



## Reading the Brain Science International QEEG Report

### **COMPLETE EVALUATION OF EEG DATA:**

A QEEG is a computer analysis of the EEG signal using 19 or more channels of simultaneous EEG recording. Raw digital EEG data is first recorded, then analyzed and compared against a reference database of normal subjects. Two main features of the digital EEG are evaluated: ***transient events***, such as spikes, or short bursts of activity (“paroxysms”), and ***background***, or average spectral content based on results of computations showing activity in each frequency for each electrode as well as correlations of activity comparing many electrodes.

Transient events are best evaluated by means of visual inspection by an experienced clinician. **Brain Science International** always evaluates the digital EEG recording first and, if ordered, includes a complete clinical EEG report. **Brain Science International** works with a panel of expert neurologists. These physicians screen the EEG for anomalies and provide a careful medical interpretation of raw EEG data prior to quantitative analysis.

As a secondary level of analysis, a QEEG provides the user with additional information obtained from ***spectral analysis***, which may not be readily identified in the visual evaluation of the EEG recording.

### **DISPLAYING THE RESULTS:**

The results of a QEEG analysis are displayed in the form of statistical tables and topographic maps. EEG topographs provide a convenient schematic representation of the results of spectral analysis. **Brain Science International** reports show the *relationships* among the EEG waveforms, topographic map displays, and results of statistical analyses.

Scaling can have a significant impact on visual detection of patterns in topographic map displays. We look at both relatively and absolute power which corrects somewhat for the  $1/f$  relationship between higher and lower frequencies.

Special consideration is given to the use of statistical analysis of EEG data. The more statistical tests are that are computed, more “significant” findings would be expected. QEEG can compare power, relative power, symmetry, coherence, phase cross spectrum correlation, burst metrics, peak frequency, all the multivariate and derived measures can be compared with all channels frequency bins, single hertz and states (eg; EO or EC). Of these thousands of comparisons available in a QEEG analysis, approximately 5% of them

may be significantly different from normal on the basis of chance alone. Thus, differences to the normative set may be observed by chance in a normal EEG. The primary difference between a normal individual and a clinical patient is that the normal individual's distribution of findings will be random and not generally replicable. That is, they are due to random variation in the selected EEG. In clinical patients, with an existing pathological condition, the distribution of abnormal findings will permit you to identify clusters of abnormalities where these anomalies appear to be associated with each other.

The clustering of the pattern of 'hits' provides evidence of an underlying functional anomaly in the EEG that can be associated with the patient's clinical condition or neurological/psychiatric problems. It is the pattern of the clustering of 'hits' that defines the QEEG profile of the individual.

### **SOME QEEG TERMS:**

In order to evaluate patient QEEG data it is important to have a working understanding of some technical terms used in QEEG studies. Basic definitions of frequency and amplitude measures, electrode location, and statistical concepts as used in the Brain Science International report should be kept in mind:

#### **EEG Frequency Bands:**

Delta: 1 – 3 Hz  
Theta: 4 – 7 Hz  
Alpha: 8 – 12 Hz  
Beta: 13– 25 Hz

**Z Scores:** The difference between the mean score of a population and the patient's individual score divided by the standard deviation of the population. The Z value indicates how "deviant" a patient's score is. For example, in the case of QEEG data, the Z-score indicates whether there is deficient or excessive activity in a given frequency for a given electrode site (or group of electrode sites), such as excessive theta activity at Fz. Z-scores are computed and displayed for each of the measurements used in the QEEG study: absolute power, relative power, coherence, frequency, and symmetry. Z-scores can also be computed for groups of measures in multivariate analyses.

**Multivariate Analyses:** In multivariate analyses several electrodes are grouped together to designate a region of interest. The regions include electrodes as listed below:

Left Lateral – F7, T3, T5	Right Lateral – F8, T4, T6
Left Medial – FP1, F3, C3, P3, O1	Right Medial – FP2, F4, C4, P4, O2
Left Anterior – FP1, F7, F3	Right Anterior – FP2, F8, F4
Left Central – T3, C3	Right Central – T4, C4
Left Posterior – T5, P3, O1	Right Posterior – T6, P4, O2
Mid (Midline) – FZ, CZ, PZ	

Note that in multivariate analyses positive Z-scores indicate divergence from normal (abnormal), a Z-score of 0 represents the mean of the normal reference population, and negative Z-scores indicate hypernormal results (multiple normal findings in combination).

