POSITION PAPER

Standards for the Use
of Quantitative Electroencephalography
(QEEG) in Neurofeedback:
A Position Paper of the International Society
for Neuronal Regulation

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ABSTRACT. *Background*. This paper presents the findings of an inter-disciplinary committee on standards for quantitative electroencephalography (QEEG) in neurofeedback which has been unanimously accepted by the International Society for Neuronal Regulation (ISNR) Board as a position paper of ISNR.

Method. The committee reviewed current standards for quantitative encephalography in other specialties as well as scholarly literature on QEEG.

Results. The panel reached the following conclusions:

1. Although clinical research indicates that a full 19 channel QEEG does not appear necessary for conducting successful neurofeedback training, an increasing number of clinicians are using comprehensive QEEG evaluations to guide their neurofeedback training.
2. An impressive body of peer reviewed scientific literature attests to the utility of the QEEG in providing a scientifically objective and clinically practical assessment of a wide range of psychiatric, psychological and medical conditions.
3. Many of the significant contributions to the field of QEEG have come from psychologists and the Board of Professional Affairs of the American Psychological Association has concluded that QEEG is within the scope of practice of psychologists trained in this specialty.
4. Unlike neurology and psychiatry, where QEEG is principally used for purposes of diagnosing medical pathology, neurotherapists who use QEEG primarily do so to guide EEG biofeedback training.
5. It is not necessary for a physician to screen raw EEG data as part of a QEEG evaluation for neurofeedback training.

Conclusions. For the purpose of encouraging high standards, recommendations are made for areas of training and study in this specialty, for certification, for equipment/software, and for procedures in data collection and analysis. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@ haworthpress.com> Website: <http://www.HaworthPress.com> © 2004 by The Haworth Press, Inc. All rights reserved.]*

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INTRODUCTION

At a September 2002 Board of Directors meeting of the International Society for Neuronal Regulation (ISNR), an interdisciplinary "Standards

for Quantitative Electroencephalography (QEEG) in Neurofeedback Committee" was formed which included representatives from neurology, psychiatry, psychology, and social work. Its members, who are the co-authors of this paper, were individuals without financial conflicts of interest concerning a QEEG product, all of whom have extensive experience in both QEEG and neurofeedback, and they were selected from among the membership of ISNR. Five additional consultants were later recruited to provide input to the committee on the initial draft of these standards. The committee agreed that the way in which QEEG is used in the field of neurofeedback is unique. Unlike medicine where the EEG and QEEG are used for diagnosis of medical pathology, neurotherapists primarily use QEEG assessment to guide the EEG biofeedback training process and as another way of evaluating therapeutic outcomes. Therefore, because of the distinctive manner in which QEEG is most commonly used in the field of neurofeedback, it was agreed that we need to have our own standards. The committee was in further agreement that a position paper was needed to encourage high standards among neurofeedback practitioners who utilize QEEG. After completion, this position paper was unanimously accepted by the Board of Directors of ISNR as a position paper of the Society.

We will begin with a basic definition of electroencephalography (EEG) and quantitative EEG (QEEG). For the purposes of this paper, EEG refers to the brain's electrical activity as it is recorded on the surface of the scalp by an electroencephalograph, and QEEG refers to the mathematical processing of digitally recorded EEG. QEEG may be done to analyze frequency components and amplitude from 1 to 19 or more channels of digitally recorded EEG that are transformed into numerical measures such as wave amplitude, absolute power, relative power, power ratios, coherence, phase lag, power asymmetry, and co-modulation. Such measures provide precise, quantitative descriptions of many different indices of brain function in comparison with a normative database.

A statement by Duffy et al. (1994) in a position paper of the American Medical EEG Association on QEEG still holds true today, particularly in the field of neurofeedback: "There is no single, agreed upon standard QEEG test battery . . ." (p. vi). We believe that an analogy can be drawn with the general field of psychotherapy where there is a diversity of opinion among psychologists, psychiatrists, social workers and counselors about how extensive assessment procedures and psychological testing should be prior to treatment. There is no common agreement

about assessment in the field of psychotherapy. A similar condition exists in the field of neurotherapy.

