COMPENDIUM OF COMMON TERMS IN EEG & NEUROFEEDBACK

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Activation Procedure refers to a procedure like photic stimulation or hyperventilation that is used to elicit or enhance normal or particularly abnormal activity.

Alpha band is the frequency band from 8-13 Hz, or sometimes defined as 7.5-12.5 Hz.

Alpha rhythm is a waking rhythm occurring from 8-13 Hz predominantly over the posterior part of the head. The wave morphology of alpha is usually typified by a sinusoidal wave, although it may be more sharp than rounded in a few people, especially children and young adults. Current belief (Niedermeyer, 1999a; Steriade, Gloor, Llinas, Lopes da Silva, & Musulam, 1990) is that there are cortico-cortico and thalamo-cortical generators of alpha which interact with one another, although there is no validation of a synchronizing mechanism at a cortical level. Sir John Eccles (1964) defined alpha as the brain seeking, and it is generally considered to be an idling rhythm of the brain where the individual is awake, but relaxed with the eyes closed. Relatedly, Walter (1950) referred to alpha as a scanning mechanism, and Giannitrapani (1985) believed that "alpha activity can be thought of as a scanning for any stimulation" (p. 212). Alpha may also be found in the parietal and posterior temporal regions, but it may be considered abnormal when much alpha activity is found in the central-temporal-frontal areas of the brain. However, Wu and Liu (1995) divided alpha into 3 frequency bands: alpha 1 (8-8.9), alpha 2 (9-10.9), and alpha 3 (11-12.9). Alpha 2 and 3 bands demonstrated the most power in the posterior part of the head. They discovered that the very slow alpha 1 band was not distributed like alpha 2 and alpha 3. When alpha 1 was combined with the 7-7.9 Hz band of theta, the distribution over the scalp was like the 4-6.9 Hz frequency band–with no significant difference between anterior and posterior head regions.

Alpha is most prominent under eyes closed, relaxed conditions, where one is mentally inactive. It is blocked or substantially suppressed when the eyes are opened, and to a lesser degree by sensory stimuli or by mental activity. Alpha rhythm also begins to disappear with drowsiness. Niedermeyer (1999a) has noted that in some individuals, posterior alpha can be faster than 13 Hz, but that this 14-15 Hz rhythm will block to eye opening, and it is only found in about 3.6% of the population (Brazier & Finesinger, 1944).

The alpha rhythm is now considered (Pfurtscheller & Klimesch, 1991; Klimesch et al., 1992; Sterman et al., 1996; Sterman, 1999) to be made up of two separate functional components. There is a low alpha band (8-10 Hz) associated with general or global attention, and a high alpha band (10-13 Hz) reflecting directed or task specific attention. Both Sterman et al. (1996) and Klimesch et al. (1993) found that individuals with good (versus poor) memories have stronger desynchronization in the lower alpha band during the encoding and retrieval of memory. Crawford et al. (1995) found more resting lower band alpha power in subjects whose attention was more distractible. When sleep deprivation occurs, it has been found to mostly affect low alpha (and theta), most negatively influencing general attention (Sterman, 1999) so that excitation is blunted and this person will revert more quickly and strongly to an inattentive idling state.

The Klimesch group (Klimesch, 1999; Klimesch et al., 1997a,b, 1994) has abandoned using fixed alpha frequency bands. They identify the peak alpha frequency, and from that point to 2 Hz above it is defined as the upper alpha band, and from that point to 2 Hz below it is defined as the lower alpha band. They have found that during eyes open semantic processing, there is a decrease in upper band alpha power, while during episodic memory retrieval there is an increase in theta power. They conclude that there is a dissociation between synchronization of theta which is maximal while processing new information, and desynchronization in the upper alpha band which becomes maximal during retrieval and processing of semantic information. Klimesch (1999) indicated that during a resting state, small theta power and large alpha power (especially in the upper alpha band) predicts good cognitive and memory performance, while the opposite is the case under task. Under task, a large increase in theta power (synchronization) and a significant decrease in alpha power (desynchronization) is associated with good cognitive/memory performance. In relation to theta activity, it should be noted that Klimesch finds that theta synchronization occurs in a narrow frequency band in the range of the peak theta frequency, whereas there is a second, inefficient form of theta synchronization associated with large but irregular activity. Klimesch (1999) concluded:

> Large scale alpha synchronization blocks information processing because very large populations of neurons oscillate with the same phase and frequency. In contrast, alpha desynchronization reflects actual cognitive processes because different neuronal networks start to oscillate at different frequencies and with different phases (p. 190).

I strongly recommend that the serious clinician read Klimesch (1999).

Alpha Amplitude. The greatest amplitude of alpha is usually found in the occipital area and is generally below 50 microvolts (µV). Amplitudes of 20-60 µV have been found in 66% of people, while amplitudes below 20 µV are found in 28%, and above 60 µV in 6% (Simonova et al., 1967). Higher amplitudes are usually found in children (50-60 µV) and 9% of children (ages 1-15) have amplitudes of 100 µV or higher (Petersen & Eeg-Olofsson, 1971). An inverse relationship exists between the frequency of alpha and alpha amplitude (Brazier & Finesinger, 1944). About 7%-9% of adults have a "low-voltage record," consisting of amplitudes under 20 µV (Markand, 1990), which may or may not display alpha activity, but hyperventilation may cause the emergence of alpha of increased voltage in such cases.

Reactivity and desynchronization. When the alpha rhythm predominates it is said to be synchronized, but when the eyes are opened and alpha is more suppressed, it is referred to as desynchronized or by the term "alpha blocking." Lack of reactivity to eye opening is especially significant if it is seen on one side, and should warrant a neurological consult. Large resting alpha power enhances desynchronization, while small eyes closed alpha power attenuates desynchronization (Doppelmayr et al., 1998).

Event-related desynchronization (ERD) refers to the suppression of alpha rhythmic activity during cognitive responding, and this is followed by a post-response rebound of the dominant alpha frequency, which has been termed post-response synchronization (PRS) (Sterman, 1999). The extent of the ERD appears to be related to the difficulty of the mental task, and the PRS is inversely related to task difficulty. Thus, "it can be proposed that increased attentional and memory requirements specifically reinforce the suppression of intrathalamic oscillation within the alpha frequency range, whereas reduced attentional requirements specifically reinforces a rebound of this oscillation" (Sterman, 1999, p. 236).

Frequency. The mean adult frequency was found to be 10.5 (S.D. = 0.9) by Brazier and Finesinger (1944), and has been found to be 10.2 in males and 10.3 in females (S.D. = 0.9) (Petersen & Eeg-Olofsson, 1971). Alpha usual reaches this frequency between age 10 (Niedermeyer, 1999b) and age 15 (Peterson & Eeg-Olofsson, 1971). When the mean alpha level is found to be below 9 Hz it should be considered significantly low. When the mean frequency is between 8 and 8.5, it should be considered suspicious, and a mean frequency below 8 Hz "is always abnormal, usually suggestive of a diffuse encephalopathy" (Markand, 1990, p. 181) (e.g., with systemic metabolic disorders like renal or hepatic disorders, hypothyroidism, hypoglycemia, or with cerebral insults). A general rule (Hughes, 1994) is that anyone from age 8 through centenarians should have an alpha background rhythm of at least 8 Hz. Wu and Liu (1995) only found 1% of healthy adults to have a dominant rhythm of 8 Hz. Above average mean alpha levels may suggest hypervigilance, perhaps high intelligence (Gasser, Von Lucadou-Muller Verleger, & Bacher, 1983) and good memory (Klimesch, Doppelmayr, Schimke, & Pachinger, 1996). The alpha rhythm may also increase with increased body temperature (Gundel, 1984) or hyperthyroidism. Giannitrapani (1985) correlated WISC IQ performance in 11-13 year old children with EEG rhythms. Although 13 Hz was by far the most common frequency, especially in central areas and for verbal functions, 11 Hz was one of the strongest correlations with many subtests and with Verbal IQ and Full Scale IQ scores. The 10-14 Hz range seemed to be important during intellectual activity. Alpha frequency is positively correlated to cognitive performance, speed of information processing, and is significantly higher in individuals with good memory performance (Klimesch, 1999).

There are frequency variations in alpha that are considered to be normal variants (Markand, 1990). There is a *fast alpha variant* that may range from 14-20 Hz, mostly prominent over posterior areas, which alternates with alpha rhythm, and which also blocks to visual stimuli. More frequently found is the *slow alpha variant* with a frequency of 4-5 Hz, which is precisely one-half the frequency of the subject's alpha rhythm. It also has a posterior distribution, is intermixed with alpha, blocks to stimulation, and may have a more square-topped appearance. It seems to occur in less than 1% of people (Aird & Gastaut, 1959). Alpha frequency may also decrease in the elderly, as will be discussed shortly.

