muscle activity may be noted on SEMG.

7. **Faulty motor schema and muscle imbalance**—This is a complex condition reflecting the chronic development of one or more of the preceding syndromes that results in the lack of coordination of two or more muscles that typically require coordination for appropriate stability and movement.

Urinary Incontinence

One of the landmark areas of biofeedback success is in the treatment of urinary incontinence.[28,86,106] Tries and Brubaker[106] review the history of biofeedback and note that Kegel used a portable pressure sensing device as part of perineometric assisted pelvic floor muscle training. His success has been mitigated, however, by well-meaning clinicians who have recommended Kegel exercises in the absence of biofeedback monitoring. As Tries points out, people have poor proprioceptive awareness of the pelvic floor and exercises performed inaccurately will not result in bladder control. Two-channel training focusing on learning to contract the pelvic floor while not contracting the abdominal wall may be necessary for highest rates of success. The benefits of pelvic floor training may be highest for cases of stress incontinence, which is the highest proportion of incontinence complaints. Protocols emphasizing these factors typically result in greater than 75% reduction in incontinent episodes. Overall, biofeedback training when properly implemented as part of a comprehensive protocol meets the Chamblis and Hollon criteria for efficacious treatment.[24] It also meets the Neurology[82] and AAPB criteria.[97]

Fecal Incontinence

Whitehead and Drossman reviewed the literature on fecal incontinence.[110] While incontinence can be caused by many conditions, injury to pelvic nerves resulting in weak sphincter contractions or impaired ability to perceive rectal distention can be successfully treated by biofeedback. Biofeedback may also help cases of constipation due to inability to relax the pelvic floor muscles when trying to defecate.

NEUROLOGICAL DISORDERS

TBI

A variety of imaging studies of the brain structure and functioning are now available to the clinician.[108] Computed tomography and magnetic resonance imaging can provide fine structural detail regarding brain tissue, but they reveal little about brain functioning. Positon emission tomography (PET) and functional magnetic resonance imaging (FMRI) are beginning to move from the research lab to applied settings, as they document patterns of brain activation in association with regional blood flow and local fluctuations in brain metabolism. Both procedures are expensive. The equipment requires special facilities and may not be readily available to many clinical settings. Electroencephalography (EEG) also reflects brain functioning and is relatively inexpensive and potentially accessible to most hospitals and free standing rehabilitation centers. Historically, the EEG has provided analogue data, typically interpreted by neurologists. Quantitative electroencephalography (QEEG), as discussed in the section on electroencephalography, is based on the ability of modern computers to perform a frequency analysis of the raw data while providing for the management of various artifacts in the signal. The data is then displayed in various ways to assist quantitative as well as qualitative analysis, based on comparisons to normative data. Bricolo[59] found asymmetries with the more damaged side of the brain showing slower frequencies and higher magnitudes in comatose patients. Klein and associates[59] found that a lack of beta response to thiopental injection was sensitive and specific to mortality in comatose patients. Thatcher et al found that multivariate analyses of QEEG from patients 21 days post injury predicted outcome 1 year post, suggesting that QEEG variables might index severity. Thatcher used QEEG to distinguish adult patients with mild TBI and age-matched controls and developed a discriminant function that was high in sensitivity and specificity. Sensitivity and specificity remained high on a replication sample.[59,105] In terms of standards for evidence-based recommendations, Thatcher's study seems to reflect a class II finding (using neurology criteria[82]). In a comprehensive review of electroencephalography in psychiatry, John Hughes and E. Roy John[59] concluded that there was a broad consensus that increased focal or diffuse theta, decreased alpha, increased asymmetry, and changes in coherence are common indicators of the post-concussive syndrome. The findings are robust across mild to moderate head injury and sports-related head impacts. Similar types of abnormalities are also noted in patients with severe head injury as they recover. E. Roy John and colleagues[66] also have a database that can be used to classify QEEGs for indexes of brain dysfunction. Interestingly enough, Marc Nuwer,[82] a

neurologist, reviewed much of the same data as Hughes and John,[59] including Thatcher's discriminant analysis data. He reported good sensitivity and specificity that were replicated. He then completely discounted the empirical and applied merit of the study, alluding to the taint of commercialization.