In the specialty of neurofeedback, quantitative EEG assessments are often done that involve single channel referential or bipolar (sequential) EEG recordings at a limited number of electrode sites (e.g., Ayers, 1999; Lubar, 1995; Monastra et al., 1999). At the outset we wish to acknowledge that many individuals with ADD/ADHD, depression, and various other conditions may not necessarily require a full, 19 channel QEEG evaluation in order for neurofeedback training to be successful. For example, an evaluation utilizing a smaller number of electrodes, at more limited electrode sites, has proven to be a sufficient assessment in scientific research conducted with ADD/ADHD and depression (Monastra et al., 1999; Monastra, Lubar, & Linden, 2001; Lubar, Congedo, & Askew, in press; Rosenfeld, Baehr, Baehr, Gotlib, & Ranganath, 1996).

A variety of publications also attest to the fact that effective neurofeedback can occur following the use of an EEG evaluation restricted to a small number of locations (e.g., Ayers, 1987, 1995, 1999; Baehr & Baehr, 1997; Baehr, Rosenfeld, & Baehr, 1997, 2001; Brown, 1995; Donaldson, Sella, & Mueller, 1998; Hammond, 2001; Kaiser & Othmer, 2000; Linden, Habib, & Radojevic, 1996; Lubar, 1985, 1995; Lubar et al., in press; Lubar & Lubar, 1984; Lubar & Shouse, 1976; Lubar, Swartwood, Swartwood, & O'Donnell, 1995; Monastra et al., 1999; Monastra, Monastra, & George, 2002; Moore, 2000; Mueller, Donaldson, Nelson, & Layman, 2001; Othmer, Othmer, & Kaiser, 1999; Rasey, Lubar, McIntyre, Zoffuto, & Abbott, 1996; Rosenfeld, 1997, 2000; Rosenfeld, Cha, Blair, & Gotlib, 1995; Rosenfeld et al., 1996; Tansey, 1991, 1993; Tansey & Bruner, 1983; Thompson & Thompson, 1998). Even when an evaluation examines a smaller number of electrode sites, some database information is now available that allows objective comparisons to norms (Montgomery, Robb, Dwyer, & Gontkovsky, 1998; Monastra et al., 1999, 2001; Thatcher, Biver, North, Curtin, & Walker, 2003).

The literature we have just cited indicates that a full QEEG assessment is not required for successful treatment with neurofeedback. It is not the intent of this paper or committee to suggest that neurofeedback clinicians need to be doing quantitative EEGs. This is an area of controversy and legitimate differences of opinion exist within the field. This committee is made up of professionals with considerable experience using QEEG and rather than seeking in any way to mandate the use of QEEG, our purpose is simply to address the issue of standards among

those neurofeedback practitioners who are doing QEEG assessments and who find them valuable.

The committee members acknowledge a bias toward QEEG assessment utilizing 19 or more electrodes. The committee is of the opinion that such comprehensive evaluations may yield additional scientifically objective information, including a quantitative description of the relationships between different brain regions. We believe that this may prove extremely valuable in many cases in guiding and individualizing subsequent treatment, especially in treatment resistant cases. Thus, some of our prominent members have done extensive clinical work (Lubar, 1995) based upon a quantitative assessment at only 1 to 6 electrode sites (Lubar et al., 1985), but currently clearly prefer a comprehensive 19-channel QEEG evaluation since this more advanced technology is now more readily available. The detection of focal or more localized abnormalities may not occur when EEG activity is only sampled at a smaller number of electrode sites. However, it needs to be recognized that abnormal findings on a comprehensive QEEG may be genuine, but may not be correlated with particular presenting symptoms of the patient, and thus may not always have clinical significance in treatment. Additionally, if a QEEG is being used for diagnostic purposes, the committee emphasizes the need to carefully study the raw EEG since abnormalities may be masked by the use of a QEEG alone. We believe that it is a common sense principle that the more complicated the clinical case, the more thorough the clinical assessment that is required. The committee also believes that this is the case in neurofeedback. However, it is acknowledged that peer reviewed research has not yet fully evaluated the effectiveness of QEEG-guided neurofeedback versus training based on quantitative evaluations of the EEG at only a more limited number of electrode sites or based on protocols derived solely from clinical experience, although some studies on the effectiveness of QEEG guided neurofeedback alone have been published (Bounias, Laibow, Bonaly, & Stubblebine, 2001; Bounias, Laibow, Stubblebine, Sandground, & Bonaly, 2002; Hammond, 2003; Hoffman, Stockdale, & Van Egren 1996a, 1996b; Laibow, Stubblebine, Sandground, & Bounias, 2001; Thornton, 2000, 2002).