Asymmetry. In right-handed individuals, alpha should be found to be somewhat higher in amplitude in the right hemisphere. However, when alpha frequency is found to be slower by 1 Hz or more in one hemisphere, this should be considered as potentially indicative of a focal abnormality (Markand, 1990) warranting a neurological consult, and should particularly be considered abnormal if it is greater than 1.5 Hz (Duffy, et al., 1989). Likewise, an amplitude difference in alpha between the two sides of more than 50% is considered significant (Hughes, 1994), and because in normal people alpha rhythm is usually of higher amplitude on the right side, a decrease of even 35% on the right may be significant (Duffy et al., 1989). Focal lesions may cause alpha to be disorganized ipsilaterally, to be of lower or higher amplitude, and may cause alpha to fail partially or totally to block following eye opening on the affected side. But, "in the absence of other findings, one should use caution in interpreting isolated *amplitude* asymmetry of the alpha rhythm, because amplitude asymmetries of the order as high as 2:3 are not uncommon in normal subjects" (Markand, 1990, p. 181, emphasis added). *Maturation & Aging*. Although alpha is considered the predominant idling rhythm in adults, theta is the predominant rhythm in children until ages 13-14, when alpha becomes the more predominant rhythm. However, slower brainwave activity continues to decline in the EEG until the late twenties or thirties. Waves with an alpha wave morphology are seen in the 6 Hz range by one year of age, in the 8 Hz range by age 3, and reach a frequency of 10 Hz by about age 10 (Niedermeyer, 1999b). In older age, beginning in the later 50's, there is a gradual decrease in alpha frequency, most likely due to pathology such as diminished vascular flow to the brain. However, it appears that alpha rhythm will remain above 9 Hz in healthy elderly subjects who do not have systemic or neurologic problems (Markand, 1990). Katz and Horowitz (1982) reported an average alpha frequency of 9.8 Hz in individuals in their 70's, while Hubbard et al. (1976) found a mean alpha frequency of 8.6 in 10 individuals between the ages of 100 and 105 years of age. Alpha frequency is lowered in dementia patients.

Amplitude is synonymous with the voltage of the EEG, measured peak-to-peak and expressed in microvolts (µV). A 10% shift in the number of synchronous neurons leads to a 300% shift in amplitude.

Artifact is a modification of an EEG tracing due to an extracerebral source. Artifacts are inevitable, but may obscure EEG activity or lead to misinterpretations when the EEG is transformed into topographic displays in a qEEG. Examples of artifacts include ones that stem from EMG (muscle) activity, lateral or vertical eye movement, body movement, EKG (pulse), drowsiness, tongue movement, sweating, salt bridge (excess use of electrode paste, or sweating creating a bridge between two electrodes), breach rhythm, poor impedance or an electrode going bad, external sounds, cellular telephones that have not been turned off, lightening, or electronic equipment nearby.

Asymmetry or power asymmetry refers to unequal amplitude or power between homologous electrode sites. Thus, **interhemispheric power asymmetry** in a qEEG database is a ratio of the absolute power within each frequency band and for total power calculated between homologous monopolar (e.g., Fp1/Fp2, F3/F4, F7/F8, C3/C4, T3/T4, P3/P4, O1/O2) and bipolar (e.g., left and right frontal/temporal, temporal, central, and parietal/occipital) regions. **Intrahemispheric power asymmetry** is a ratio of absolute power within each frequency band and for total power calculated between frontal/temporal (F3/T5, F7/T5, F4/T6, and F8/T6) and frontal/occipital regions (F3/O1, F7/O1, F4/O2, and F8/O2) within each hemisphere. The gradient of EEG amplitudes across the scalp has an expected distribution which is referenced in our databases. Distortions in this can particularly be expected when there have been focal head injuries. The functional interpretation of asymmetries is the opposite of that for EEG coherence. A statistically significant reduction in amplitude asymmetries represents reduced functional differentiation, while enhanced amplitude asymmetries is related to reduced connectivity between two brain regions. However, amplitude asymmetries are less clinically sensitive than coherence generally because of the dependence on skull and scalp differences, and because amplitude differences can occur independent of the magnitude of the coupling between two regions (unlike coherence). **Abnormal asymmetry:** When the alpha frequency is found to be slower by 1 Hz or more in one hemisphere, this should be considered as potentially indicative of a focal abnormality (Markand, 1990) warranting a neurological consult, and should particularly be considered abnormal if it is greater than 1.5 Hz (Duffy, et al., 1989). Likewise, an amplitude difference in alpha between the two sides of more than 50% is considered significant (Hughes, 1994), and because in normal people alpha rhythm is usually of higher amplitude on the right side, a decrease of even 35% on the right may be significant (Duffy et al., 1989). Porencephalic cysts and subdural hematomas may be associated with big asymmetries. **Frontal alpha asymmetry** is a term used to refer to a very robust research finding in depression in which there is an activation difference between the right and left prefrontal cortex. The left frontal area is associated with more positive affect and what has been called approach motivation and behavior, while the right frontal area is more involved with depression and anxiety, and what has been called withdrawal or avoidance motivation. Thus, if there is more slow (e.g., alpha activity) in the left frontal area, this is believed to reflect a biological or trait marker of a vulnerability to more easily becoming depressed, as well as correlating with the degree of depression. The *Rosenfeld Protocol* is both a method for measuring this asymmetry and for attempting to correct it. This protocol compares F3 and F4 against a reference at Cz. Hammond's protocol for treating this asymmetry consists of having referential electrodes at Fp1 and F3, and inhibiting alpha and theta while reinforcing beta activity.

Attenuation refers to a reduction in the EEG amplitude, for example, as occurs to the alpha rhythm with eye opening.

Augmentation means an increase in the amplitude of EEG activity.

Background activity or rhythm is the EEG activity which is most predominant or common. This is usually, but not necessarily always, synonymous with alpha activity. In younger children this will be slower than in adults. This may be considered as representing the usual level of excitability in the central nervous system. Conditions that affect the brain diffusely (e.g., metabolic, toxic, vascular, infectious, aging) can decrease the frequency of the background rhythm. A background rhythm below 8 cps is abnormal in older age. It is not unusual to see decreased amplitude of background activity in the dominant hemisphere (left hemisphere in right-handed subjects), but when there is more than a 50% difference in the peak-to-peak amplitude of the two hemispheres, it should be considered abnormal, and even more so when it is seen in the nondominant hemisphere.

Band-Pass Filter is a filter that lets EEG frequencies between two set frequency points to pass with minimal attenuation (e.g., .5-3.5 Hz is a delta band-pass filter).

Bandwidth refers to the range of hertz levels that an EEG channel is measuring (e.g., 8-12 Hz for alpha, or 15-18 Hz as a reinforcement band for beta).

Baseline generally refers to a 30 second to 2 minute eyes open and/or eyes closed period of data gathering prior to the beginning of a neurofeedback session. It can then be used in comparison with a post-session period.

Beta band is the frequency band from 13-30 Hz or higher.

Beta rhythm predominantly occurs in the frontocentral areas of the brain, usually has an amplitude of 30µV or less and is symmetrical. Cobb (1963) considered amplitudes that were persistently over 20 µV to be abnormal, and in 70% of subjects beta is 10 µV or less (Kellaway, 1990). There appear to be sex differences in beta, with females of all ages displaying more beta than males (Matsuura et al., 1985). Niedermeyer (1999a) noted an important distinction between beta and fast posterior alpha--sometimes posterior alpha is fast, but a 14-15 Hz alpha rhythm will still block to eye opening and increase with eye closure. Although we are inclined to think of beta as a cognitively involved rhythm, Niedermeyer (1999a) also pointed out that frontal beta of 30-40 cycles per second occur when patients fall asleep, and (Niedermeyer, 1999b) faster beta activity is commonly seen in adolescents, especially frontally. Developmental changes are found in beta. In infancy, the average power of beta is seen predominantly in the occipital and posterior areas. However, as we grow it shifts to frontal dominance, first in the lower beta frequencies, and later in the higher frequencies (Yamamoto et al., 1987). The total power in the higher beta frequencies is also largest in infancy, and with aging, there is a shift toward the greatest power being in the lower beta frequencies. Reduced beta activity may be seen with focal lesions, stroke, or tumor (Green & Wilson, 1961) diffuse encephalopathies (e.g., anoxia) or serious retardation. Although we usually think of beta as a healthy brainwave, we must note that there can be too much of a good thing. Thus, excess beta activity may be associated with alcoholism (along with a deficiency of alpha and theta) and the children of alcoholics, anxiety, and some types of OCD. Giannitrapani (1985) noted in children in a resting condition that there were beta spectral peaks at about 17 Hz, 21 Hz, and 29 Hz. However, in an intellectual task, there was more activity in the frequency ranges of 13 Hz (central and temporal areas, spreading to frontal areas) and 23 Hz (frontally), with more energy in the 17 Hz range in posterior areas, spreading to frontal and central areas. Excess beta activity is perhaps most often seen with the use of sedative/hypnotic medications such as barbiturates and tranquilizers, as well as with antihistamines, caffeine, some antidepressants, ritalin, cocaine, mephenytoin, milacemide, and methaqualone (Kozelka & Pedley, 1990). However, focal lesions may diminish barbiturate-induced beta activity (Pampiglione, 1965). In the process of artifacting during quantitative EEG, it is vitally important to recognize signs of drowsiness, one of which is enhanced beta activity (Kellaway, 1990), particularly associated with beta spindles. Although in the beta band, these spindles are associated with the blockage of information transfer in thalamocortical systems (Steriade, 1997) associated with early sleep.

