Baker Neuropsychology

Quantitative EEG and Neurotherapy Fact Sheet

Quantitative EEG is the measurement, using digital technology, of electrical patterns at the surface of the scalp which primarily reflect cortical electrical activity or "brainwaves." Below is a normal adult male, eyes closed, showing good alpha activity at P3/P4, O1/O2, the back of the head where one should find alpha if the eyes are closed.

Brain waves occur at various frequencies, that is, some are quick, some quite slow. The classic names for these "EEG bands" are delta, theta, alpha and beta. The dominant wave pattern you see above is alpha; these waves happen between 8 and 13 times per second, or 8-13 Hertz (Hz). Alpha represents a sort of "idle" state, or "ready but not doing much" state and is normally fairly large over the back third of the brain when the eyes are closed and when you are awake. Alpha disappears when we either get mentally busy (e.g., open the eyes, start doing intense mental work even eyes closed) or when we become drowsy. Thus the presence of alpha can show the presence of an awake, resting state. If it is present at a fairly high voltage when the eyes are open, this would usually indicate an inattentive, daydreamy state. In fact we often see this sign in adolescents and adults with attentional difficulties.
When we get mentally busy and engaged, we should see alpha "block," or reduce significantly in size. In its place we see mostly smaller, quicker "beta" waves. The beta family of waves happen at frequencies from 16-35 Hz, with higher frequencies known as "gamma".

Delta and theta waves are relatively slow. Delta is usually defined as waves occurring from 1-4 times per second (1-4 Hz). Theta occurs at 4-7 Hz. During drowsiness, first alpha disappears, then the size of theta waves begins to increase. As sleep begins, theta waves get quite large, then become mixed with and eventually give way to slower delta waves.

The presence of delta and theta waves in the waking, eyes open EEG is normal, but only if the waves are fairly small. High amplitude slow waves can be signs of various neurological and psychological problems, ranging from epilepsy to ADHD.

For years all that was possible was recording these waves on paper with the traditional polygraph. Over the last 25 years, advances in signal processing made it possible to sample these waves many times per second (usually 128 or 256 samples per second; our current equipment samples at 4096 per second) and to analyze them in various ways. Using this technology we can now measure precisely the amplitude and frequency of waves of interest, be fairly exact about the scalp distribution of the waves, and even compare a client's qEEG to a normative life-span wide reference database that shows how the person's brain activity compares, on the average across a particular task, to healthy people of similar age and same sex.

We use a 24 channel EEG system, the Truscan 24 by Deymed Diagnostic, which allows high quality digital recording as well as EEG biofeedback. The digital quantitative EEG (qEEG) shows the actual brain electrical events associated with periods of inattention very clearly, for example the under-aroused, "sleepy" signals. The recording below shows big "theta" waves over the front of the brain, indicating periodic "sleepiness" in these critical executive systems.
The excess theta pattern is the most common pattern seen in children with ADHD diagnoses. About 80% show this pattern. A recent study (Synder & Hall, 2006) meta-analyzed 9 QEEG studies covering a total of 1498 children diagnosed with ADHD. The study showed an amazing sensitivity and specificity of 94% for identifying ADHD from the QEEG alone. That means that if excess theta and diminished beta activity is present, there is very likely going to be an ADHD diagnosis. The pattern correctly predicts ADHD 94% of the time.


A meta-analysis of quantitative EEG power associated with attention-deficit hyperactivity disorder.

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A meta-analysis was performed on quantitative EEG (QEEG) studies that evaluated attention-deficit hyperactivity disorder (ADHD) using the criteria of the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, 4th edition). The nine eligible studies (N = 1498) observed QEEG traits of a theta power increase and a beta power decrease, summarized in the theta/beta ratio with a pooled effect size of 3.08 (95% confidence interval, 2.90, 3.26) for ADHD versus controls (normal children, adolescents, and adults). By statistical extrapolation, an effect size of 3.08 predicts a sensitivity and specificity of 94%, which is similar to previous results 86% to 90% sensitivity and 94% to 98% specificity. It is important to note that the controlled group studies were often with retrospectively set limits, and that in practice the sensitivity and specificity results would likely be more modest. The literature search also uncovered 32 pre-DSM-IV studies of ADHD and EEG power, and 29 of the 32 studies demonstrated results consistent with the meta-analysis. The meta-analytic results are also supported by the observation that the theta/beta ratio trait follows age-related changes in ADHD symptom presentation (Pearson correlation coefficient, 0.996, P = 0.004). In conclusion, this meta-analysis supports that a theta/beta ratio increase is a commonly observed trait in ADHD relative to normal controls. Because it is known that the theta/beta ratio trait may arise with other conditions, a prospective study covering differential diagnosis would be required to determine generalizability to clinical applications. Standardization of the QEEG technique is also needed, specifically with control of mental state, drowsiness, and medication.

