EEG coherence effects of audio-visual stimulation (AVS)

Thursday, 04 December 2008

EEG coherence effects of audio-visual stimulation (AVS) at dominant and twice dominant alpha frequency

Jon A. Frederick, Ph.D.* DeAnna L. Timmermann, Ph.D.** Harold L. Russell, Ph.D.*** Joel F. Lubar, Ph.D.****

Journal of Neurotherapy, In Press

*Corresponding author. Center for Computational Biomedicine, University of Texas Houston Health Science Center, 7000 Fannin Suite 600, Houston, TX 77030. (713) 500-3464, email: smiile@psynet.net **Department of Psychology, Eastern Oregon University, One University Avenue, LaGrande, OR 97850. ***P.O. Box 240, Galveston, TX, 77553. ****Department of Psychology, University of Tennessee, 307 Austin Peay, Knoxville, TN 37996.

SUMMARY. The effects of a single session of audio-visual stimulation (AVS) at the dominant alpha rhythm and twice-dominant alpha frequency on EEG coherence were studied in 23 subjects. An eyes-closed baseline EEG determined each subject's dominant alpha frequency. Subjects were stimulated at their dominant alpha frequency or at twice dominant alpha frequency for twenty minutes, while EEG was recorded in 5-minute intervals. A post-session baseline was recorded 30 minutes after each session. AVS decreased coherence in the intrahemispheric projections from the occipital region and the parietal midline, and generally increased coherence, with few exceptions, among all other longitudinal pairs. Interhemispheric coherence increased posteriorily and high frequencies, and tended to decrease frontally and low frequencies. Alpha AVS was more effective than twice-alpha AVS at producing interhemispheric synchronization, and tended to produce more effects overall. Although main effects of frequency and time were observed, when individual coherence pairs changed, they almost always changed in only one direction. Overall coherence was greater during the first ten minutes than the last ten minutes, and greatest in the beta 1 and delta 2 bands, and lowest in the alpha and delta 1 bands. Few, if any, significant effects persisted into the post-stimulation baseline. A new method of assessing the effects of multiple comparisons on experimentwise error, based on randomization theory, is proposed and implemented.

Click 'Read More' below for the rest

INTRODUCTION

The ability of a flashing light stimulus to evoke EEG rhythms related to the stimulus frequency has been studied since the early history of electroencephalography (Adrian & Matthews, 1934). Known as the photic driving response (PDR), or steady state visual evoked potential, this effect is commonly measured in routine clinical EEG examinations, and has been proven useful for investigating neurological disorders (Takahashi, 1987; Coull & Pedley, 1978; Duffy, Iyer, & Surwillo, 1989).

The diverse perceptual and emotional effects of photic stimulation (Walter & Walter, 1949; Stwertka, 1993; Gizycki, Jean-Louis, Snyder, Zizi, Green et al., 1998), and it’s ability to cause seizures in susceptible individuals (Walter, Dovey & Shipton, 1946; Striano, Meo, Bilo, Ruosi, Soricellis et al., 1992) have led many to investigate whether rhythmic auditory and visual stimulation (AVS) might also induce clinically beneficial changes in brain activity. In the 1950’s and 60’s, many studies focused on the ability of AVS to induce relaxation and hypnosis (reviewed in Morse, 1993). Others have reported AVS to be effective for relieving a diversity of pain symptoms (Solomon, 1985; Anderson, 1989; Shealy, Cady, Cox, Liss et al., 1990), treating dental anxiety (Morse, 1993), premenstrual syndrome (Noton, 1997), fibromyalgia (Mueller, Donaldson, Nelson & Layman, 2001) and for alleviating the cognitive dysfunctions associated with closed head injury (Montgomery, Ashley, Burns & Russell, 1994) and strokes (Russell, 1997; Rozelle & Budzinski, 1995). Since the enhancement of beta (13-21 Hz) and inhibition of theta (4-8 Hz) is a goal of EEG biofeedback for the treatment of attention deficit hyperactivity disorder (ADHD; Lubar & Lubar, 1999; Lubar, Swartwood, Swartwood & O’Donnell, 1995), some have proposed using AVS in neurofeedback as a “priming stimulus” to encourage the endogenous production of desired cortical frequencies, which are then reinforced as the conditioned response. In a study of 25 ADHD children, Patrick (1996) found “photic-driven EEG neurotherapy” effective in improving cognitive, behavioral, and clinical EEG measures in less than half the number of sessions usually required. Meanwhile, Micheletti (1999) found AVS alone effective in improving cognitive and behavioral measures, in a study of 99 ADHD children. Carter and Russell (1993) reported significant improvement in cognitive and behavioral functioning, related to the number of AVS sessions, in learning disabled boys. Joyce and Siever (2000) reported that a 7-week audiovisual stimulation treatment in 8 reading-disabled children, compared to a control group, normalized scores on the Test of Variables of Attention (TOVA), improved scores on the Standardized Test for the Assessment of Reading (STAR), and improved general behavior as noted by teachers and parents.