Bipolar (sequential) montage refers to a scalp to scalp recording (or neurofeedback training protocol) where the activity between the two sites is subtracted and compared with a ground electrode, rather than showing the activity at the individual site compared with a more neutral reference or ground (which is what a referential recording or montage does). Both active electrodes are on the scalp (e.g., instead of a reference electrode on one ear). What is seen in a bipolar montage is the activity that is different at the two sites, because common mode rejection subtracts activity that is common to the two sites. In neurofeedback training, because of better common mode rejection of noise (that is frequently in phase), it can be somewhat easier for patients to learn and the training tends to show less variability. However, when there is a great deal of synchrony (zero phase delay) between the two electrode sites, the signal will be lower in amplitude. It is believed that bipolar training, particularly over longer distances, may facilitate and require more communication between cortical areas and the thalamic regulatory centers. In examining the raw EEG, different bipolar montages provide different windows for examining the EEG. Bipolar montages assist in source localization through being able to examine phase reversal. Thus, a spike discharge at T4 will be revealed when looking at the bipolar channels F8-T4 and T4-T6, because the spike discharge that is common to each will point toward each other. Interhemispheric sequential montage training is believed to decrease coherence and increase phase.

Bipolar training refers to neurofeedback training where both active electrodes are placed on the scalp, rather than one active electrode on the scalp with the other electrode as a reference on the earlobe. The training is generally done to decrease the amplitude of inappropriate EEG activity (such as theta activity). Bipolar training affects not only amplitude but also connectivity (coherence)between the two electrode sites. Thus, using bipolar training to reduce theta activity would be anticipated to also down-train synchronous activity between the two sites. A particular advantage to bipolar training is that it reduces the influence of artifacts, such as EMG muscle activity, through common mode rejection.

BORTT refers to bursts of rhythmical temporal theta, which may particularly be seen in the left hemisphere, and be associated with early cognitive decline associated with aging.

Breach rhythm is an artifact where the amplitude is larger in a region of one hemisphere compared with the other hemisphere due to a skull defect, such as a burr hole, skull fracture, or craniotomy. The skull attenuates and laterally diffused activity, especially faster activity. The skull defect magnifies or exaggerates the activity that is present, thus causing it to appear higher in voltage. This higher amplitude can resemble spikes, but should not be misinterpreted as epileptiform discharges.

Bursts are a group of waves of increased amplitude, appearing and disappearing abruptly, which is distinguishable from the background activity.

Coherence refers to the connectivity between different parts of the brain. It is a cross correlation between two electrode sites in a frequency band, indicating the extent to which two wave forms are similar in shape (synchrony). It represents the degree of joint variation between the electrode pairs. Frontal focal delta coherence problems may be eye movement unless F3-F4 delta is bigger than FP1-FP2, in which case it is genuine. If recordings contain small subtle EMG artifacts, there will be a reliable drop in coherence because muscles are random generators and very unreliable phase results. Focal delta may be a tumor or other neurological impairment. Electrode sites closer together have more coherence. Significant decreases in coherence are often correlated with increased phase delays. A statistically significant reduction in coherence is more serious clinically than excessive coherence. **Hypercoherence** suggests inadequate differentiation of function. The areas are too similar and the activity in these bands is excessively synchronized or coupled. The sites are doing too much of the same thing at the same time. This has been seen in epilepsy and in problems with rage. **Hypocoherence** indicates that the two sites are out of synchrony with each other and are not doing enough of the same thing at the same time. Thus, if these are homologous sites, it indicates that the activity in these bands is poorly synchronized between the hemispheres. This lack of relationship which may indicate a *functional uncoupling* of the shared source generator within or between the hemispheres. They are not doing the same thing and there is less integration. With either too much or too little coherence there is not optimally efficient cortical function and the different brain areas are not working with each other enough.

Common Mode Rejection is a quality of differential amplifiers that reduces the amplification of signals that are common between two electrode sites compared to signals that are different.

Comodulation is a metric used exclusively in the SKIL QEEG database. Whereas coherence refers to cross-correlation in the frequency domain, comodulation refers to temporal synchrony in the dominant frequency range (e.g., alpha in adults).

Contralateral refers to the opposite side of the head. Thus a contralateral ear reference would be an electrode placed on the ear lobe on the other side of the head from the active electrode.

Delta band refers to the frequency band from 0 or .5 to 3.5 or 4 Hz (cycles per second).

Delta rhythm is the dominant activity during the first few months of life. Although usually thought of as being associated with sleep and parts of the brain being "off line," taking up nourishment, delta activity is always present in normal EEG's of any age. It is generated cortically and inhibited by afferent stimulation of the cortex. Delta does not seem to be nearly as well understood as some of the other rhythms. However, *focal* delta activity should always be considered abnormal, possibly indicating a lesion, and should result in referral of the patient to a neurologist for further evaluation. The delta band may be composed of delta rhythm activity (usually over 75 µV and rather rhythmic), slow cortical potentials (DC shifts) at .5 Hz and below, and also artifact (e.g., eye movement, glossokinetic artifact, electrodermal or sweat artifact). Decreased delta power in quantitative EEG's has been found to be associated sometimes with complicated depression, chronic migraine, closed posterior head/neck injury, alcoholism, and a subgroup of patients who display lack of control over repetitive thoughts and behaviors and minor motor symptoms (Gerez-Malo & Tell-Valdes, 1996). An excess of delta activity may be seen in the records of individuals with learning disabilities, Alzheimer's disease, demyelination, toxic or metabolic disturbances, edema, and with aging there is frequently an increase of delta waves, especially in the left hemisphere. Pathological delta patterns, known as FIRDA and OIRDA are defined elsewhere. There is a substantial QEEG literature relating delta power to higher order mental functions in normal awake humans. Increased delta activity has been observed in normal subjects performing calculations, reaction time tests, abstract thought, or an omitted stimulus paradigm and to covary positively with P300 amplitude. A functional role has been suggested for delta in facilitating 'inner concentration' by suppressing extraneous cortical inputs in order to maximize the allocation of attention to tasks involving internal representation. Approximately 20%-30% of the voltage of awake normal subjects in anterior leads is in delta as revealed by multiple replicated studies. A delta deficit could be a correlate of reduced frontal cortical regulation or gating of responses to maladaptive behavioral impulses or extraneous cues. Groups with a delta deficit: Cocaine addicts, ADD, subtypes of OCD, and schizophrenia--they all have definite problems with frontal cortical regulation of attention or impulsive behavior, as well as the gating of preattentive or extraneous stimuli. There is evidence suggesting a significant functional relationship of the delta rhythm to the mesotelencephalic dopamine (DA) projection. The estimated location of the major site for delta generation in midline and the anterior frontal cortex corresponds with the location of the main cortical terminal field of the mesotelencephalic DA projection. Frontal delta excess s often correlated with damage to the white matter since the white matter axons are exclusively excitatory.

Diffuse means that the EEG activity occurs over large areas of one or both hemispheres, but not everywhere. Thus, compared with the term "generalized," it tends to refer to a more intermediate size area of occurrence. Diffuse means the abnormality is not lateralized or focal. In contrast, "random" is used to describe EEG activity (e.g., slow waves) that occur only occasionally or sporadically.

Diffuse slow waves may be associated with toxic, metabolic, or infectious causes. If it is symmetrical, the problem may be near the midline subcortically. If the general background frequency is decreased, it may be a diffuse problem such as dementia or hypothyroidism.

Epileptiform discharges refers to sharp waves or spikes (but not sharp transients like V waves, for example), but this does not necessarily indicate that epilepsy is present. The polarity of the primary components of epileptiform discharges is generally negative. Diagnostically there is not a difference between sharp waves and spikes.

Evoked potentials refers to EEG signals that are coupled to an eliciting sensory stimulus

F Waves are frontally dominant V waves that occur over frontal regions during sleep, in response to a stimulus that alerts the person to some degree. See V waves.

Fast alpha variant consists of activity in the range of 14-20 Hz, 20-40 µV in amplitude, that alternates with or is mixed in with alpha activity. It is most prominent in posterior areas, and like alpha, is expected to block with eye opening or mental activity.

Filter is an electronic device that is used to reject signals at certain frequencies while allowing other signals to pass. See "notch filter," "high pass filter," and "low pass filter." Common types of digital filtering procedures include FIR (finite impulse response), IIR (infinite impulse response), and FFT (fast Fourier transform).

FIRDA refers to frontal intermittent rhythmic delta activity. This 1.5-3 Hz (usually 2.5 Hz) activity is rhythmic, occurs intermittently and exclusively at frontal electrode sites, may be in one or both hemispheres, and it must be distinguished from vertical eye movements. It is reactive to external stimuli and suggests a problem in the anterior subcortical brainstem structures, particularly the anterior diencephalon. It may be associated with metabolic conditions (e.g., diabetes), deep midline tumors, degenerative or infectious disorders. These are focal slow waves. Vertical eye movement artifact can be mistaken for FIRDA. An example of FIRDA may be seen under the definition of ORIDA.

Focal refers to a focused area of two or more electrodes that is displaying a type of EEG activity.

Focal slow waves should result in a referral for a neurological consult. Very slow activity may be associated with a space-occupying lesion. If it is frontal focal slow activity that is not eye artifact, it may be FIRDA. If it is unilateral, it may be associated with a problem with the ipsilateral carotid artery (CVA). Temporal focal slowing (which occurs more often in the left hemisphere) may be associated with a traumatic brain injury, anoxia, dementia, and vascular problems. In the parietal area it may be a associated with a tumor. In the occipital area it may be associated with a learning disability in children, or when accompanied by temporal slowing in adults, it may be associated with vertebral-basilar insufficiency.

