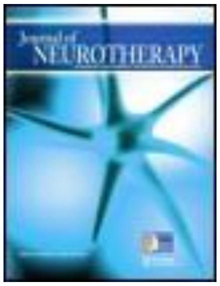

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Clinical Corner

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CLINICAL CORNER

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The purpose of the Clinical Corner is to provide responses to clinically oriented questions that may not, in many cases, have been evaluated yet by research. Therefore, the personal opinions expressed in the column are exactly that, the opinions of the individual authors, often based on their clinical experience. The opinions shared belong to the authors and are not necessarily those of the Society for Neuronal Regulation (SNR) or the Journal of Neurotherapy. Nonetheless, it is hoped that the diversity of opinion expressed in this column will stimulate thought and the further exchange of ideas.

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In this Clinical Corner, we respond to the question, "Can someone review information about the alpha frequency band and rhythm?"

THE ALPHA RHYTHM IN EEG

Alpha is a waking rhythm occurring from 8 to 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 sharper versus rounded in a few people, especially children and young adults. Current

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belief (Niedermeyer, 1999a; Steriade, Gloor, Llinas, Lopes da Silva, & Musulam, 1990) is that cortico-cortico and thalamo-cortical generators of alpha 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 three frequency bands: alpha 1 (8 to 8.9), alpha 2 (9 to 10.9), and alpha 3 (11 to 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 to 7.9 Hz band of theta, the distribution over the scalp was like the 4 to 6.9 Hz frequency band–with no significant difference between anterior and posterior head regions. Slow alpha (7.4 to 8.9 Hz) has also been found to be rather independent of state variables such as drowsiness (or being in REM sleep), while fast alpha (11.3 to 12.8 Hz) was found to be associated primarily with a waking (eyes closed) state and not with drowsiness (Cantero, Atienza, Gomez, & Salas, 1999).

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 decrease in amplitude or disappear in the occipital area with drowsiness and alpha distribution becomes more centrofrontal and temporal (Santamaria & Chiappa, 1987). The more anterior (e.g., frontopolar) alpha that begins to appear is in the range of 7 to 8 Hz, and rather than emanating from a posterior source, it has a dipole deep in the central, anterosuperior part of the brain (Hasan & Broughton, 1994), and is correlated with a slow eye movement pattern (Kojima et al., 1981). The temporal alpha of drowsiness is seen in only about 10 percent of normal adults and tends to be 1 to 2 Hz slower than posterior alpha (Santamaria & Chiappa, 1987). Niedermeyer (1999a) has noted that in some individuals, posterior alpha can be faster than 13 Hz, but that this 14 to 15 Hz rhythm will block to eye opening, and it is only found in about 3.6 percent of the population (Brazier & Finesinger, 1944).

The alpha rhythm is now considered (Pfurtscheller & Klimesch, 1991; Klimesch, Pfurtscheller, & Schimke, 1992; Sterman, Kaiser, & Veigel, 1996; Sterman, 1999) to be made up of two separate functional components. There is a low alpha band (8 to 10 Hz) associated with general or global attention and a high alpha band (10 to 13 Hz) reflecting directed or task specific attention. Both Sterman et al. (1996) and Klimesch, Schimke, and Pfurtscheller (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, Knebel, Vendemia, Kaplan, and Ratcliff (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, Doppelmayr, Pachinger, & Ripper, 1997a; Klimesch, Doppelmayr, Pachinger, & Russegger, 1997b; Klimesch, Schimke, & Schwaiger, 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 (such as we use in qEEG data recording), small theta power and large alpha power (especially in the upper alpha band) predict good cognitive and memory performance, while the opposite is the case under task. I believe that this is vitally important for clinicians to understand who are gathering qEEG data under task conditions. 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)