**Absolute Power:** The actual power (voltage) in the patient's EEG database. (Power is microvolts squared.)

**Frequency Ratios (such as Theta/Beta; Alpha/Theta; etc.):** The percentage of power in one divided by the percentage of the other. They can be slow-to-fast relationship measurements or fast to slow.

**Relative Power:** The percentage of power in any band compared with the total power in the patient's EEG (e.g. "relative theta" is the percentage of theta of the combined sum of delta, theta, alpha, and beta).

**Interhemispheric and Intrahemispheric Coherence:** Interhemispheric (between left and right hemisphere sites) and intrahemispheric coherence (between sites in the same hemisphere) measures the similarity or correlation of the EEG signal between regions.

**Mean Frequency:** The mean frequency of the EEG within a frequency band. For example, the alpha band is defined as 8 – 12 Hz. The frequency measure indicates whether the patient's alpha frequency is slow (closer to 8 Hz.) or fast (closer to 12 Hz.).

**Symmetry:** The right-left and front-back balance in power of the patient's EEG.

### **READING THE RESULTS:**

- Examine the topographic maps for an appropriate distribution of EEG amplitude. Since the normative values change as a function of age, it is impossible to develop a preconceived notion of what the normal values should be for a specific age. Still, in general, you can use the following as a good starting point:  
The distribution of delta, theta, and beta activity should be somewhat flat throughout the cortex. Alpha amplitude should build towards the posterior portions of the head, and be greatest over occipital regions. Remember that approximately 40% of all individuals show low EEG amplitude under normal conditions. The EEG should be symmetrical.
- Examine the Z-score tables for the distribution of abnormalities, reviewing, in order:
  1. Absolute power
  2. Relative power
  3. Coherence
  4. Mean frequency
  5. Asymmetry values
- The statistical tables provide you with Z-score values that reflect both the direction and the extent of the difference between the patient's raw scores and the normative reference group average values.
- Any highlighted values in the patient Z-Score tables should be noted as possible abnormalities. In particular, one should focus on highlighted values that appear to be clustered in a specific region of the cortex. At times, however, some abnormalities are diffuse, and affect all areas of the cortex.

- Blue highlighted values indicate trends, differences that are greater than -1.50 standard deviations but less than -2.00 standard deviations from the mean of the reference group. Red highlighted values indicate potential findings, differences that are greater or lesser than +2.00 standard deviations from the mean. Values that are beyond +/-2.00 standard deviations have lower levels of probability of occurrence by chance and are more likely to represent abnormal activity.
- The direction (either plus or minus) represents either an increase (+) or a decrease (-) of patient values compared to normal.
- The magnitude of the difference provides an indication of the degree of difference between the patient's score and that of the normal reference value.
- In general the direction of the z-score provides an indication of the type of disorder, while the magnitude of the z-score provides an indication of the severity of the disorder compared to normal. Remember that all statistical results should be clinically correlated with other information available for the patient to evaluate clinical significance. Important: *statistical significance is not the same as clinical significance.*
- Abnormal observations that cluster together may be indicative of a localized abnormality of cortical function. For example, increased theta absolute and relative power, coupled with asymmetries and coherence anomalies in the same region may be indicative of a localized area dysfunction. More globally distributed patterns of abnormalities may indicate generalized patterns of disturbed function.
- Restricted areas of dysfunction may be related to focal abnormalities due to head injury, stroke, cerebrovascular dysfunction, or other organic insult.
- Regional abnormalities may be associated with dementia, depression, schizophrenia, head injuries, attention deficit and learning disabilities, and other disorders.
- Generalized disturbances may be related to metabolic or toxic encephalopathies, or maturational or degenerative processes.
- Interpretation of the location of the abnormalities with reference to the patient's symptom, as defined subjectively or through the result of testing, and the correlation of the standard EEG, quantitative EEG and other test results, is an important aspect of a QEEG analysis. Clinical correlation is required!

***General rules:***

We all know that the EEG maps generally show a voltage, or "amplitude-" related metric. The amplitude of the raw waveform is averaged over the sampled epochs to show "magnitude" (measured in microvolts), log of the magnitude (to normalize the distribution), or power (magnitude squared). Magnitude is calculated as amplitude over time.

These traditional metrics all use a reference point, and the real voltages mapped are the

difference between the voltage at the reference and the surface electrode's actual voltage. The references are all "active" with voltages, and these can skew the images. An example of this skewing is provided when temporal lobe EEG contaminates the ear references, and the voltages are false-localized in the maps frontally by the difference between the two voltages, distant from the reference site.