Forty Hertz Activity. The 40 Hz rhythm has been found in animals to be associated with the acquisition of learning (Galambos, 1958; Killam & Killam, 1967; Rowland, 1958; Sheer, 1970), occurring in many species most strongly in rhinencephalic structures, especially the olfactory bulb (Sheer & Grandstaff, 1970). A MEG study (Tesche & Hari, 1993) verified that 40 Hz responses are unrelated to 10 Hz activity, thus suggesting that they have independent generators. In humans, synchronous activity around 40 Hz is hypothesized to be associated with preattentive binding operations. This rhythm seems to mediate the binding of disparate stimulus components of perception into coherent wholes so that information is processed simultaneously from different cortical areas (Engel et al., 1991a). For example, Desmedt and Tomberg (1994) documented how during selective attention tasks, there is a functional synchronization between critical brain areas (e.g., prefrontal and parietal areas) as far as 9 cm apart, "binding" cognitive features that are processed in these different brain areas so that conscious perception can occur. It thus may mediate the transient coupling of different areas of the brain that are involved in processing sensory input, binding various sensory inputs into a unitary sensation so that it is perceived (Jeffreys et al., 1996; Krause et al., 1998).

In contrast with event-related desynchronization that occurs to alpha rhythm with mental engagement, 40 Hz activity (similar to theta) appears to represent event-related synchronization. Sheer (1975) believed 40 Hz was "'optimal' for consolidation because repetitive synchronous excitation of cells maximizes the efficiency of synaptic transmission over the limited circuitry," and that it has an effect behaviorally "in sharpening of attention to relevant stimuli" (p. 356). This rhythm occurs in connection with cognitive activity such as selective attention, stimulus perception, and consciousness (Tiitinen et al., 1993). Therefore, 40 Hz activity during visual object perception seems to increase the efficiency of perceptual organization (Elliott & Muller, 1998), and Crick (1994) believed that 40 Hz bursts controlled visual mechanisms in the brain.

Brief 40 Hz activity also seems to be associated with the initiation of movement (Niedermeyer, 1999), and Pfurtscheller and Neuper, 1992) discovered rhythmic 40 Hz activity over C3 associated with beginning voluntary movements of the right finger. Activation of this gamma rhythm will not occur with meaningless words, but does occur in response to meaningful stimuli (Lutzenberger et al., 1994). Pantev (et al., 1991) believed that auditory (or other sensory modality) perception induced gamma might function to synchronize and bind different regions of the auditory cortex together so as to combine different auditory features into a single auditory perception. Krause (et al., 1998) found that gamma frequencies were elicited by meaningful auditory stimuli (e.g., words), even when they were not attended to.

Rather than this rhythm carrying information itself, it has been suggested that it provides a temporal structure, correlating neurons that encode information (Gray et al., 1989; Engel et al., 1991a, 1991b; Engel et al., 1992; Krause et al., 1998). Giannitrapani (1966, 1969) found that increases in the range of 35-45 Hz occurred immediately prior to answering in tasks such as multiplication questions, in moderate to high IQ subjects, and 40 Hz activity seems to synchronize and coordinate neurons that process incoming sensory stimuli. Forty Hz activity has also been found in problem solving in children (Sheer, 1974) and adults (DeFrance & Sheer, 1988), but a deficit has been found in 40 Hz activity in children with learning disabilities (Sheer, 1976). Recently, Miltner (et al., 1999) found that increased fast activity is involved in associative learning. In addition, gamma-band coherence increases between areas of the brain that receive the two classes of stimuli involved in an associative-learning procedure. They found that "not only did gamma-band [37-43 Hz] abundance increase in regions of the brain that received the two classes of stimuli involved in the training procedure, but gamma-band coherence also increased between them. Coherence or in-phase synchronicity is, in conceptual terms, the simplest and most straightforward process that could provide the basis for the formation of hebbian cell assemblies" p. 435). Thus, in-phase synchrony in the 40 Hz band literally seems to bind together parts of the brain that must communicate with each other for associative learning to take place.

After reviewing some of the 40 Hz research, De Pascalis (1999) has similarly stated: "Common to these studies is the view that 40-Hz EEG activity serves as an operator on attentional sensory and motor functions to allow single elements in the central nervous system to be linked or bound into functional states that represent and integrate external stimuli and motor sets into a unified whole" (p. 120). De Pascalis (1999) reviewed studies showing 40 Hz activity associated with hypnotic response and conceptualized it as focused arousal, much like Sheer's (1970, 1976, 1984) perception, and that of others (Makeig & Inlow, 1993; Steriade et al., 1990; Tiitinen et al., 1993). This rhythm has been found to occur at high amplitude levels in the occipital area in highly trained yogis while in the samadhi, the final, intense state of concentration in one form of meditation (Das & Gastaut, 1955). In the third deep stage of transcendental meditation, Banquet (1973) also observed 40 Hz activity in left occipital and frontal sites.

Sams (1995) has hypothesized this as the brain's "operating system frequency." This faster, 40 Hz activity clearly seems capable of being dissociated from slower frequency beta activity and of being enhanced through neurofeedback and conditioning, which has been demonstrated in cats (Amzica et al., 1997) and in humans (Bird et al., 1978; Ford et al., 1980; Sheer, 1977, 1984). Amzica (et al., 1997) noted in cats that instrumentally conditioning these oscillations resulted in a widespread increase in synchrony, diffusely activating different levels of the thalamocortical network. Furthermore, this instrumental conditioning generalized; that is, it not only occurred during a behavioral task, but the increased synchrony was present at other times, such as quiet waking, and NREM and REM sleep. They also found that a three-session extinction period could eliminate the increase in gamma oscillations, returning them to initial levels.

Gamma level activity has also shown to be capable of being induced by photic and visual stimulation (Basar-Eroglu et al., 1996; Elliott & Muller, 1998; Lutzenberger et al., 1995; Tallon-Buadry et al., 1995; Tallon et al., 1996), auditory stimuli (Basar et al., 1987; Jokeit & Makeig, 1994; Makela & Hari, 1987; Tiitinen et al.,1993), and motor behavior (Pfurtscheller, Flotzinger, & Neuper, 1994; Pfurtscheller & Neuper, 1992; Pfurtscheller, Neuper, & Kalcher, 1993). However, it is also possible that there may be too much of a good thing. Baldeweg (et al., 1998) reported a case of psychotic somatic hallucinations which were associated with a mean frequency of 38 Hz that occurred most frequently during the most intense symptoms. The 40 Hz rhythm was most prominent over the right central and temporoparietal areas. This author has also noted in clinical practice that as little as 3 full sessions of 40 Hz neurofeedback training can produce a somewhat overstimulated, overalertness, with difficulty sleeping.

Gamma band is an infrequently used term, but most commonly refers to frequencies from 30 Hz upward, and sometimes used synonymously with 40 Hz activity.

Generalized means EEG activity that is occurring throughout all regions of the head.

Gibbs artifact is introduced by discontinuities in the filtering and processing of transients that have high amplitude and "ring" a system.

Glossokinetic artifact usually resembles delta activity, but is an artifact caused by tongue movement. This occurs because the tongue is an electrical dipole, with the tip being negative in relation to its base. Tongue movements (like eye movements) result in potential changes, which are seen most prominently in frontotemporal channels.

High Pass Filter is one that restricts low frequency activity and allows the high frequency activity to pass through unattenuated..

Homologous refers to a corresponding structure or electrode site in the other hemisphere.

Hypsarrthythmia is generalized, continuous slow activity that have an amplitude higher than 300 µV, with spikes or sharp waves in multiple regions over both hemispheres. It is an epileptogenic pattern.

Hyperventilation is used as an activation procedure by electroencephalographers, to see if it elicits abnormal EEG activity. It decreases cerebral blood flow, slowing the EEG. It's abnormal if you get focal slowing or epileptiform activity.

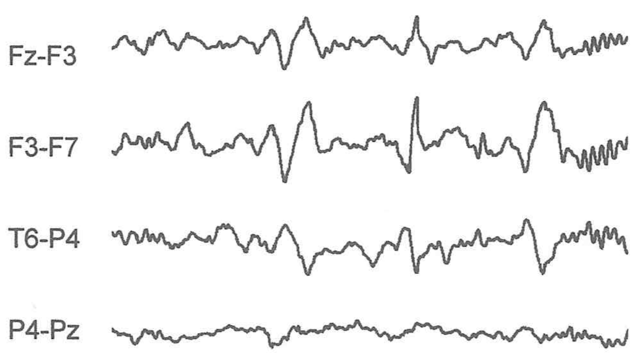
Impedance refers to the resistance to electrical current between the scalp and the preamplifier. Impedances should be less than 5 Kohms.

Inion refers to the prominent center part of the ridge on the occipital bone on the back of the head.

Interictal spikes refers to epileptiform discharges occurring between epileptic seizures.

Ipsilateral refers to on the same side. An ipsilateral ear reference would mean placing an electrode on the ear in the same hemisphere as the other electrode(s).

K complex is a burst of usually high voltage slow activity *associated with a sleep spindle*. The amplitude is typically maximal near the vertex. They occur during sleep, often in reaction to sound in the background. It represents the brain alerting without waking into arousal. It usually occurs in stage 2 sleep. An example is below, followed by spindles.



Lambda waves are usually, though not always, small amplitude (under 20 µV) waves associated with visualizing something or visual scanning (saccadic eye movements). When the eyes are closed, these waves are referred to as lambdoidal. is a sharp transient that is seen over occipital areas during reading tasks, visual scanning, or visualizing, and it is time-locked to saccadic eye movements. It is also seen during 1-6 Hz photic stimulation and basically represents a visual evoked potential. Lambda waves will usually appear in the theta band on topometric maps, although they can drop into delta range frequencies, but can only be distinguished by their wave form. They are usually bi- or tri-phasic, with a triangular or sawtooth shape, are most frequent between ages 3-12, and one cannot elicit them in darkness. Lambda waves are most reliably seen at electrode sites O1 and O2, although they have some spread.