This pattern is very responsive to the stimulant drug methylphenidate, since it "wakes up" the frontal and prefrontal cortex enough so that it can do the critical jobs of motivation, impulse control. Until the medication wears off.

Many adolescents, some pre-adolescents and many adults with ADHD diagnoses show too much alpha, with normal levels of theta. This is a different type of brain. The excess alpha pattern does not commonly respond to methylphenidate or amphetamine very well. The excess alpha pattern represents vast processing regions that are "awake" but are failing to "allocate" their resources to the job at hand. This causes the experience of "I heard your voice but I have no idea what you just said." The pattern looks like this:
This recording shows high amplitude alpha waves over most of the back half of the head. Notice the first example, the excess theta waves were over the front of the head (top four tracings plus the third one from the bottom).

Some people, often with more severe difficulties, show a mixture of alpha, theta and often delta waves. This next example is from an 11 year old girl previously diagnosed with Pervasive Developmental Disorder NOS, a major failure to develop age-appropriate social and academic skills:
Some of the big waves are alpha, the wider ones are theta and the widest ones are delta. Contrast these patterns with the following example of entirely normal activation during a task:
Notice all the waves are much smaller. There are some little alpha waves, e.g. immediately above the word "normal", but they don't go on for a long time and they are not big. This indicates "pretty good" allocation of brain resources to the job.

You can see clear signs of over-excitement in some people, correlating with high anxiety. The next recording shows an anxious adult female with her eyes closed. Notice there is very little alpha activity, but a whole lot of beta (the small, close together waves). This person was also diagnosed with "ADHD", but reacted very badly to a stimulant medication given by a physician who was simply "going by the book" and diagnosing ADHD by the symptoms, or complaints. Examining the QEEG would easily have suggested this person is already very aroused, over-excited and that anxiety and distracting thoughts were causing the inattention. Contrast this eyes closed "resting" recording with the normal recording at the top of this page.
WHAT ABOUT THE QUANTITATIVE PART, THE DATABASE?

First one must be able to read and understand the "raw data," the recording themselves (as in the examples above). Then, we select areas of the raw data that are free from "artifact" (eye movements, too much muscle tension, etc.). Those chunks of data are analyzed statistically. The size, frequency and coordination of the various waves are measured by the software (Neuroguide, by Robert Thatcher, Ph.D., http://www.appliedneuroscience.com) and presented as numbers and as statistical "brain maps."

Below is a statistical topographic map of the record above. The small dots on each circle represent the recording electrodes. Each separate circle represents the electrical power that was found at a particular frequency, e.g., at 1 Hz, 2 Hz, 3 Hz, up to 30 Hz. Notice the first row maps the 1-5 cycle per second (Hz) waves, the second row maps 6-10 Hz waves, etc. Green means the size of the waves is normal at the frequency of the map. Red indicates 3 standard deviations above the mean power for the person's age and sex. That is like being 7 feet tall. Very big. The analysis proves that there is in fact a large excess of electrical power in the "beta" range. That's what my experienced eye told me from looking at the raw data, but it is nice to have this confirmed and made more precise by comparison with age and sex normals. This excessive beta activity over sensorimotor and parietal "association" cortex reflects a very busy brain that's working over time producing thoughts, images and tension. This is commonly found in anxious people. Settling this down (training for lower beta amplitudes, coupled with increased alpha activity) helps the person find a relaxed mental and physical state.
Below is a topographic map of a teen with an excess of alpha activity during listening. This alpha waxes and wanes, but on the average - which is what the statistical maps show - there is a major excess of it.
Thus we can see a physical reason for the inattention. We can also see which regions of the brain are having the problems. This lets us "aim" the neurofeedback training at these regions. This information also tells us which task is the hardest for the particular person, so we can have them do that task (e.g., listening) while doing neurofeedback.

We can usually predict which type of task is hardest or least fun for a child to do, based on the presence of slow, "sleepy" or "out-of-gear" brain waves. The child and parents usually confirm that. We then know what type of task to focus on during EEG retraining. Some kids (and adults) have what I call "art brains." They get very fine activation when they draw, although they may be very inattentive during listening or other verbal/analytic tasks. These kids I encourage to take "picture notes" in class instead of just writing down words.