The remainder of this report will discuss QEEG and the standards that the committee believes should be utilized by those clinicians who conduct comprehensive QEEG evaluations. We will begin with a brief discussion of the value of QEEG in comparison with other available methods for assessing brain function.

The Practical Value of QEEG

Quantitative EEG studies have been conducted since the 1970s and have the advantage of analyzing EEG components that are not available through visual inspection of the EEG alone. QEEG has been used, along with neuroimaging modalities, to study brain dysfunctions associated with various medical (e.g., dementia, mild traumatic head injury, stroke) and psychological-psychiatric conditions (e.g., depression, anxiety, ADD/ADHD, learning disabilities, obsessive-compulsive disorder, schizophrenia), as well as normal brain function throughout the life span (e.g., Duffy, 1985; Duffy, Burchfiel, & Lombroso, 1979; John et al., 1980; Matousek & Petersen, 1973a, b; Thatcher, Walker, & Guidice, 1987). It was recently concluded (Hughes & John, 1999) that of all the brain assessment modalities, the greatest volume of replicated evidence for pathophysiological concomitants is provided by EEG and QEEG studies. However, in addition to having been extensively studied and well validated, QEEG has some special benefits. For instance, QEEG may sometimes identify and localize subtle EEG components that may be overlooked during visual inspection of the EEG.

Research has found that the QEEG has high reliability (Arruda et al., 1996; Burgess & Gruzelier, 1993; Corsi-Cabrera, Solis-Ortiz, & Guevara, 1997; Fein, Galin, Yingling, Johnstone, & Nelson, 1984; Gasser, Bacher, & Steinberg, 1985; Hamilton-Bruce, Boundy, & Purdie, 1991; Harmony et al., 1993; John et al., 1983; John, Prichep, & Easton, 1987; Kaye, John, Ahn, & Prichep, 1981; Kondacs & Szabo, 1999; Lund, Sponheim, Iacono, & Clementz, 1995; Oken & Chiappa, 1988; Pollock, Schneider, & Lyness, 1991; Salinsky, Oken, & Morehead, 1991; Van Dis, Corner, Dapper, Hanewald, & Kok, 1979), including under task conditions (McEvoy, Smith, & Gevins, 2000)–reliability which is equal or superior to routinely used clinical tests such as mammograms, cervical screenings, blood tests, MRI, and CAT scans (Swets, 1988). This kind of intra-individual stability over time makes QEEG analysis an excellent tool for evaluating longitudinal changes through time with conditions such as Alzheimer's disease and dementia, as well as a follow-up measure of change (particularly after neurofeedback training) with conditions like stroke, depression, obsessive-compulsive disorder, schizophrenia, traumatic brain injury, ADD/ADHD, and learning disabilities. There are now some QEEG analysis packages available for statistical evaluation of pre-post or baseline versus task conditions.

While conventional (clinical) EEG, as often utilized by neurologists, concentrates on visual inspection of the EEG to discern patterns, and

thus is quite subjective in nature, QEEG provides an additional computerized, quantitative, and objective evaluation of the EEG. In years past, the field of psychology relied upon psychological evaluation tools such as the Rorschach, Draw-a-Person, and Thematic Apperception Test. These were helpful tools, but they also included a definite element of subjectivity in interpretation. Through the years psychological assessment has moved toward much greater reliance upon objective testing wherein patient responses are compared to scientifically established norms.