Laplacian Montage is a montage for localizing where EEG activity is coming from. A limitation of this type of montage is that they false-localize to the edge of a regional finding (e.g., the midline for a hemispheric phenomenon) and they display diffuse phenomenon poorly.

Lateralized is an EEG term that refers to activity that is mainly on the left or right side of the head.

LORETA refers to low resolution electromagnetic tomography. Sometimes we perform this extra analysis when we do qEEGs. It provides an estimation of the localization of underlying generators of the patient's activity within any specified frequency band. From scalp-recorded electrical potential distribution, LORETA computes the three-dimensional intracerebral distributions of current density for specified EEG frequency bands. In research simulations comparing five source localization techniques using linear solutions for the EEG inverse problem, only LORETA has reliably localized sources in three-dimensional space. The physiological validity of the algorithm has been demonstrated in studies investigating basic visual and auditory processes, epileptic discharges, and cognitive tasks tapping specific brain regions as assessed independently in functional hemodynamic imaging studies. In a recent study cross-modality validation was provided by showing that LORETA generators of ictal discharge were remarkably close to the locations of MRI-identified epileptic foci (Worrell et al., 2000). It has also been received cross-modal validity with functional MRI results (Seeck et al.,1998) as well as with electrocorticography from subdural electrodes (Seeck et al., 1998). The LORETA utilizes a head model registered to the Talairach brain atlas (Talairach & Tournoux, 1988).. Computations are restricted to cortical gray matter and the hippocampus by using the digitized Talairach and probability atlases of the Brain Imaging Centre, Montreal Neurologic Institute. The solution space contains 2,394 voxels with a spatial resolution of 7 mm. For analyses in the frequency domain, at each voxel, LORETA values represent the power (i.e., squared magnitude) of the computed intracerebral current density (unit: amperes per square meter).

Low Pass Filter is one that attenuates high activity and allows the low frequency activity to pass or move through the circuit..

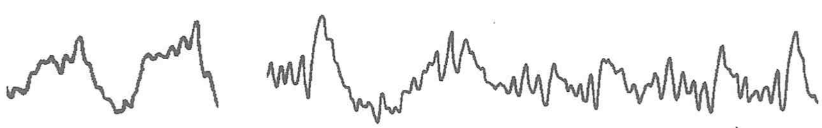
Low voltage EEG refers to a waking amplitude of 20μV, or more commonly 10μV or less, throughout the head. This EEG may be further distinguished as low voltage fast activity or low voltage slow activity. Low voltage fast activity can occur in about 11% of normal and may display an increased alpha rhythm following hyperventilation. Low voltage slow activity must be differentiated from stage one sleep or drowsiness. Low voltage slow activity should be evaluated by a physician as it may be associated with metabolic or toxic disturbances, or a diffuse encephalopathy from an infection, hypoxia, or hypothyroiditis. Low voltage fast is a normal variant, but may be associated with anxiety and hypervigilance.

Maturational Lag refers to an estimate of whether or not a person is slow in developing. In the Nx Link QEEG database it is used if the patient is under age 16 and the estimates are an expression of the time, in years, that this particular profile lags behind the reference group profile for persons this age (suggesting that it corresponds with a person of a younger age). Functional deviations occur when the observed Z-score values lie beyond the normal limits for individuals of *any* age, not just the patient's age.

Mean Frequency is the frequency of the EEG above and below which half the power lies, calculated within each frequency band and for total power (when a qEEG is done). Thus, if we see that mean frequency is high for theta and low for alpha (and total power of alpha is decreased), it suggests that a slowing of alpha is appearing in the theta band. If there is decreased mean frequency for alpha everywhere, and there is an alpha excess, it suggests that the excess may reflect an increase of frequency in generators responsible for theta. If the mean frequency is moderately increased for alpha and beta, it suggests that there is a shift of alpha into the beta range because excess beta is speeding everything up.

Mismatch Negativity refers to an evoked potential occurring in response to a mismatched tone. Unlike the P-300, it occurs even if one is not paying attention.

Mittens resemble a mitten with the short thumb of the mitten formed by the wave of a spindle waveform, and followed by wider slow waves. They have a fast and slow wave component and occur over frontocentral areas, and they are bilateral and synchronous. Do not mistake them for spike and wave discharges. Some have suggested that when the "thumb" is 1/8 to1/9th of a second, it may be associated with Parkinson's, when it is 1/10th to 1/12th of a second, with psychosis, and when it is slower (1/6th to 1/7th of a second) it ay involve thalamic problems. However, it is a *controversial pattern* not often mentioned. Here are two examples of how mittens look:



Monophasic wave is an EEG wave that only occurs on one side of the baseline.

Monopolar refers to a single electrode compared with a reference (e.g., on the ear lobe). The more up-to-date term is referential. In point of fact, all recordings are bipolar because they represent the difference between the active site and the "reference" site.

Montage means a pattern of linking electrodes together to generate a display of the EEG channels in particular ways. Different montages provide different windows for viewing the EEG activity. Common montages include bipolar (sequential), referential, longitudinal, transverse, and Laplacian.

Morphology refers to the study of the EEG wave forms.

MTBI Probability Index is a discriminant function in Robert Thatcher's NeuroGuide qEEG program that is particularly used in cases of a head injury within the past year. Twenty different EEG variables are selected from the total number analyzed and a discriminant score is computed based on the studies of Thatcher et al. (*Electroencephalography and Clinical Neurophysiology*, *13*, 93-106, 1989). The MTBI discriminant is a type of "pattern recognition" program that searches the patient's EEG for a pattern that is commonly present in people who have suffered a traumatic brain injury. Based on cross-validation studies of over 600 mild TBI patients, a probability of membership in the TBI population is provided in this analysis.

MTBI Severity Index is a qEEG index that is only computed when a statistically significant MTBI discriminant function is detected in the NeuroGuide database. Thirteen different EEG variables are selected from the total number analyzed and then a discriminant score is computed based on the studies of Thatcher et al. (*Journal of Neuropsychiatry and Clinical Neuroscience*, *13*(1), 77-87, 2001). She SI uses similar EEG variables to the MTBI, but it focuses specifically on the "severity" of traumatic brain injury as defined by length of coma, Glasgow Coma Score, and post traumatic amnesia in a study of 102 TBI patients. The SI score varies from 0 to 10 with zero representing low severity and 10 representing severe TBI. The SI was cross-validated in over 503 TBI patients as well as in its correlation with neuropsychological test performance.

Mu Rhythm has an arch, wicket or comb-shaped wave morphology, a frequency in the mid-alpha range, centering on 10 Hz (although it may range from 7-12 Hz, and is often about 1 Hz faster than the posterior peak alpha frequency), and it most commonly occurs in brief bursts of .5-2 seconds. Niedermeyer (1999) cautions that when mu only occurs unilaterally that it may mean "the possibility of an ipsilateral Rolandic disturbance as, for instance, an early stage of parasagittal meningioma, an arteriovenous malformation, or other types of neoplasm" (p. 157) or a skull defect (e.g., burr hole). Just as alpha is considered as an idling rhythm, so mu has been conceptualized as the idling rhythm of the sensorimotor area. Thus, it is particularly seen at electrode sites C3 and C4 (and sometimes Cz), and has often been referred to as rolandic or central mu. The mu rhythm blocks with body movement (or the intention to move) the contralateral limb or with gentle touch, and has thus been described as a "rhythm of immobility" by Niedermeyer (1999). Mu can be distinguished from alpha by its responsiveness to moving a finger, its location over the central region, and by the fact that it does not block with eye opening. Curiously, intermittent photic stimulation enhances Mu (Brechet & Lecasble, 1965). Although prevalence estimates have varied from 2.8% to 16%, they have been revealed in 50-100% of subjects when frequency analysis has been used (Pfurtscheller & Aranibar, 1979; Schoppenhorst et al., 1977, 1980; Storm van Leeuwen et al., 1978), and have been found in 100% of patients when recording has been done with subdural electrodes (Arroyo et al., 1993). Thus, it is now regarded as a normal cortical rhythm. It appears that it originates from both the sensory and the motor cortex (Arroyo et al., 1993). When it is blocked, there is a decrease in overall power density and a relative increase in power at higher frequencies. When mu is absent on one side (while present on the other), there may be an abnormality on the side where it is absent (Duffy et al., 1989). Here is an example of what mu looks like:

N-400 is an evoked potential that occurs in response to semantic incongruity. For instance, instead of saying, "This morning, I ate, my breakfast," it would be evoked by saying, "This morning, I ate, my computer."

Nasion is the area right at the top of the nose, just below the eyebrows.

Notch Filter is one that attenuates a narrow band around 60 Hz (50 Hz in Europe) to reduce electrical interference.

Ohm's Law states that the electrical current (amp) is directly proportional to the voltage (volts) and inversely proportion to the resistance (ohms) in a conductor.