In an attempt to eliminate the effects of the reference electrodes, many attempts to remontage have been tried. Most modern attempts utilize Laplacian techniques to show the voltage distribution (see Hjorth's paper in the AJET, 1980). The Laplacian mathematics describes voltage and current gradients in a sphere without a reference point, though the Laplacian data is a continuous function, and the EEG is measured at discrete points... and to map something we are interpolating the points in-between the electrodes.

We are using a "spline interpolation" method to fill in these points, which provides excellent results, and is used in most modern analysis software. This is one of the few methods that can predict actual inter-electrode voltages accurately and match those actually measured... even when the voltage maximum is in-between electrodes.

The spline interpolation's exact mathematical procedure is given in:

F. Perrin et al. (1989), Spherical splines for scalp potential and current density mapping, *Electroencephalography and Clinical Neurophysiology*, 72, 184-187. This should be viewed together with a correction in *Electroencephalography and Clinical Neurophysiology*, 76 (1990), 565.

The CSD method uses the spline interpolation and the Laplacian mathematical "operators" to make maps that are not voltage, but voltage-per-meter squared, without the influence of the reference on the measurement due to the remontaging. This technique is referred to as the "reference-free" montage.

Before implementing the CSD maps, the parameters of the spherical splines were checked. We generated a mapping view for the data set and did spherical splines compared with interpolation by triangulation, verifying that the spherical splines satisfactorily approximated the actual voltage distribution on the surface of the head.

### ***Specific Interpretive Considerations:***

It is important to obtain a 'Gestalt' of the patient's QEEG analysis—a general or collective impression of the location, direction of deviation and degree of difference of the patient's QEEG abnormalities compared to normal. This requires correlation of the results of the visual interpretation of waveforms, topographic representation of EEG amplitude and frequency, and results of statistical analyses and database comparisons.

Since the QEEG highlights values that are +2.00 standard deviations or more from the mean, other score values in adjacent areas may have a low probability of occurrence but not be highlighted. Always examine adjacent values to determine if the focal abnormality spreads to other adjacent areas of the cortex. The appreciation of the spread of effect may provide you with additional and useful clinical data that you would otherwise overlook if you focus only on the highlighted values in the QEEG tables.

QEEG measures are defined for referential, sequential, and regional multivariate combinations of electrode sites. Monopolar measures (properly called "referential" measures) reflect comparison of scalp electrodes with the linked ear reference electrode.

Significant activity at the linked ears can strongly influence signals recorded from the scalp. Bipolar measures (accurately called "sequential" measures) provide measures of differences between scalp electrodes and are largely unrelated to activity at the linked ears.

Always examine the multivariate measures for their conformity to the existence of abnormalities in the monopolar and bipolar measures. When examining the multivariate measures, remember that just because a single referential or sequential value is abnormal does not mean that the multivariate value will be abnormal. The statistical method used for combining observations across measures in the multivariate feature set may reduce the likelihood of observing the abnormality in the multivariate feature set. On the other hand, an extreme value on one measure within the multivariate feature set may offset normal score values on other measures in the set, making the multivariate value abnormal.

Statistically identified "abnormalities" is an assumption we need to look closely at. A statistical outlier finding may actually be an abnormal clinical finding, though the outlier may also be a compensatory mechanism counter-acting another feature (like SMR stabilizing discharges), or it may be a unique performance outlier, like very fast alpha and superior semantic/declarative memory during a performance. Correcting an abnormality will be an improvement; however correcting compensatory mechanisms will not be a positive outcome; removing unique outliers associated with peak performance states is not "therapy" it is reducing a skill.

When examining the topographic maps, always remember that they represent an interpolation from the 19 site's electrode values to the adjacent areas, and the assignment of colors represent the voltages in the EEG across the various frequency bands.

**RESOURCES:**

Tyner, FS. and Knott, JR. (1983). *Fundamentals of EEG Technology: Volume 1: Basic Concepts and Methods*. Raven Press

Hjorth, B. (1975). An on-line transformation of EEG potentials into orthogonal source derivations. *ECNS*:39 526-530

Hughes, J.R. *EEG in Clinical Practice. 2nd Edition*. Butterworth-Heinemann, 1994.

Goldberg, S. (2000). *Clinical Neuroanatomy Made Ridiculously Simple*. MedMaster Series, 2<sup>nd</sup> edition 2000.

Sheskin, D. J. (2000). *Handbook of Parametric and Non-parametric Statistics: 2<sup>nd</sup> Ed*. CRC Press.

ASET: American Society of Electroneurodiagnostic Technologists -publications  
<http://www.aset.org/pubs.html>