At this time, the experts seem to disagree and it is unclear why. Practically, the question is whether the QEEG can provide neurometric evidence for the diagnosis of mild brain injury. A clear neurometric classification of mild brain injury, when combined with a comprehensive review of the EEG, may help to establish an organic basis for disturbed functioning. On the other hand, an absence of significant findings, in the context of otherwise normal EEG functions, would be a meaningful absence. Such a finding may be very helpful in forensic contexts. Another approach to using QEEG is to compare an individual's findings with respect to well-developed databases in order to characterize aspects of brain functioning. Abnormal findings can then be monitored over time to identify temporal stability and/or the impact of treatment. This approach has clinical appeal because the practical questions that we have as clinicians involve managing a case to improve health and functioning and monitoring for signs of deterioration.

Treatment involving the use of EEG signals in a learning protocol is called EEG biofeedback or neurotherapy. A number of reports have documented improved functioning following a series of neurotherapy treatments. Ayers applied QEEG biofeedback training to 250 TBI patients.[5] She used a two channel bipolar QEEG and found that mood and attention variables improved the most and recovery of short-term memory improved the least. On the EEG, she noted progressive improvement including decrease of phasic spikes and decrease in 4–7 Hz activity. Ayers[7] reported a series of 50 postconcussive patients responding favorably to the neurofeedback protocol as described above. Each patient was at least 2 years post injury. Ayers subsequently investigated 12 patients with closed head injury affecting the right hemisphere.[8] All individuals were 3 or more years post injury and between the ages of 30 and 45, so spontaneous recovery and natural course of brain growth would be unlikely explanations of any benefit. These patients were in psychotherapy and had significant emotional disturbance. Six patients were treated initiallly, with the other six serving as "wait list controls." As in the previous study, they received 15–18 Hz augmentation training and 4–7 Hz inhibition training, although the training sites were not specified. Results indicated significant resolution of emotional difficulties and improvement on standardized cognitive tests for the treated group and no improvement for the untreated group. The untreated group did show progress once they were treated with neurofeedback. The Othmers[39] report several successful case studies using 4–7 Hz suppression and 15–18 Hz augmentation over Cz, C3, or C4 in monopolar configuration. Walker[107] treated 17 cases with the Othmer protocol and found that all patients benefitted with 50% reduction in symptoms by patient report and 15 of the 17 were able to return to work. Ham and Packard[51] treated 40 patients with post-traumatic headaches and found that 53% reported improvement in their symptoms. Hoffman and collegues[54] reported that approximately 60% of mild TBI patients showed improvements in cognitive performance and/or self-reported symptoms and their EEG showed significant normalization after 40 biofeedback sessions. Schoeberger and others[93] have recently completed an initial evaluation of 12 patients with TBI on-setting at least 12 months prior to the study. Half were randomly assigned to a treatment group that received 25 sessions of EEG-guided photic stimulation while the other half served as a wait list control. All patients were evaluated with standardized measures of emotional and cognitive functioning. Treatment resulted in impressive reductions of emotional problems and some cognitive gains. Altogether these data are encouraging, they raise a lot of questions. At best, the current literature for neurofeedback as a treatment is at a class III level in the neurology system and "possibly efficacious" in the psychology system. Practically, it is safe to say that we do not empirically know if neurofeedback will help a substantial number of TBI patients at this time. Outcome measures have been impressionistic and unsystematic. However, it is reasonable to offer treatment if treatable abnormalities are found on a QEEG, because operant learning paradigms for other brain-related conditions including ADD and seizure disorders respond to operant conditioning of the EEG.[94,101] Additionally, there are no reports of harm due to neurotherapy.