In a similar way, QEEG represents an evolution and advancement in EEG technology that now enables one to examine statistical comparisons between an individual patient and age-matched normal subjects (and abnormal populations in some databases). QEEG lets us examine measures such as amplitude, absolute and relative power, power ratios across different frequency bands, inter- and intra-hemispheric asymmetries, coherence and phase-lag measurements, co-modulation, mean frequencies, and even analysis at single hertz levels. The QEEG still requires careful editing of the wave forms and visual examination of the raw EEG, but it also allows a higher level of scientific objectivity, more refined analyses, remontaging to examine the EEG from different perspectives, and enhanced capacity for localization of the sources of EEG activity through the use of Laplacian, weighted average, and other montages, as well as low resolution electromagnetic tomography (LORETA).

In recent years there have been many exceptional developments in structural neuroimaging with the MRI that have enabled scientific discoveries about structural brain abnormalities in conditions such as schizophrenia. There have also been many impressive research findings utilizing functional neuroimaging methodologies such as SPECT, PET and fMRI. These neuroimaging technologies are of great scientific value in assisting us to understand various abnormal conditions, as well as brain function associated with various mental tasks. However, while they may have some practical applications such as facilitating advances in drug research, they have not had direct, practical value in treatment planning.

In comparison with costly and less available neuroimaging modalities, some of which require exposure to radioactive material, the QEEG provides a relatively inexpensive, culture-free, non-invasive assessment of brain function. It is by far the most available and practical tool for the clinical evaluation of brain function and dysfunction. Furthermore, QEEG assessment findings have direct relevance for clinical in-

terventions utilizing EEG biofeedback (neurofeedback) to assist in normalizing and enhancing brain function.

QEEG as an Assessment Tool

Conventional EEG records in the hands of an electroencephalographer or neurologist can be extremely valuable in evaluating epilepsy, dementia, neurological disorders and organic pathology such as tumors. It is a routine clinical practice among neurologists using QEEG to carefully evaluate the raw EEG prior to performing QEEG analyses. However, there are many neurologists who prefer to rely only on traditional visual inspection of the EEG. Some of these individuals, selectively reviewing only a few of the peer reviewed scientific studies that exist on QEEG in a psychiatric population (and then frequently lumping them together with "other disorders" such as tumors, M.S., migraine, solvent and radiation exposure), authored a controversial position paper (Nuwer, 1997). It defined QEEG as a useful adjunct and gave it a positive recommendation for use in evaluating cerebrovascular disease and dementia, but as being investigational for clinical use with post-concussion syndrome mild head injury, attentional disorders, learning disability, depression, alcoholism and drug abuse, and schizophrenia, saying there was inconclusive or conflicting evidence in the literature.

In the last ten years several hundred well designed EEG and QEEG papers, with sizable samples and normal controls, have documented that there are electrophysiological abnormalities in a high proportion of psychiatric/psychological conditions. A review of these studies has revealed numerous consistent findings among the different diagnostic groups (Hughes & John, 1999) demonstrating high specificity (normal persons being classified as normal) and sensitivity (persons with a disorder being correctly classified). These QEEG findings are now becoming quite robust.

Consequently, there have recently been scholarly rebuttals to the selective and misleading review of Nuwer (1997). Using the very criteria that Nuwer used (which consisted of eight major categories for evaluating a procedure and quality of evidence ratings for making recommendations about the clinical usefulness of procedures), and a thorough and complete review of the literature, these other papers have arrived at very different conclusions. In a 1999 report in the *Journal of Neuropsychiatry*, John Hughes (a neurologist at the University of Illinois School of Medicine) and E. Roy John (a psychologist at the Department of Psychiatry at New York University) concluded that there should be a *strong*

positive recommendation for using QEEG with dementia, and positive recommendations for using QEEG clinically with cardiovascular disease patients, learning and attentional disorders, mood disorders, and post-concussion syndrome. They determined that at the current time there was conflicting evidence on its routine use with schizophrenia and substance abuse.

Similarly, Hoffman et al. (1999) criticized the Nuwer (1997) paper for problems of "bias and misrepresentation," and reviewed many excellent QEEG studies that were omitted in the report of Nuwer. They cited studies attesting to the test-retest reliability of QEEG and independent cross-validations, as well as evidence demonstrating the sensitivity and specificity of QEEG. They also reviewed evidence for the positive utility of QEEG with seizures, mild traumatic brain injury, and ADD/ADHD.