ORIDA: Occipital intermittent rhythmic delta activity, which is2-3 Hz occipital waves in one or both hemispheres, that occurs intermittently and is rhythmic in nature. It is often blocked or attenuated by eye opening. An example is below:

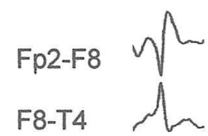
P-300 is an evoked potential that occurs in response to rare or infrequent but meaningful stimuli (such as a low tone that periodically occurs among high tones, when the subject has been told to listen for low tones). It measures how much attention one is paying to a stimulus, and is associated with short term memory and working memory.. The P-300 latency increases with age and is related to the stimulus complexity. The P-300 amplitude depends on the depth of processing and concentration–the bigger P-300 predicts that you will remember a stimulus better. It is largest at Pz, and second largest at Cz. P-300's are usually gathered with a linked ear reference and require one to be paying attention.

Paroxysm refers to an event that is distinguished from the background EEG activity by its abrupt onset, rapid achievement of its maximal amplitude, and which then abruptly ends. This term generally refers to epileptiform events.

Peak-to-Peak refers to a measurement that is made from the peak or point of maximal amplitude of a wave, to the next peak.

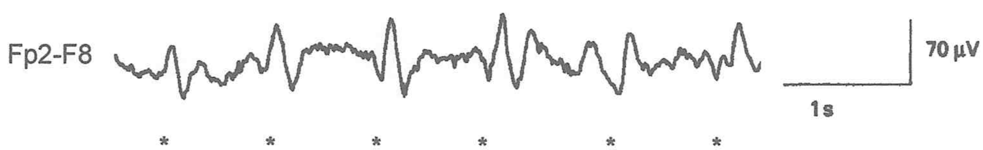
Phase refers to relationships between a point on an EEG wave and the identical point on he same wave recorded simultaneously at another electrode site. Phase represents covariation in time or conduction time. Does it arrive at the same point in time, lead, or lag? A high **phase lag** means there is time delay and conduction time and communication efficiency is delayed. Low phase lag means the speed of transmission is rapid and there is good efficiency and communication. Reduced coherence and/or increased phase delay is often related to reduced connectivity between two brain regions and is often clinically correlated with white matter or axonal injury as well as gray matter dysfunction. Significant decreases in coherence are often correlated with increased phase delays. Because of the short, medium, and long distance fibers that interconnect regions of the cortex, normal cortical integration is characterized by a stable set of relationships (coherence) and conduction times (phase) among the EEG waveforms from each electrode site. Evidence for disturbed cortical integration is inferred from excessive or deficient differentiation among these cortical system boundaries. It is important to note that if EEG recordings contain small EMG artifacts, there will be a reliable drop in coherence because muscles are random generators and there will also be unreliable phase results.

Phase reversal refers to movements in the opposite direction that are caused by waves when seen in two different bipolar derivations. It indicates where the potential field is maximal at the electrodes common to the two bipolar chains, thus helping to localize abnormal EEG activity. Here is an example, localizing a spike at F8:



Photoparoxysmal response refers to epileptiform discharges elicited by photic stimulation. This can be sharp transients limited to the occipital area, that are time-locked to the photic driving frequency, which is normal. However, when this is more generalized and persists after the end of photic stimulation, it is potentially epileptogenic activity.

PLEDS stands for periodic lateralized epileptiform discharges. These have a sharp wave (or spike appearance), often occurring on and off at a frequency of roughly once a second. It has a unilateral (and often parietal or posterior) focus (although it can occur anywhere) and it usually occurs at a frequency of 1-2 Hz throughout the entire record. Because of its continuous (periodic or semiperiodic) appearance, it must be distinguished from EKG. The etiology is often cerebrovascular (e.g., emboli, cerebral infarct), a (metastatic) fast-growing tumor, or herpes encephalitis). Most adults will have alterations of consciousness, but children will not. The majority of these patients have seizures, in which case there may be fast rhythms between the periodic discharges (referred to as PLEDS PLUS). Here is how PLEDS may look:



Polymorphic form refers to brainwaves that have many shapes. **Polymorphic delta activity** is delta that is nearly continuous, nonreactive to external stimuli, and is usually associated with a white matter disturbance.

POSTS are positive occipital sharp transients of sleep. This is 4-5 Hz activity over the occipital area that is similar to lambda waves when someone is awake, but they have higher voltage and may last longer. They are predominantly seen in drowsiness or light sleep, and should not be mistaken for abnormal sharp waves. They must be recognized as drowsiness and edited out in QEEG artifacting.

Power or absolute power is a QEEG measure of amplitude. The greater the amplitude, the greater the power. Voltage is the primary index of the amplitude and power is magnitude squared (microvolts squared or picowatts). The power in each frequency band is equal to the square of the voltage measured within that band. The power spectrum tells you about the excitability of cells.

Ratios refers to one frequency band compared with another, for example, a theta/beta ratio. A higher number in a theta/beta ratio indicates that there is more theta with respect to beta.

Reference refers to a site, often considered to be "less active" in terms of EEG activity than scalp locations, which an active electrode or electrodes are compared. The ears, or linked ears, are often used, and sometimes a mastoid or linked mastoid reference is used. Even the tip of the nose has been used, but there is still some EEG activity in the tip of the nose or the ear lobes. The spatial distribution of the scalp EEG will depend on the reference that is used. There is no one ideal reference. This is the reason that in examining raw data and doing QEEGs we tend to use multiple montages or windows for examining the raw data. All references have their advantages and limitations. For instance, ear or linked ear references are not good in identifying temporal lobe problems because of their closeness to the temporal lobes, but tend to show drowsiness the best and give less EKG artifact.. A Cz reference may assist in examining temporal lobe activity, but can be problematic if the patient is drowsy. An average reference is good for identifying a localized problem, but not helpful with global problems, and if there are under 32 electrodes it can be problematic if there is significant artifact present on several channels.

Referential Training is neurofeedback training where one active electrode is placed on the scalp, while the other electrode serves as a reference and is placed on the earlobe.

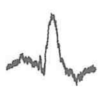
Reinforcement Threshold typically refers to a microvolt level below which, and/or above which the EEG must be within a bandpass in order to hear a reinforcement tone.

Relative Power represents one frequency band compared to all bands, including itself. Thus it represents a percentage of total power. **Monopolar Relative Power** refers to the percentage of total power found in each frequency band at each individual electrode site. **Bipolar Relative Power** is the gradient of relative power that exists between two electrodes.

Relative & Absolute Power Ratios are qEEG measures computed and compared with age matched norms for different ratios of the frequency bands. For example, theta/beta, alpha/beta, theta/alpha, delta/beta/ and delta/theta. The ratio measures assist in determining which frequencies to reinforce and which to inhibit in neurofeedback.

Sampling Rate refers to the rate at which the EEG is being sampled per second (e.g., 128, 256, 512). The sample rate must be twice the minimum frequency you wish to sample.

Sharp Wave refers to a transient with a pointed peak and a duration of 70-200 milliseconds (a fifth of a second or less). It is clearly distinguishable from background activity. The distinction between sharp waves and spikes is for descriptive purposes and is largely arbitrary. Both sharp waves and spikes indicate epileptic potential. **Occipital sharp waves** tend to be associated with benign occipital epilepsy and visual-perceptual problems. **Parietal sharp waves** tend to be associated with sensory or versive seizures. **Prefrontal sharp waves** are associated with neurovegatative seizures. **Centrotemporal sharp waves** are associated with benign epilepsy of childhood. **Frontal sharp waves** are associated with Jacksonian or versive seizures or repetitive movements. **Midline sharp waves** are associated with simple partial seizures. **Temporal sharp waves** in the posterior or mid-temporal region are associated with neurovegetative symptoms and seizures, and in the anterior temporal region with complex partial or generalized tonic-clonic seizures. An example of a sharp wave is seen below.



Sigma rhythm is an outdated term referring to sleep spindles.

Sinusoidal refers to a wave that has the form of a sine curve.

Six Hz spike-and-slow-waves refers to spike-and-slow-wave complexes that occur in the theta band, but particularly at 6 Hz that occur usually in brief, synchronous, bilateral bursts. They are of high amplitude, but are generally lower in amplitude than spike-and-slow-wave complexes.

Sleep spindles refers to bursts of rhythmic activity in the range of 11-15 Hz (usually at14 Hz in adults) that progressively increase and then decrease in amplitude, and generally occur for 4 seconds or less (most commonly for half a second to 1.5 seconds). They may occur at intervals of between 5 and 15 seconds. They may occur diffusely, but tend to have higher amplitude over central areas. They are a good indicator that the subject is drowsy and has slipped into the early stage of sleep. **Extreme spindles** are more exaggerated, generally have a duration of over 10 seconds, have high amplitude and possibly a slower frequency, and may be associated with mental retardation (or with benzodiazepine or barbiturate use). An example of beta spindles is seen below under the heading of spindles.

Slow activity has been subdivided by Luders and Noachtar (2000) into 1) background slow, 2) intermittent slow, and 3) continuous slow activity. **Background slow activity** refers to a slow background rhythm of less than 8 Hz for someone over age 8, less than 7 Hz for a 5 year old, less than 6 Hz for a 4 year old, and less than 5 Hz for a one year old. This is a nonspecific finding that may relate to cortical or even subcortical dysfunction. **Intermittent slow activity** us bit constant, but you must rule out drowsiness. It can be generalized, regional, or lateralized. The background rhythm is generally not well preserved. Intermittent slow activity suggests diffuse cortical dysfunction or possibly epilepsy. This may be FIRDA or ORIDA. When it is consistently and clearly asymmetrical, it could indicate a supratentorial lesion on the side with the highest amplitude. **Continuous slow activity** is continuous and nonresponsive to external stimuli. It is usually irregular (polymorphic) and in the delta or theta frequency range. Consider regional continuous slow activity to always be abnormal.