Molle, Marshall, Fehm, and Born (2002) recently confirmed and extended the Klimesch group's research. They found that efficient learning was accompanied by 10 to 12 Hz desynchronization and 4 to 8 Hz synchronization compared with poor recall performance. A combined measure of theta synchronization plus high alpha desynchronization was enhanced in the left frontotemporal area during efficient learning of words and over the right parietal area during efficient learning of faces. Thus, these two oscillatory processes contribute to learning in a complementary way. We should note, however, that all of this research is based on adults and more research with children is needed in this area. The one study (Krause, Salminen, Sillanmaki, & Holopainen, 2001) concerning these issues with children did find parallel occurrences in the high alpha range, but their 4 to 6 Hz event related synchronization responses were of lesser amplitude and of delayed latency compared with adults. Their 6 to 8 Hz and 8 to 10 Hz responses were also of lower magnitude than with adults. I strongly recommend that the serious clinician read Klimesch (1999). The implications from the findings of this research group are that neurofeedback clinicians should be particularly focusing on inhibiting alpha when we are training during a cognitive task such as reading, playing tetris, or doing math.

With regard to alpha desynchronization being associated with cognitive activity, it is fascinating that this seems to occur even during sleep. For example, alpha power decreases in the occipital area during REM sleep (Cantero et al., 1999; Gomez, Vazquez, Vaquero, Lopen-Mendoza, & Cardoso, 1998) as well as during mental imagery in a waking state (Roland & Friberg, 1985), and over Broca's and Werniche's areas in REM sleep when the dreams are essentially verbal (Hong et al., 1996).

Amplitude

The greatest amplitude of alpha is usually found in the occipital area and is generally below 50 microvolts (μV). Amplitudes of 20 to 60 μV have been found in 66 percent of people, while amplitudes below 20 μV are found in 28 percent, and above 60 μV in 6 percent (Simonova, Foth, & Stein, 1967). Higher amplitudes are usually found in children (50 to 60 μV) and 9 percent of children (ages 1 to 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 to 9 percent 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 we say that it is 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. Decreased alpha blocking after eye opening is consistently found in Alzheimer's dementia (Pritchard et al., 1994; Signorino, Pucci, Belaardinelli, Nolfe, & Angeleri, 1995). For this author, when I do not see reduced alpha (blocking) with eye opening, I anticipate that EEG abnormalities may become even more apparent in data gathered under eyes open and task conditions. Thus, for me, reduced alpha blocking is a particular indication for including an eyes-open condition and a task condition in a qEEG. Large resting alpha power has been found to enhance desynchronization, while small eyes closed alpha power attenuates desynchronization (Doppelmayr, Klimesch, Pachinger, & Ripper, 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), and thus, alpha rhythm may be considered a brain maturation index (John et al., 1980). When the mean alpha level is found to be below 9 Hz in adults 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). Wu and Liu (1995) only found one percent of healthy adults to have a dominant rhythm of 8 Hz. Above average mean alpha levels may suggest hypervigilance, problems with anxiety, perhaps high intelligence (Gasser, Von Lucadou-Muller, Veleger, & 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-to 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 to 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 to 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 to 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 one percent of people (Aird & Gastaut, 1959). Alpha frequency may also decrease in the elderly.

The mu rhythm occurs in the same frequency and amplitude range as the alpha rhythm, but its morphology is different. It has a comb or wicket appearance, occurs centrally (C3 and C4), and unlike alpha, it does not block with eye opening. Thus, on a QEEG when there appears to be excess central alpha activity, one must examine the actual raw EEG centrally and one Hz topographic maps for the appearance of an owl-eye looking appearance around the electrode sites of C3 and C4 that will occur in the mid-alpha frequency range.

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, Iyer, & Surwillo 1989). Likewise, an amplitude difference in alpha between the two sides of more than 50 percent 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 percent 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).

Maturation & Aging

Although alpha is considered the predominant idling rhythm in adults, theta is the predominant rhythm in children until ages 13 to 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 50s, 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 70s, while Hubbard, Sunde and Goldensohn (1976) found a mean alpha frequency of 8.6 in ten individuals between 100 and 105 years of age. Alpha frequency is lowered in dementia patients.