Considerable additional evidence has accumulated since the writings of Nuwer which further demonstrate the value of QEEG with different conditions, but particularly with ADD/ADHD and learning disabilities (e.g., Barry, Clarke, & Johnstone, 2003; Bresnahan & Barry, 2002; Bresnahan, Anderson, & Barry, 1999; Chabot, Merkin, Wood, Davenport, & Serfontein, 1996; Chabot & Serfontein, 1996; Clarke, Barry, McCarthy, & Selikowitz, 1998, 2001a, 2001b, 2001c, 2002a, 2002b; Clarke et al., 2003; Lazzaro et al., 1998; Monastra et al., 1999, 2001). An impressive and robust body of research (summarized in Davidson, 1998) also documents the value of QEEG with depression. It additionally appears that QEEG variables predict those alcoholics and drug abusers most at risk for relapse (Bauer, 1993, 2001; Prichep, Alper, Kowalik, & Rosenthal, 1996a; Prichep et al., 1996b, 2002; Winterer et al., 1998) far better than substance abuse history, severity of abuse, personality, patient history, or demographic variables.

We believe that conventional EEG in the hands of a neurologist is very valuable in evaluating epilepsy, neurological disorders and organic pathology. However, we believe that QEEG has advantages over analog EEG alone. The committee wants to emphasize that QEEG and QEEG discriminant analyses should never be used as the sole basis for making a diagnosis, just as a single psychological test should not be used in this manner. Discriminant functions should also be calculated only when the patient's condition is congruent with criteria for the use of the discriminant function. A QEEG is not a substitute for clinical judgment or expertise, but is simply an additional source of objective, normative assessment information to take into account in treatment planning. The

QEEG enhances other clinical evaluation procedures by adding scientifically objective information concerning brain function and the extent to which there is a neurophysiologic basis for patient problems.

We note that considerable heterogeneity has been found to exist within traditional diagnostic categories, such as schizophrenia and ADD/ADHD. For this reason we believe that QEEG as well as neuro-imaging will always have limitations in firmly establishing traditional diagnoses of many conditions. Nonetheless, the addition of QEEG information may assist in providing greater diagnostic clarity in some cases, most especially for purposes of guiding neurofeedback training, and it may become increasingly useful in the future to guide the selection of medications, as an example, through delineating distinctive sub-types of ADD/ADHD (Chabot et al., 1996; Chabot & Serfontein, 1996; Clarke et al., 1998, 2001a, 2001b, 2001c, 2002a, 2002b, 2003; Suffin & Emory, 1995) or OCD (Hansen, Prichep, Bolwig, & John, 2003; Prichep et al., 1993).

Naturally, neurotherapy clinicians should only seek to diagnose conditions within the limits of their training and licensure. It is emphasized that the use of QEEG data in the field of neurotherapy is generally not for the purpose of making a diagnosis. The principal use of QEEG data by neurotherapists is very different from the use of the EEG and QEEG in medicine-it is to provide information to guide subsequent neurofeedback training, assisting in the cognitive rehabilitation of brain-related disorders and enhancement of optimal cognitive functioning.

STANDARDS FOR COMPREHENSIVE QEEG ASSESSMENT IN NEUROFEEDBACK PRACTICE

Professionals Qualified to Utilize QEEG

Concerning which health care professionals should be using QEEG, Hoffman et al. (1999) concluded: "There should be no restriction concerning the type of professional permitted to use these techniques as long as the person is trained and qualified" (p. 404). The position supporting the clinical use of QEEG by trained non-physicians was also taken by the neurologist Ernest Rodin (1999). Both of these articles have challenged the views of Nuwer (1997) and the American Academy of Neurology who believed QEEG should be the exclusive domain of physicians. In actuality, non-physicians have been centrally involved in

the development and research of quantitative EEG. Thus, the Board of Professional Affairs of the American Psychological Association (1995) indicated that "psychologists have training and experience in areas of test, measurement, research and statistics. QEEG is one of many techniques that has been investigated and utilized by psychologists" (p. 1). They then concluded that "it is appropriate for psychologists who are trained and practicing within the scope of their competence to use QEEG and biofeedback" (p. 1). We agree with this position, but extend it to include other licensed or certified health care professionals.