QEEG is not intended to be a "stand alone" diagnostic or as a substitute for other medical diagnostics. It is, however, a helpful adjunct which can guide prognosis and intervention. qEEG is best used as an tool to aid in the clinical diagnosis of various dysfunctional states and not as a substitute for clinical judgment and medical opinion. The qEEG should be combined with other medical, psychological and neuropsychological data to best aid the patient.

The sister technology to qEEG is called EEG biofeedback, neurofeedback or neurotherapy. The qEEG provides the "targeting" information. That is, it tells us where and under what conditions (reading, listening, math, etc.) the problem is worst. This analysis allows accurate electrode placement for feedback and suggests the tasks that should be used during therapy. Neurotherapy is EEG feedback-assisted cognitive behavior modification. It couples EEG feedback with the full range of traditional cognitive behavior therapy methods, including imaginal rehearsal,
correction of maladaptive thought patterns, and rehearsal of new skills. We commonly utilize intensely activating, challenging tasks during the sessions to enhance brain activation and teach what it feels like to be focused and functional again. The EEG feedback signals the patient when their brain is in fact in a more activated state, indexed by decreased delta and theta brain wave amplitudes, and increased beta and/or alpha amplitudes.

Neurotherapy is no panacea. Like any therapy it works best with people who are motivated, who want to improve, who are experiencing some significant suffering from their symptoms and who are not so discouraged by years of trouble that they don't even want to try any more. In this latter case, depression, helplessness and negative attitudes toward the self - and often others - may have to be treated before the underlying attention, organization or learning problems can really be addressed.

THE SCIENTIFIC BASIS OF qEEG TESTING and NEUROFEEDBACK: References to Publications

The 1970's and 80's were decades of exploration and experimentation with qEEG. The technology is no longer "experimental." It is used in literally thousands of scientific studies to assess how people's brains are functioning under various conditions of illness, stress and mental difficulties. Patterns in the qEEG reflect emotional and cognitive states and predict whether people will be able to attention, or even what their mood is likely to be. The 25 year-long research programs of Richard Davidson at the University of Wisconsin, Madison, for example have shown an association between under-excitement in the left front brain and/or over-excitement in the right front brain to be associated with depression. The work of Joel Lubar at the University of Tennessee, E. Roy John, Robert Chabot at New York University's Department of Psychiatry and many others have shown qEEG abnormalities associated with ADHD, learning disorders and a range of emotional problems. For even more information go to PubMed (the National Library of Medicine portal) and simply search "QEEG". You'll pull up abstracts of hundreds of articles showing how QEEG is sensitive to dementia, depression, ADHD, etc. For more specific articles, enter the terms "QEEG ADHD."

Operant conditioning of EEG characteristics (what we now call "neurofeedback" or "EEG biofeedback") is also well documented in the scientific literature. Training easier access to the calm state of "alpha" (10 Hz synchronized brain rhythms associated with relaxed awareness, little active thinking, "just being there") has been used for decades to promote learned relaxation. There are at least 18 studies showing neurofeedback can suppress epileptic seizures. With some people, particularly those with Post-Traumatic Stress Disorder, we may train for increased alpha and theta to access deeper states where the unconscious mind can bring up personally important images and feelings.

Alpha and theta is what anxious, stressed people have too little of (too little access to) and what "ADD" kids often have too much of. Training to decrease slow activity and increase fast desynchronized EEG activity has been used for over 25 years to ameliorate ADHD and epilepsy. More recently EEG operant conditioning has been successfully applied to patients with mild traumatic brain injury. Reports of literally hundreds of case studies have been presented at conferences of the National Head Injury Society as long ago as 1987. Many clinicians are reporting case studies of depression being improved with the proper type of neurofeedback training (calming down the right front brain, getting the left front side more activated). The applications are many. Unfortunately, there are those in the medical and pharmaceutical industries that choose to ignore the existing research and the large body of clinical experience that exists and claim there is no evidence for the utility of QEEG or neurofeedback. You should look at some of the actual literature and judge for yourself. Or access some of it and talk it over with a physician or psychologist you trust. It is worth noting that the American Psychological Association has endorsed qEEG and neurotherapy as within the venue of psychologists with appropriate training. Professionals with other healthcare licenses may also be qualified to do qEEG and neurofeedback, but the potential client should ask about the credentials and training of anyone they are considering working with.