Mechanisms by which long-term AVS therapies may cause these behavioral changes have been suggested by research in neuronal plasticity. A number of investigators (van Praag, Kempermann & Gage, 2000; Rosenzweig, 2003; Mohammed, Zhu, Darmopil, Hjerling-Leffler, Ernfors et al., 2002) are in essential agreement that ongoing direct experience that evokes persistent neuronal activation alters brain structure and brain functioning. Although most studies have focused on effects of an enriched environment, persistent neuronal activation can also be evoked by trains of sensory stimuli. Human subjects have been shown to respond to flicker frequencies from 1-100 Hz with steady-state activity at all frequencies up to at least 90 Hz with clear resonance phenomena or harmonics at 10, 20, 40 and 80 Hz (Herrmann, 2001). A possible linkage between steady-state stimulation induced neuronal activation and neuronal plasticity is the increasing evidence that brain electrical activity regulates the synthesis, secretion and actions of neurotrophins (Schindler and Poo, 2000), which promote synaptogenesis.

The most commonly studied PDRs have been the effects of stimulation on alpha (8-13 Hz) power over the occipital region (Iwahara, Noguchi, Yang & Oishi, 1974; Aranibar & Pfurtscheller, 1978). The photic driving response is most reliable when the stimulus approximates the subject’s peak alpha frequency (Toman, 1941; Townsend, Lubin, & Naitoh, 1975). However, recent studies have shown that AVS activates a diverse range of EEG frequencies, beyond the primary sensory cortices, and outside of the frequency of stimulation. Using low-frequency theta AVS, Dieter & Weinstein (1995) described a significant reduction in "mean activity" (an increase of delta and theta activity) in frontal, central, and parietal regions, in addition to occipital regions. In a study of 13 college students (Timmermann, Lubar, Rasey & Frederick, 1999), we found that effects of AVS were widely distributed across the standard 10-20, 19-channel montage. AVS at a subject's dominant alpha frequency had no effect in the alpha band, but significantly increased power in the delta 1, delta 2, theta, beta 1, and beta 2 bands. Stimulation at twice the dominant alpha frequency significantly increased theta, alpha, beta 1, and beta 2 power.

While the amplitude and power effects of AVS have been widely studied, relatively little is known about the effects of AVS on EEG coherence. Coherence is a correlational measure, varying between zero and one, of the variability in phase between two signals over time (Shaw, 1981). This frequency-specific signal correlation suggests the extent to which two regions are cooperating on the same task. High coherence indicates a common signal, whether it is synchronous between two locations, or delayed by a constant conduction velocity. Coherence in the eyes-closed baseline reflects the number of synaptic connections between recording sites, and the strength of these connections (Thatcher, 1992). Coherence has been shown to be lower in Alzheimer patients, comatose subjects, and in brain-injured subjects, while it is higher in mentally retarded persons, during sleep, and during epileptic seizures. Between these extremes, "optimal levels" of coherence for normal functioning have been described (Silberstein, 1995). Some have suggested that EEG coherence biofeedback could be used to normalize the coherence deviations seen in dyslexic and head injured subjects (Evans & Park, 1996; Hoffman, Stockdale, Hicks & Schwaninger, 1995).

Differences in photic driving of coherence have been described between normal subjects and patients with Alzheimer's disease (Wada, Nanbu, Kikuchi, Koshino, Hashimoto et al., 1998a), schizophrenia (Wada, Nanbu, Kikuchi, Koshino & Hashimoto, 1998b), and between genders (Wada, Nanbu, Kadoshima & Jiang, 1996). However, the effects of combined auditory and visual stimulation on coherence in normal subjects have not been previously reported.

Although AVS devices are used by many neurotherapists as an adjunct to EEG biofeedback, the overall pattern of effects of AVS on coherence needs to be better understood, to ensure that AVS treatment is influencing coherence in the appropriate direction. To begin to achieve this understanding, we conducted an exploratory study of the effects of AVS on coherence in normal college students. We hypothesized that AVS would increase coherence at the frequency of stimulation, and assumed that effects would be most prominent over the occipital and temporal leads, which are closest to the primary visual and auditory cortex. Given our previous findings of increased amplitude in multiple frequency bands (Timmermann et al., 1999), we anticipated effects across the coherence spectrum. However, since our goal was to observe the effects rather than to verify any hypothesis about them, beyond the expected increase at the stimulus frequencies, we did not predict directions of change.

The rest of this study can be found in PDF format here: http://www.mindmodulations.com/resources/Study-frederick-avs-coherence.pdf