Our panel concludes that it is not necessary for a neurologist or an electroencephalographer who is a physician to screen the raw EEG data as part of a QEEG evaluation for neurofeedback training, although this may be desirable in medical-legal cases. In cases where QEEG is being done to document a medical diagnosis, it is recommended that the practitioner be able to document the necessary training and certification to make such a diagnosis, or that a consultation be obtained from a neurologist or electroencephalographer in such cases. In the vast majority of cases, however, when neurofeedback practitioners conduct a QEEG assessment it is not for the purpose of making a medical diagnosis if they are not physicians, but rather to guide subsequent neurofeedback training. Nonetheless, the committee is of the opinion that neurofeedback practitioners should examine the raw EEG prior to QEEG analysis and QEEG analyses should not be considered as replacing or obviating the need for visual inspection of the EEG.

We believe that neurofeedback practitioners using QEEG should engage in an informed consent process and in obtaining a written informed consent (Scheflin & Hammond, in preparation) from patients both prior to doing a QEEG and before doing neurofeedback. In areas where neurofeedback does not yet have scientifically established benefits, we believe that it is also advisable for the informed consent to openly indicate that it may be regarded as an experimental procedure. We further suggest that the informed consent document explicitly say something of this nature: "It is important for you to understand that a QEEG is not the same as a 'clinical EEG' which is used in medical diagnosis to evaluate epilepsy or to determine if there is serious brain pathology, such as a tumor or dementia. The quantitative EEG that we do evaluates the manner in which a particular person's brain functions. It is not designed and we do not try to diagnose tumors, epilepsy, dementia, or other medical conditions in a manner like an MRI, CAT scan, or clinical EEG."

Preparation and Training for Using QEEG

This panel agrees with the position statements by Hoffman et al. (1999) and Rodin (1999) and believe that any health care professional who is licensed or certified for independent practice, who is working clinically with EEG neurofeedback training, and who has had training in EEG and in QEEG can legitimately utilize QEEG. In addition to training workshops, consultation, or supervised training, we strongly recommend that practitioners who want to conduct their own QEEG evaluations should first study scholarly material on regular EEG such as, for example, Hughes (1994), Duffy, Iyer, and Surwillo (1989), Niedermeyer and Lopes Da Silva (1999), Fisch (1999), Wong (1996), Goldensohn, Legatt, Koszer, and Wolf (1998), Luders and Noachtar (2000), Tyner, Knott, and Mayer (1983) and volumes by the American Society of Electroneurodiagnostic Technologists (1995, 1996, 1997, 2000).

We believe that neurofeedback clinicians doing QEEGs should have studied and received some formal training in functional neuroanatomy, EEG rhythms, age-dependent differences and changes in the EEG, electrodes, EEG instrumentation, recognition of EEG patterns, EEG recording techniques, artifact identification, how to minimize artifacts, the effects of artifacts on QEEG findings, montages and remontaging, QEEG interpretation, and medical-legal issues. We emphasize that study and training in careful artifact removal is crucial, and for those practitioners who are using the QEEG for purposes of medical diagnosis, it is critical that they be very skillful in the recognition of abnormal EEG patterns.

Individuals doing QEEG analyses should also have training in statistics, as used in QEEG. Fundamental knowledge of statistics is important in not only interpreting Z-score data when using a QEEG database, but also in understanding that when there are a large number of statistical tests performed, there can be problems with false-positive errors in which someone who is normal is identified as being abnormal. Thus, for example, if 64 statistical tests are performed under each single frequency band for coherence analysis, at the 2 Z-score level of significance one can by chance expect to find three error connections under the delta, theta, alpha, and beta frequency bands for coherence. Clinicians must be cautious to not over interpret findings. One can approximate the number of false positives by multiplying the number of variables by the statistical significance level (e.g., $p = .05$).