Slow alpha variant is a mostly posterior rhythm occurring usually at 4-5 Hz, and alternating or mixing with the alpha rhythm, of which it may be a sub-harmonic. Like alpha, it is generally blocked by eye opening or mental effort. Although the amplitude may vary, it is often of ab out 50 µV.

Slow cortical DC potentials (SCPs) are the positive or negative polarizations of the EEG in the very slow frequency range from .3 Hz to usually about 1.5 Hz. SCPs may be thought of as the the DC baseline that the AC EEG rides on. There is generally a negative shift in DC potentials that occurs during cognitive processing (to create excitatory effects) and positive SCPs occur during inhibition of cortical networks. During and prior to an epileptic convulsion, the cortex is electronegative, and this same kind of hyper-excitability tends to be seen before many migraines. After a seizure when the cortex is fatigued it tends to be electro-positive. Neurofeedback training has been done in this range, particularly in Europe with epilepsy, and is referred to as slow cortical potentials training.

SMR (the sensorimotor rhythm) is a rhythm between 12 and 20 Hz, peaking in the 12-14 Hz range, that occurs over the sensorimotor strip of the brain. It is suppressed by movement, and its presence reflects reduced motor excitability and quiescence. This rhythm is seen in animals during grooming, undirected quiescent behavior, movement suppression, and prior to sleep (Sterman, 1999)--in other words, during reduced somatosensory input--and it seems to be the equivalent in animals of the posterior alpha rhythm in humans. Sterman (2000) has stated that SMR reflects "motionlessness in the context of attention" (p. 48).. This rhythm is similar, both in location and frequency, to sleep spindles. Thus, when SMR is increased through neurofeedback, there is an accompanying increase in sleep spindle density and the person generally reports more stable, improved sleep with decreased awakenings (Sterman et al., 1970). SMR is generated in the thalamic relay nuclei of the somatosensory pathway, collectively known as the ventrobasal (VB) complex (Sterman, 2000).

Spike refers to a transient that is like a sharp pin at the peak and occurs for 70 milliseconds or less (a millisecond is 1,000th of a second. They are electro-negative. It is often about 10 ms at the peak and has a field (e.g., it appears on more than one channel). It is often negative in electrical potential. They indicate a potential for epileptic activity. Spikes are usually unilateral and after a spike there will often be a slow wave. Spikes do not occur at only one electrode, and will have a field, spreading to nearby electrodes. Although amplitude is variable, spikes are often over 100 µV. **Bilateral 3/sec spike-and wave-complexes** that last at least 3 seconds are associated with absence seizures ("petit mal") associated with staring, eyelid fluttering, mouth movements and automatisms (picking, throat clearing) and usually occurring in children 6-14 years old. **Biooccipital spike-and-wave complexes** are associated with partial and generalized seizures (and migraines). Irregular but repetitive spike and wavelike complexes in the presence of a depressed background rhythm are seen in anoxia. Maultsby (1971) proposed the following guidelines for assessing spikes and sharp waves: 1) "Every spiky-looking wave is an artifact unless there are one or more good reasons for suspecting otherwise." 2) Spikes and sharp waves of cerebral origin always occupy a definable electrical field on the scalp and should always be seen in two or more nearby electrode sites. If a questionable spike is seen in only one electrode, it should first be considered as an artifact." 3) "Clinically significant spikes and sharp waves are almost always surface negative in polarity initially, or at least the sharpest or highest voltage component of the wave is usually surface negative." 4) "Most spike or sharp wave discharges of clinical import are followed by a slow wave or series of slow deflections. If it does not have a slow after-wave, be more suspicious of artifact." 5) "If the wave in question has the same length as other waves of the ongoing rhythms and occurs at a time when one would normally expect the next normal background wave to appear (i.e., it 'fits in' temporally with the waves before and after), it should probably be ignored. Sharp alpha-like waves are common in the temporal leads [and are especially more prominent in the left temporal area] of adults, particularly during drowsiness." 6) I advise ignoring all such spiky looking waves when excessive fast activity is present unless they: a) have a fairly consistent location, b) are very much higher in voltage than other background activity, c) are followed by prominent slow transients, and d) the same general wave form is repeated over and over through much of the record." **Spike-and-wave complexes** refers to spikes and slow waves that occur repetitively, but do not fulfill criteria for more specific patterns such as 3 Hz spike-and-wave complexes or slow spike-and-wave complexes. **Slow spike-and-wave complexes** refers to these patterns that repetitively occur with a rate of less than 2.5 Hz. and is a very serious seizure pattern (e.g., often associated with chronic encephalopathy, Lennox-Gastaut Syndrome, and tonic seizures). **Polyspikes** are a group of three or more spikes, that may or may not be followed by a slow wave, and need to not be overlooked as being beta spindles.. This generally means epilepsy (e.g., generalized myoclonic or tonic seizures). An example of a polyspike is seen below.

Spike and slow wave refers to an epileptogenic pattern in which there is a spike followed by a slow wave. An example of a spike and wave is below.

Spindles refers to spindling beta, usually occurring during sleep at about 14 Hz in adults. When occurring otherwise, beta spindles are generally thought to reflect cortical excitability or irritability, or an easily kindled cortex. They may also be seen in a beta excess subtype of ADHD, which represents about 15% of ADHD. An example of beta spindles is seen below in the last half of the tracing below.

Status epilepticus means continuous seizure activity in an EEG.

Symmetry refers to being approximately equal in amplitude, frequency and form between homologous sites in the two different hemispheres, or approximately equal in distribution of waves.

Synchrony is the occurrence of waves simultaneously over regions of the head, without a delay in phase.

Ten-Twenty System is an internationally recommended system of standardized electrode placements in which measurements represent 10% and 20% of measurements from landmarks on the skull.

Theta band is generally defined as the frequency band from 3.5 to 7.5 or from 4 to 8 Hz.

Theta rhythm. While the alpha rhythm desynchronizes with brain activation, theta tends to synchronize with cognitive demands (Schacter, 1977). Theta seems to be involved with encoding and retrieving newly learned information (Klimesch et al., 1996, 1997), recognizing familiar stimuli (Burgess & Gruzelier, 1997) or novelty-related brain activity that may relate to updating internal models of the environment (Dietl et al., 1999), and learning (Holscher et al., 1997; Lang et al., 1987; Powell & Joseph, 1974), although Kahana (et al., 1999) found it occurred more frequently during memory than during learning trials. Winson and Abzug (1978) hypothesized that theta may serve as a "gate," directing the flow of information through the hippocampus Theta has also been found in both rodents and humans to be associated with spatial navigation, occurring for example, in navigating more complex mazes (Kahana et al., 1999; Skaggs et al., 1996). When hippocampal theta was reduced in power, this was found to be related to behavioral impairment in a spatial alternation learning task (Wan et al., 1995). Vinogradova (1995), in a comprehensive review of literature on theta, indicated that "the theta-rhythm can be regarded as a mechanism of selective attention, a prerequisite for memory trace formation" (p. 562), and that through focusing attention it assists the hippocampus with its special function as a comparator device, performing match-mismatch operations. Vinogradova's (1995) review arrived at the conclusion that theta serves a double gating function in information processing: it facilitates and prolongs the action of stimuli entering the hippocampus ("filtering in"), while at the same time it "filters out" or prevents the admission of interfering inputs while information is being registered and processed. "Thus, the theta-rhythm may be regarded as a mechanism of selective attention, a prerequisite for memory trace formation" (p. 574).

"Hedonic theta" refers to 4 Hz posterior-central activity which has been found to be associated with an infant being kissed by its mother (Maulsby, 1971) and with young children enjoying puppets, toys, and picture books (Kugler & Laub, 1971), but this pattern has not been noted in adults, including during sexual activity (Graber et al., 1985; Heath, 1972). Slower theta activity (4-6 Hz) can also be associated with drowsiness and stage 1 sleep, and the associated hypnogogic or hypnopompic images associated with this state. This tends to especially be seen in the central and parietal areas

Frontal Midline Theta Rhythm. A theta rhythm of approximately 6-7 Hz, centering on about 6.5 Hz, appears over both frontal regions and attains the highest amplitude at about Fz (or just slightly anterior and left of Fz). It usually has an amplitude of 30-60 µV during cognitive tasks. It is a normal rhythm that appears in mental performance tasks, during drowsiness and stage 1 sleep, and during REM sleep. It was first noted in the early 1950's. Magnetoencephalogram and simultaneous EEG evaluation has estimated two sources for Fm theta--the prefrontal-medial superficial cortex and the anterior cingulate cortex, with the hypothesis that the appearance of Fm theta reflects alternative activities of these two areas (Asada et al., 1999).

Schachter (1977) reviewed the literature on theta rhythm. On the basis of his review, he believed that there were two types of theta; one which was associated with drowsiness, and another which may involve a superimposed faster rhythm and which his review found was associated with intense concentration (e.g., doing continuous mental math) (Kurahashi et al., 1957)--findings since supported by others (Ishihara & Yoshii, 1972; Mizuki et al., 1980; Yamagushi, 1981; Nakashima et al., 1992, 1993). Ishihara and Yoshii (1973) noted that when frontal, eyes-closed theta appeared for three seconds or longer that subjects introspectively indicated that they were "thinking continuously on only one theme and the field of their attention was narrowed" (p. 701). A similar report of being in "a state of concentration" was found by Yamaguchi (et al., 1973). In relation to focused attention and vigilance, it is interesting that spectral analysis of the EEG of astronaut Frank Borman before and during the Gemini-7 flight documented a sharp increase in theta power and coherence over his usual baseline during the minutes just before launch, with theta power then decreasing during the flight, although remaining above baseline (Adey et al., 1967).