Neurofeedback Strategies with Alpha

After reviewing much of the research on alpha, let me now turn to clinical experience and possible implications of this research. Increasing alpha posteriorly has been documented in controlled research to reduce anxiety (Garrett & Silver, 1975; Moore, 2000). This is one of the few areas in which we have good neurofeedback research demonstrating that according to the psychology guidelines for efficacious treatments (Chambless et al., 1998; Chambless & Hollon, 1998), that alpha training appears to meet the criteria for a probably efficacious treatment. The popular and similar alpha/theta training of Peniston and Kulkosky (1991) has usually been done as single occipital site with the patient's eyes closed, and may be viewed as similar to high tech meditation training. Sequential (bipolar) training at T4-O2 to increase alpha while inhibiting beta from 20 Hz upward with eyes closed has also proven highly effective in my experience (M. Ayers, personal communication, July, 2000).

The Klimesch (1999) findings cited earlier in this article are intriguing with regard to neurofeedback training. Because his research found that in a resting state, small theta power and large alpha power (especially in the upper alpha band) predicted good mental performance, perhaps uptraining the 10.5 to 12.5 or 13 Hz band in an eyes-closed state might enhance cognitive performance. I find myself thinking about the work of Budzynski (1996) in increasing high alpha, and of the work of Fehmi (1978) in enhancing eyes-closed alpha synchrony. Although qEEG findings of frontal alpha may sometimes be artifactual (Hammond & Gunkelman, 2001) and indicative of drowsiness, clinical experience has shown that excessive frontal alpha sometimes can be somewhat resistant to being inhibited. In such cases, one clinical strategy that has seemed helpful at times has been to have several sessions of eyes-closed, alpha increase training at Pz. In relation to this and the work of Fehmi (1978), we should remember that Doppelmayr et al. (1998) found that large resting alpha power actually enhances desynchronization, while small eyes-closed alpha power attenuates desynchronization! May this be the reason why Frank Ramos (1998) in Honolulu has found increasing alpha to be helpful with ADD? Now, think about this in the opposite way. Suppose we have an OCD patient with excess beta along the frontal to central midline, who also has a generalized alpha excess which a weighted average or Laplacian map localizes along the midline. Since resting state (non-mental task) alpha power enhances desynchronization under task, may the presence of this excess resting alpha be increasing beta and the associated mental overactivity? If this might be the case, could a potential strategy to decrease the excess beta consist of simply inhibiting resting, eyes-closed alpha or high alpha while mildly reinforcing and encouraging theta over the midline area? I don't have the answers to these questions, but I believe we need to ponder together such interesting issues that are raised by this high quality research.

Klimesch's (1999) research, on the other hand, also found that during a cognitive task, a large increase in theta power (synchronization) and a significant decrease in alpha power (desynchronization) was associated with good performance–a finding similar to Sterman's (1999). Thus, we might also hypothesize that during training under a cognitive task such as reading or playing tetris (which requires intense attention), neurofeedback training may be most effective if we inhibit alpha rather than theta. It also raises the interesting speculation as to whether we could consider reinforcing theta or high theta simultaneously with inhibiting alpha when training under task. Marvin Sams (1995) has advocated a limited amount of training to increase frontal midline high theta under task. The work of Giannitrapani (1985) also makes me wonder about the potential superiority of simultaneously reinforcing lower beta frequencies (e.g., 12 to 15) as opposed to higher frequencies (e.g., 16 to 20). Recent research by Egner and Gruzelier (2001) with normal individuals has raised the possibility that lower beta training is particularly more desirable in facilitating impulse control compared with 15 to 18 Hz training. Although many of these training implications from scholarly EEG research are speculative and currently without supportive research, perhaps they will stimulate clinical innovation and future research.

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