When Worlds Collide

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Clinical electroencephalography (EEG) and quantitative EEG (QEEG), despite their common underpinnings in electrophysiology and instrumentation, have quite different origins, histories, and priorities. This is exemplified by the fact that quite commonly, EEG practitioners do not use QEEG, and may not even be aware of it. A third field that interacts with EEG and QEEG is neurofeedback, in which signals derived from the EEG, principally QEEG metrics, are used as feedback information to facilitate learning and self-regulation in clients. This discipline also has its history and evolution, which is distinct from both EEG and QEEG. As a result, in the world of practitioners, these three worlds can be applied individually, in pairs, or together.

Figure 1 illustrates quite simply that these three disciplines exist in their own right, and that practitioners use them individually or use two methods together, and a small number of practitioners are competent in and make use of all three areas. Some of the authors of the articles in this issue are among this group, and as clinical neurophysiologists using EEG, who also employ QEEG and neurofeedback, qualify to combine the strengths of each of these fields.

The origins of clinical EEG began with pioneers such as Berger, Adrian, Matthews, Knott, and legions of neurologists who have refined the art of inspecting raw waveforms for clinical purposes.[1,2] In this world, computers are used to reformat montages, apply filtering, and adjust displays, all in the pursuit of a superior ability to recognize patterns using experience and knowledge.[3] EEG is currently Board certified and practiced by neurologists the world over, in the service of patients with disorders including epilepsy, brain injury, and other serious conditions.

The physiological bases of these disciplines rely on a much common ground. All practitioners should agree that the scalp EEG is produced by the postsynaptic membrane polarization of pyramidal cells in predominantly layers 2, 4, and 5 of the cerebral cortex. The phenomenon of volume conduction is not an item of contention insofar that everyone will agree that this process occurs and is responsible for the manner in which postsynaptic potentials appear in a highly attenuated form on the surface of the head.[4] Where worlds differ is in how these signals should be acquired and viewed, how computers should be applied, and what the end goal of the process is.

QEEG had its origins in the 1970s with John et al.[5] QEEG takes the same signal as any other EEG, but it computer processes to produce metrics such as amplitude, coherence, phase, and other measures. Such analysis and precision may be viewed askance by experienced EEG'ers, as unnecessary and even misleading, as it neglects morphology, context, and detailed time behavior. In this regard, QEEG processing has been described as being a "blender" that reduces the signal to its constituent parts, while destroying structural information in the process. In my decade in clinical EEG for epilepsy, 1986-1996, the concepts of QEEG and mapping were generally viewed as "a problem" about which "something must be done." An example expressing this viewpoint is found in Nuwer.[6,7] who articulately details the unique value of EEG in clinical medicine, and the pitfalls and shortcomings of the blind use of QEEG in the clinical neurophysiology, as well as concerns with using various montages such as average or Laplacian, in place of a standard reference. However, QEEG has demonstrated value as an assist to diagnosis and treatment planning and in the prediction of medication response, as a guide to optimal pharmaceutical use.[8,9]

Indeed there was a problem, and something needed to be done. Inspecting maps of metrics, z-scores, etc. is limited in scope, and is not reliable in the absence of understanding of the underlying EEG and clinical situation. What is needed is the continual refinement of QEEG practice to incorporate informed visual inspection of the EEG into the decision-making paradigm. The field can continue toward consistency with traditional EEG, even while holding to the commitment to computer analysis using harmonic and related methods. As a step in the right direction, a certification board for QEEG was established and set forth standards for the sound practice (www.qeegcertificationboard.org). Among the content areas are anatomy and physiology, principles of amplifiers, filters, and digital signal processing, artifacting and recognition of key events, and the use of the raw EEG as a preliminary step before maps are created and interpreted. A second QEEG certification board has also been initiated, offered exclusively to doctoral-level practitioners and researchers, and with the intention of supporting a presumably more stringent set of scientific and technical knowledge principles.

QEEG has grown to incorporate advanced statistical methods, three-dimensional inverse solutions, and connectivity. There is a vast and strong literature validating QEEG as an indicator of brain function with relevance to conditions and disorders including psychiatric disorders, aging, epilepsy, and autism.[9]

Neurofeedback had its beginnings as early as the 1960s with work by Joe Kamiya, Barry Sterman, Margaret Ayers, Joel Lubar, and Les Fehmi, and has experienced growth in the ensuing decades (www.brainmuseum.com/). Neurofeedback

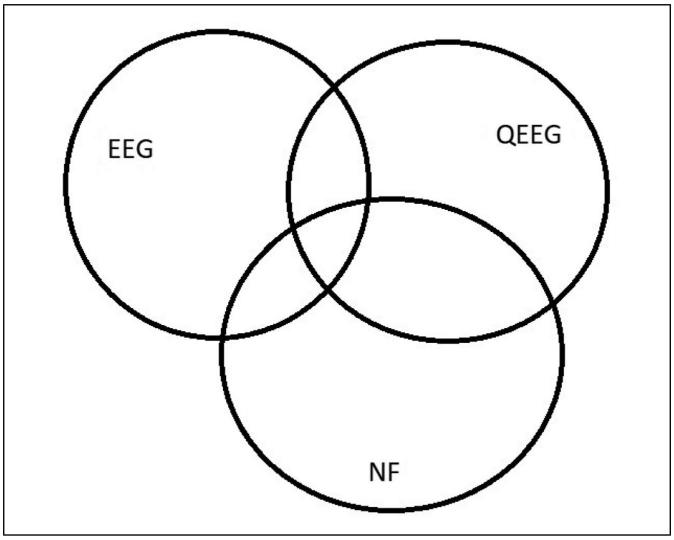

Figure 1. EEG, QEEG, and Neurofeedback have arisen and exist as separate disciplines, yet may be practiced in any combination in research or clinical practice.