We also wish to point out that certification programs for physicians and non-physician clinicians in the area of QEEG currently exist through the Quantitative Electroencephalography Certification Board (at the Technologist and Diplomate levels), and for MDs and PhDs in EEG and QEEG through the EEG and Clinical Neuroscience Society. BCIA and the Neurotherapy Certification Board certify in the area of EEG biofeedback. Practitioners who have received training in QEEG are strongly encouraged to pursue such certification, which provides safeguards for the public.

Technical Qualities of Equipment and Recordings

For purposes of QEEG evaluations related to neurofeedback training, EEG equipment should have a minimum sampling rate of 128. Software analysis must include a method for artifact exclusion and the ability to store raw and processed data. We believe that software analysis packages should have the capacity for remontaging, allowing for the examination of the raw (and preferably also the analyzed) EEG from several different perspectives (e.g., Laplacian, common average reference, longitudinal bipolar montage, transverse bipolar montage). In the position paper by Duffy et al. (1994) for physicians, they expressed the belief that any QEEG database should be mandatorily required to be capable of creating absolute and relative spectral data, with better systems providing asymmetry and coherence measures. In the field of neurotherapy, we believe that it is desirable for a QEEG database to include normative measures with direct relevance to the neurofeedback that is being done, but we believe it is premature to designate which measure this should be (e.g., magnitude, absolute or relative power, asymmetry, coherence, comodulation). We also consider it to be ideal for a database to include a method for estimating reliability such as test-retest reliability or split-half reliability (John, Prichep, Fridman, & Easton, 1988; Thatcher, Biver, North, Curtin & Walker, 2003). This is particularly true for any medical-legal applications.

Concerning the value of test-retest reliability procedures, Hughes and John (1999) indicated: "If one were to require that the QEEG evaluation be performed on two separate samples and that any significant finding deviant at the $P < 0.05$ level be replicated in each of these two samples, the probability that this would occur by chance would be approximately $P \times P$, or 0.05×0.05, or 0.0025. If such a replication were required, false positives would seem rather unlikely" (pp. 192-193). Similarly, Duffy et al. (1994) has recommended that to avoid statistical

false positives, one should repeat a study multiple times and then "retain as clinically relevant only those that show consistency across all trials. Demanding that all clinically relevant findings replicate virtually eliminates chance as by definition chance findings do not replicate" (p. xi).

Clinicians using QEEG should have reviewed and be knowledgeable about the following characteristics of any database that they use: the number of subjects in the database, the age range of the subjects, selection criteria for subject selection and exclusion, if data were collected on the same EEG equipment (and how any differences were taken into account), and whether statistical corrections were made to ensure a "normal" or gaussian distribution if parametric statistics are used. With this knowledge, clinical database comparisons should only be made with a sample that is congruent with the age of the patient.

Patient Preparation and Quality of Recordings

We believe that it is ideal to do an eyes-open recording in addition to an eyes-closed recording and recordings under task conditions (e.g., during reading or math) are also desirable. However, before recording the EEG we recommend that clinicians obtain certain basic background information: Patient birth date, handedness, time of day, medications taken in the last few weeks, time of last food intake and of the last use of caffeine or nicotine, whether there are any skull or head deformities, and whether there have been any skull surgeries. It is also desirable to have information about medical history (e.g., thyroid function, history of high fevers, metabolic disorders, tics or twitches, viral illnesses, were they slow in motor or speech development, or in reaching developmental milestones, complicated birth, headache or migraine history, seizures, memory difficulties, head injuries, including concussions in athletics, whiplash injuries, physical abuse, chronic pain, exposure to toxic agents, etc.), and psychological/psychiatric history (depression, anxiety, OCD, ADD/ADHD, learning disability, family history of depression, alcoholism, bipolar disorder, OCD, schizophrenia).

Clinicians utilizing QEEG must be skillful in recognizing and minimizing artifacts, as well as in careful pre-recording preparation procedures to minimize artifacts in the EEG (Hammond & Gunkelman, 2001; Thornton, 1996). The EEG should be observed carefully prior to ever beginning the recording, as well as during recording, so that artifacts can be controlled or eliminated. It is vitally important for clinicians to become skillful in careful preparation of the patient in order to gather reliable data. All electrode impedance levels should be below 5 Kohms,

and we recommend that ideally no interelectrode differences should be greater than 1 Kohms from each other and from the reference electrodes. Because QEEG evaluations include examination of inter-hemispheric asymmetries, it is recommended that homologous electrode sites be as close to one another in impedance level as possible. Likewise, in preparing patients for data gathering, we recommend that ear references should be as close to identical as possible when compared with a centrally located, vertex ground reference. When artifacts are observed during EEG recording, the record should be paused and efforts made to control and minimize artifacts such as EMG, movement or eye movement, and the effects of drowsiness.