CVA

Lincoln and Sackley[73] reviewed literature about the efficacy of SEMG in stroke management. They concluded that there is evidence for efficacy in facilitating recovery of motor function and postural symmetry in contrast to placebo biofeedback. Ayers[6] reviewed the EMG literature for treating spasticity in the affected arm and leg of stroke patients. She went on to report a within-group "controlled" study of six CVA patients treated with EEG biofeedback and EMG monitoring of hand functioning. Training was apparently conducted over a 15-month period. The results were reported as favorable. Ambiguities in the study design as well as the small number of cases limit its interpretability and applicability. King[71] also reviewed the EMG literature and concluded that favorable results were often found immediately after treatment but the gains did not persist over time. In light of the poor additional recovery 1 year or more post CVA and the relative safety of the procedures, the results should encourage more small scale studies of SEMG and EEG. These studies should characterize the patient's stroke-related impairment and other conditions and should use standardized measurements of functioning prior to treatment as well as at treatment completion.

Seizure

Barry Sterman[101] reviewed the literature indicating that EEG biofeedback can significantly reduce seizure frequency and intensity. The model he recommends starts with a QEEG to identify areas of abnormal brain wave activity. Feedback to return abnormal activity to normal patterns is undertaken in an operant conditioning model.

Other Neurological Conditions

Cleeland[25,26] reviewed literature indicating that electromyography has been useful in reducing spasticity in a number of conditions including cerebral palsy and torticollis. Debacher[32] reviewed biofeedback for spasticity control and provided a number of practical guidelines. With respect to spinal cord injury (SCI), Wolfe[117] reviewed the literature and noted that there were few reported studies applying biofeedback to SCI patients. There were very little data about technique and outcome. In general, biofeedback with SCI patients requires special training and planning because of the variety of clinical complexities. Scattered results do suggest some success in reducing clonus and some success in facilitating active range of motion in affected extremities. Brucker[18] reported a study involving 100 subjects with injuries at C6 or higher. He provided triceps biofeedback with up to four sessions per subject and concluded that EMG training facilitated voluntary elbow extension.

Autonomic

MIGRAINE

Compas[27] reviewed the use of biofeedback to treat migraines. Thermal and SEMG biofeedback is useful alone or in combinations with additional relaxation training, cognitive behavior therapy, and prophylactic medicines. The effect sizes are modest but robust. Like all treatment of migraines, the mechanism of treatment effect is not clear. Thermal biofeedback may facilitate learned vasodilation, accomplishing some of the effect of prophylactic vasodilators without medication side effects. Behavioral treatments such as biofeedback are recommended when a patient has not been optimally responsive to standard medication regimens. The published research suggest that biofeedback and other behavioral procedures may have their most useful role in reducing the frequency and intensity of migraine episodes. There is little evidence that these procedures can stop a migraine episode that is in the course of developing.

RAYNAUD'S

The literature indicates that thermal biofeedback is a treatment associated with consistent improvement in primary Raynaud's.[95] Practically, if a patient is not optimally responsive to medications, it may be useful to consult with a biofeedback clinician to consider a course of thermal biofeedback. When Raynaud's is a secondary symptom, thermal feedback may still be of some help, but the data are not as strong.

PHANTOM LIMB PAIN

Sherman has published a protocol accessible on the Internet[98] concisely reviewing phantom limb pain and the use of surface electromyography for "cramping" pain and thermal biofeedback for "burning" pain associated with decreased regional blood flow. The treatment protocol is well described.

DIRECTIONS

Applied psychophysiology and biofeedback have an established role in assisting patients with problems, particularly with problems associated with chronic pain. Protocols currently assist diagnostic clarification and treatment. However, much of the basic work delineating the precise elements that produce useful outcomes remains to be undertaken. Developing successful and cost-containing protocols remains a challenge. With advances in biomedical engineering, we may be able to monitor new variables and blend man and machine into interesting functional combinations. A number of manufacturers of biofeedback equipment seem encouraged by efficacious protocols and are encouraging a wide variety of professionals to add biofeedback to their clinical armamentarium. Care of patients with brain damage could be revolutionized if preliminary successes were sustained in larger scale and more rigorous research designs.

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