Whereas the alpha rhythm desynchronizes with brain activation, Schachter's (1977) review found that theta synchronizes with cognitive activity. Asada and Yamada (1999) documented that the appearance of FmTheta is a good index of continuous attention, and that a videogame requiring more lengthy, continuous attention such as Tetris, evoked more FmTheta than other videogames or addition tasks. Other studies have likewise demonstrated that this rhythm is evoked with more difficult and/or interesting mental tasks such as a videograme (Yamada et al., 1991, a computer game (Dodo & Kakigi, 1994; a tracing task (Mizuki et al., 1982, or counting cubes (Nakashima & Sato, 1992). An auditory evoked potential study (Mizuki, 1987) validated that the appearance of Fm theta is closely related to heightened vigilance and the maintenance of concentration. Laukka (et al., 1995) found that successful learning of a simulated driving task was associated with more Fm theta, which they believed was associated with "relaxed concentration." And, an experiment by Suetsugi (et al., 2000) indicated that its appearance may be closely related to an improvement of anxiety symptoms among patients with generalized anxiety disorder.

Mizuki et al. (1984, 1989) documented that the frequency of appearance of Fm theta increased with habituation and anxiolytic medication, and that when state anxiety was eliminated, this was directly correlated with Fm theta appearing. Dietl (Dietl et al., 1999) suggested "that the frontal theta response is part of the brain electric processes accompanying 'passive' involuntary attention switching caused by obtrusive sensory events and orienting" (p. 1208). Fm theta has also been found to increase in response to EEG neurofeedback (Sams, 1995; Yamaguchi & Niwa, 1974).

Csikszentmihalyi (1991) has talked of the "flow" experience that is associated with peak performance in athletics, mental or leisure activities. He found that in order to evoke "flow," the task needed to strongly capture attention so that the individual became immersed and absorbed in the task, achieving a sense of union and oneness with the activity. The activity could not be too difficult, but, on the other hand, it had to be interesting and challenging enough to strongly capture and hold attention. Similarly, Jackson has discussed the concept of the zone of optimal performance in which the person was adequately challenged and aroused by a task, but not overaroused. Along these same lines, Asada and Yamada (1999) discovered that "when the task contains too much information or it is too easy or too difficult, subjects are liable to think of things unrelated to the task, to lose fixed contact with the task and Fmθ appears little" (p. 174).

This appears to be a healthy rhythm and various studies (Mizuki et al., 1976, 1989; Nishijima, 1982; Niwa, et al., 1975; Takahashi, et al., 1995, 1997) have found that frontal midline theta appears to be associated with being less anxious, less neurotic, more extroverted, and more active. Individuals with good Fm theta scored the most positive on these characteristics, while those with limited Fm theta scored significantly less positively, and those without Fm theta scored the most negative on measures of these characteristics. The results from one study indicated that a placebo increased the amount of Fm theta and freedom from anxiety seemed to allow the appearance of the rhythm.

FM theta may well be the same rhythm (5.5-7.5 Hz) that has been found to distinguish highly hypnotizable individuals from low hypnotizable persons, both in a waking, non-hypnotic state, and while being hypnotized. This is of particular interest since hypnosis has been defined as a state of concentration and intently focused attention or absorption (Hammond, 1990, 1998a). Further correlational evidence that Fm theta may be what occurs in high hypnotizability is the fact that the incidence of Fm theta peaks between 8-11 years of age (present in 68.8%) (Yamaguchi, 1994)--an age corresponding with the peak of hypnotizability (Hammond, 1998b). Highly hypnotizable individuals have the capacity to block the perception of pain as or even more effectively than morphine (Stern et al., 1977). This is interesting since recently, Russ (et al., 1999) found that in borderline personality disorder patients who engaged in self-cutting, those who experienced no pain during self-injury and who reported less pain in a laboratory pain procedure were found to have significantly higher total absolute theta power compared with depressed (P = .0074) and normal (P = .0001) groups, and they had higher scores on the Dissociative Experiences scale (P = .0004). Theta activity was significantly correlated with pain ratings ® =-.43, P = .0001) and DES scores r = .32, P = .01). Takahashi (et al., 1997) believe that the theta found in light drowsiness (usually found in persons who also have Fm theta) represents a kind of inhibitory mechanism that is an indicator of stages of consciousness.

Takahashi (et al., 1997) discovered that Fm theta is much more likely to occur in waking EEG's of individuals who also produce it during light drowsiness. Shinomiya et al. (1994) found Fm theta in 6.2% of healthy subjects, but in only 1.4% of hospital patients. Fascinatingly, with echoes of Schachter's (1977) speculations, their research differentiated two types of theta. One type had a duration of less than 5 seconds, and it spread from the frontal midline (Fz) to the frontal area bilaterally. It was mainly distributed in the anterior. This type was associated with a higher mean frequency (6.63 Hz, DS = 0.50), low voltage (54 μV, SD = 16.22) and a regular waveform. It occurred in short, 2-3 second bursts, and only during light drowsiness or relaxation. The second type had a lower mean frequency (6.06 Hz, SD = 0.71), higher voltage (74 μV, SD = 12.86), and often had a notch-shaped, irregular wave form. It often appeared during wakefulness, was reinforced by drowsiness, blocked to eye opening, and was distributed more posteriorly. EEG and MEG data suggest a distribution of Fm theta bilaterally in the frontal cortex, maximal at midline electrodes (Sasaki et al., 1996).

This differentiation seems to correspond with the recently popularized conceptualization of "good theta" and "bad theta." Type 1 theta was almost always found by Shinomiya's group in only healthy subjects with normal CT scans, while type 2 theta was usually found in found in the hospital patient group, and, while not necessarily an epileptogenic pattern, it was associated three-fourths of the time with persons having epilepsy and occasionally with headaches. In this sense, the type 2 theta of Shinomiya (et al., 1994) seems similar to Ciganek's (1961) midline theta, which had a mean frequency of 5.75 and was found in 36% of temporal lobe epilepsy patients. Gibbs and Gibbs (1950), Westmoreland and Klass (1986), Okada and Urakami (1993), and Palmer (1976) likewise described a midline or central theta rhythm that had some association with epileptic activity. Thus, Takahashi et al. (1997) expressed the opinion that "when the frontal midline theta rhythm is recorded during light drowsiness, it is important not only to evaluate the clinical symptoms and results of brain CT scans or magnetic resonance imaging (MRI), but also to differentiate this rhythm from the Fm theta, before diagnosing it as a paroxysmal finding" (p. 54).

Three Hz spike and slow waves is a repetitive paroxysm that consists of 3-3.5 Hz, bilaterally synchronous activity, that is usually of maximal amplitude frontally.

Topography refers to the distribution of EEG amplitude on the head.

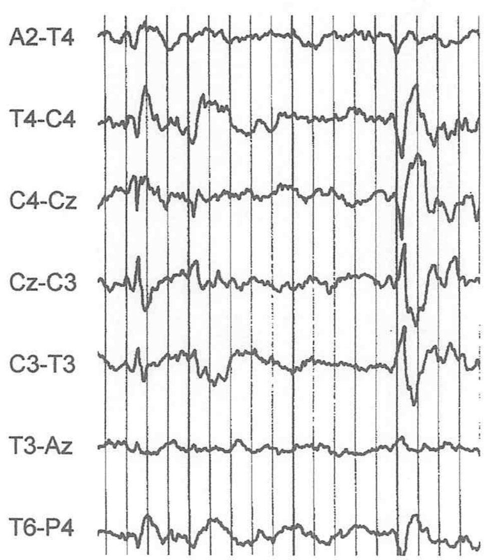
Transient is a term used to describe an isolated wave or pattern that is distinguished from the background rhythm.

Triphasic waves refers to a wave with three components that alternate from the baseline. It may be associated with metabolic diffuse encephalopathies (e.g., liver disorders or uremia), and is more often seen in sleep or semi-coma. They generally have high amplitude (over 70μV), and are a positive sharp transient, preceded or followed by low amplitude negative waves, and usually with a frequency of 1-2 Hz. It is sometimes called a "blunt spike-and-wave," which is a good descriptor. Some examples are below.

Unilateral means occurring on one side of the head.

Unipolar montage is a dated term that refers to a referential montage.

Vertex sharp wave, also referred to as a V wave, is a vertex sharp wave that is maximal in amplitude at the vertex, and that occurs during sleep or as a response to a sensory stimulus in sleep. In children they may have a sharp or spiky appearance and maybe of high voltage, and thus can be mistaken for epileptiform activity. On the next page below are 2 V waves in a child.



Volume conduction refers to the spread of EEG wave patterns across the skull and scalp from their point of origin.

Recommended Reading

Introductory Reading

American Society of Electroneurodiagnostic Technologists (Ed.). (1996). EEG Patterns & Normal Variants. Carroll, IA: ASET.

Fisch, B. J. (1999). Fisch & Spehlmann's EEG Primer: Basic Principles of Digital and Analog EEG. New York: Elsevier.

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A Little More Advanced Reading

American Society of Electroneurodiagnostic Technologists (Ed.). (1995). EEG Montages & Polarity. Carroll, IA: ASET

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