We encourage the use of a bipolar recording channel to monitor eye movement artifacts and the use of an EKG monitoring channel to allow greater precision in recognizing pulse artifacts. An EKG monitoring channel is particularly useful if neurofeedback work is anticipated to include coherence training because EKG artifact will inflate coherence. EKG artifacts are more likely to be found in patients with thick or muscled, large necks. Changing the location on the ear of reference electrodes may assist in controlling such artifacts. Eye movement and EKG monitoring channels may also be valuable when QEEG data is anticipated to be used in medical-legal proceedings.

Care must be taken to gather a tracing of EEG that is long enough to provide a sufficient sample of artifacted data for analysis. If anything, clinicians should err on the side of gathering too much data rather than too little. All of the committee members have been frustrated by receiving data for analysis that were so brief that after careful artifact removal, there was an insufficient sample of data left for a valid and reliable analysis. This is particularly a problem in recordings with children and individuals who produce a great deal of artifact. Thus, we want to emphasize that EEG recordings should be of sufficient quality and of sufficient length so that after artifacting there is a minimum of 40-50 seconds of artifact-free data available for analysis. It is strongly recommended that the sample of data be large enough to allow at least 60 seconds of data for analysis following artifacting, and 90-120 seconds should be considered ideal, especially for measures of coherence, phase, and power asymmetry.

State of Alertness

Prior to recording the EEG, it is recommended that the patient should be questioned concerning the quantity and quality of sleep that they had

the previous night and that they be questioned concerning whether they feel rested, slightly tired, moderately fatigued, or extremely fatigued. This information is important in determining the potential for drowsiness. Eyes-closed EEG recordings should be vigilance-controlled, meaning that they should be paused sufficiently often (e.g., every couple of minutes) to allow interaction with the patient to control drowsiness, unless drowsiness is desired to evaluate the raw EEG in this state. Likewise, the clinician should be both trained to recognize and be alert to signs of drowsiness in the EEG as it is being recorded (e.g., bilateral and rhythmic mid-temporal theta; frontal theta or alpha followed within a few seconds by a decrease in posterior alpha activity; flattening of posterior alpha activity; slow, asymmetrical, roving eye movements; vertex sharp waves; POSTS; spindles). When such patterns are observed, the recording should be paused and the problem corrected.

SUMMARY AND CONCLUSIONS

A full 19-channel QEEG does not appear necessary for conducting successful neurofeedback training. However, because an increasing number of clinicians are beginning to do such evaluations to guide their EEG biofeedback work and that of other neurotherapists, it has been deemed important to provide standards for those clinicians who are using QEEG evaluations in neurofeedback. An impressive body of peer reviewed scientific literature attests to the utility of the QEEG in providing a scientifically objective and clinically practical assessment of a wide range of psychiatric, psychological and medical conditions.

The panel noted that many of the most significant contributions to the field of quantitative EEG have come from scientific work done by psychologists. In addition, the Board of Professional Affairs of the American Psychological Association, as well as some state psychological associations, have concluded that QEEG is within the scope of practice of psychologists when they have received training in this specialty. Unlike neurology where the QEEG is primarily used for the diagnosis of medical pathology, neurotherapists are distinctive in using a QEEG assessment to guide the neurofeedback training process. This interdisciplinary panel concludes that it is not necessary for a neurologist or a physician to screen the raw EEG data as part of a QEEG evaluation for neurofeedback training. Licensed or certified health care professionals with training in EEG and QEEG are qualified to utilize QEEG in association with neurofeedback work. Recommendations are made for topical

areas of training and study in this specialty and for equipment/software, data collection, and analysis procedures to encourage high quality and standards. Certification is strongly encouraged.

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