has developed its own "legs" and has progressed at times in combination with EEG or QEEG, and at other times on its own basis. I have heard leading practitioners of EEG and QEEG express incredulity that the brain could change in response to visual or auditory feedback, believing strongly that such changes could simply not happen. And even within the world of neurofeedback, practitioners and researchers who are rooted in single-channel simple feedback of alpha or sensorimotor rhythms may find it impossible to accept that feedback of complex multichannel information such as live *z*-scores or inverse solutions (LORETA, etc.) data can possibly be effective for operant learning.

Significant differences exist in how EEG and QEEG view the importance of particular sample lengths or test conditions. For example, QEEG databases are generally constructed using epochs in the 2-5 min range. In contrast, when recording EEG for clinical purposes, a minimum standard of 20 min has long existed in the world of routine clinical EEG. Therefore, another area of difference, which is looking to be resolved, is how one acquires an EEG assessment that is suitable for QEEG and neurofeedback planning but can also be conveyed to a clinical neurophysiologist and evaluated as a routine EEG. To satisfy both worlds, one would need to collect 10 min each of eyes open and eyes closed, and incorporating photic activation, and also hyperventilation. However, only a shorter segment of the EEG should be submitted to the QEEG analysis, to avoid the time effects that compromise QEEG metrics. Beyond the recording itself, certain testing or surveys may be needed, such as symptom questionnaires, cognitive testing, and so on. This level of recording and testing may be out of the scope of a typical neurofeedback-oriented lab, making it harder for such entities to exchange EEG recordings with the clinical world at large.

Differences between the essential elements of EEG recording and QEEG recording are numerous. QEEG databases have traditionally been constructed using amplifiers with a bandwidth in the 30-40 Hz range, with signals digitized at 128 samples/s for a typical length of 2-5 min. The first such database was from John et al[5] and its replication studies, used eyes-closed data exclusively. In contrast, the American EEG Society guidelines specify an amplifier bandwidth of at least 70 Hz, recording of raw EEG with this bandwidth, requiring in practice a sampling rate of at least 200 samples/s, and with recordings of a minimum of 10 min eyes open and 10 min eyes closed as a routine, plus photic stimulation and hyperventilation to evaluate the paroxysmic activity. When digitally processing EEG for visual inspection, it is necessary to provide montage reformatting and filter adjustment, features that are foreign to the original QEEG procedures. Another difference is that QEEG quickly began to construct, and then to depend on, reference databases containing thousands of metrics. To many EEG'ers, such a process yields little more than a large amount of distracting information.

The use of montage reformatting, changes in filter settings, and time and amplitude scales is essential to the reading of EEGs. However, these operations are not part of the essential QEEG toolkit. In contrast, QEEG moves in the direction of using fast Fourier transforms,[3] digital filters, and other mathematical processes to coax essential quantitative information from the waveforms, in the process losing information about morphology, time courses, or the appearance of rare events such as spikes or sharp waves. Given a computer, an EEG'er is more likely to look for montage reformatting, automated detection of spikes, other epileptiform activity, or seizures, using joint time frequency analysis (JTFA) and related methods.

It is thus remarkable that these fields, each based on the exact same physiological basis and with similar goals, should have such different origins, philosophies, and practice models. But they can coexist, as shown by the articles in this special issue. These include clinical reports, research results, and reviews that describe just some of the current range of applications of EEG, QEEG, and neurofeedback. A diverse range of authors have chosen to reflect the broadening and deepening of these fields, with current results and interpretations. It is hoped that these reports serve to both strengthen the understanding of current EEG, QEEG, and neurofeedback science, but also to highlight and advance combined methods that achieve results that could not be obtained by any single approach on its own.

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References

1. Collura TF. History and evolution of electroencephalographic instruments and techniques. *J Clin Neurophysiol*. 1993;10:476-504.
2. Collura TF. History and evolution of computerized electroencephalography. *J Clin Neurophysiol*. 1995;12:214-229.
3. Knott JR, Gibbs FA, Henry CE. Fourier transforms of the electroencephalogram during sleep. *J Exp Psychol*. 1942;31:465-77.
4. Lopes da Silva FA. Computer-assisted EEG diagnosis: pattern recognition and brain mapping. In: Neidermeyer E, Lopes da Silva FH, eds. *Electroencephalography*. 3rd ed. Williams & Wilkins; 1993.
5. John ER, Prichep LS, Fridman J, Easton P. Neurometrics: computer-assisted differential diagnosis of brain dysfunctions. *Science*. 1988;239:162-169.
6. Nuwer MR. Quantitative EEG: I. Techniques and problems of frequency analysis and topographic mapping. *J Clin Neurophysiol*. 1988;5:1-43.
7. Nuwer MR. Assessment of digital EEG, quantitative EEG, and EEG brain mapping: report of the American Academy of Neurology and the American Clinical Neurophysiology Society. *Neurology*. 1997;49:277-292.
8. DeBattista C, Kinrys G, Hoffman D, et al. The use of referenced-EEG (rEEG) in assisting medication selection for the treatment of depression. *J Psychiatr Res*. 2011;45, 64-75.
9. Collura TF. *Technical foundations of neurofeedback*. Routledge; 2007.