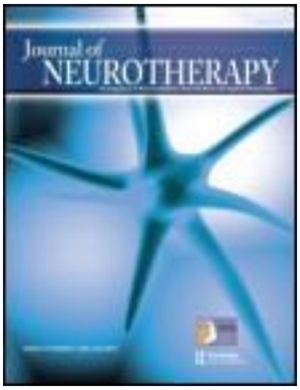


Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience

EEG Power-Spectral and Coherence Differences Between Attentional States during a Complex Auditory Task

Grant Benham B.Sc [a] , Howard W. Rasey B.A. , Joel F. Lubar Ph.D. [b] , Jon A. Frederick M.S. [c] & A. Charles Zoffuto B.S.

[a] Experimental psychology , University of Tennessee , Knoxville, USA

[b] University of Tennessee , USA

[c] Department of Psychology , University of Tennessee , Knoxville, USA

Published online: 20 Oct 2008.

To cite this article: Grant Benham B.Sc , Howard W. Rasey B.A. , Joel F. Lubar Ph.D. , Jon A. Frederick M.S. & A. Charles Zoffuto B.S. (1997) EEG Power-Spectral and Coherence Differences Between Attentional States during a Complex Auditory Task, Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience, 2:3, 1-9, DOI: 10.1300/J184v02n03_01

To link to this article: http://dx.doi.org/10.1300/J184v02n03_01

EEG Power-Spectral and Coherence Differences Between Attentional States during a Complex Auditory Task

Grant Benham, B.Sc., Howard W. Rasey, B.A., Joel F. Lubar, Ph.D., Jon A. Frederick, M.S., and A. Charles Zoffuto, B.S.

This electroencephalographic (EEG) study was designed to explore the differences in power spectra and coherence associated with subjective levels of engrossment, or absorption, in an auditory task. Quantitative referential EEG activity was recorded using 19 electrodes while subjects (n = 17) listened to a story and indicated on a continuous basis, by means of a hand held switch, whether they were engrossed or non-engrossed in the story content. Results from power spectra data indicated significant differences between subjective engrossed and non-engrossed states (particularly in the theta and beta1 bands) with increased mean power during engrossed states. Differences in coherence were not shown to be significantly different. The results suggest that engrossed and non-engrossed states have different EEG correlates for power measures during specific complex tasks.

Key Words: EEG, Coherence, Engrossment, Attention, Absorption

Attention was usefully defined by Tecce (1972) as a hypothetical process of an organism that facilitates the selection of relevant stimuli from the environment (internal or external) to the exclusion of other stimuli and results in a response to the relevant stimuli. Although numerous electroencephalographic investigations have studied attentional processing (Born et al., 1986; Dalbokova and Kolev, 1992; Molle et al., 1995), research in this area has generally relied on the use of signal detection procedures using continuous performance tests (Rasey et al., 1996) and vigilance tasks (Makeig and Inlow, 1993).

A contrast has been made between tasks that necessitate attention to stimuli in order to be processed (intake) and tasks that necessitate the exclusion of environmental stimuli (rejection) for their effective completion (Ray and Cole, 1985; Valentino and Dufresne, 1991). Additionally, the role of perceptual structuring in attentional processes was demonstrated in a study by Giannitrapani (1971), who found increases in high beta activity (21-33Hz) when subjects were required to structure stimuli, such as when they listened to a story and had to organize the sounds into a meaningful narrative.

In order to understand how the brain, particularly the cerebral cortex, is involved in complex cognitive processes, it is necessary to develop measures that reflect the degree to which activity in different cortical areas represents functional linkages. Two areas that receive information from either subcortical generator or another cortical region may be linked not only to those areas but also linked together because of this relationship. Typically EEG activity measured from two different electrode sites employing either a common reference (e.g., linked ears) or in a bipolar configuration can be compared by their relative amplitude or power spectra as a function of frequency. These measures represent the degree to which they have a similar amplitude or power (amplitude squared) distribution within the typical range of EEG frequencies (approx. 0.5 - 40 Hz).

Another measure of functional linkage

between brain regions is coherence. Coherence provides a quantitative measure of the association between pairs of signals as a function of frequency. The importance of coherence estimates in the study of functional organization of the cortex was first emphasized by Shaw and Ongley (1972). Coherence measures have found a strong foothold in electroencephalographic research, with increasing literature on the use of coherence as a measure of abnormality in clinical medicine (Cantor et al. 1982; Flor-Henry et al., 1982; O'Conner et al. 1979; Shaw et al., 1977) and as a correlate of cognitive processing (Beaumont et al., 1978; Busk and Galbraith, 1975; Shaw et al., 1977; Thatcher et al., 1983; Tucker et al., 1982).

According to Thatcher (1992), coherence reflects a number of synaptic connections between recording sites and the strength of these connections. Thatcher (1992) and Nunez (1995) argue that high coherence indicates integration of function while low coherence indicates differentiation of function. Coherence shares some of the characteristics of a correlation coefficient in that it is a value which varies between 0 and 1. High coherence occurs during epileptic seizures, for example, in 3 Hz wave discharges associated with absence seizures. Coherence is also increased after closed head injury and in mental retardation (Thatcher, 1991). Low coherence can also be a sign of inappropriate brain function, particularly following penetrating wounds of the brain where cortical-cortical connections have been physically severed.

Although a formal understanding of coherence requires complex mathematics, an excellent non-mathematical description of coherence was provided by Shaw (1981). Shaw explained that coherence can be considered as a measure of the degree to which two signals at a given frequency maintain a phase-locked relationship over time. Regardless of the phase angle difference between the signals at a specific frequency, if it is constant, the coherence will be 1.0. If signals have an entirely random phase relationship, coherence will be 0. The degree to which a phase relationship is maintained over time between two signals of the same frequency at two locations in the cortex appears to be a measure of the degree to which they are either functionally linked, or working together to carry out some kind of processing task. As Shaw points out, coherence is independent of the amplitude of the signals over the epochs considered, and dependent on their pattern of fluctuation.

The objective of the current study was to focus on another specialized field of attention -- to determine whether there are EEG correlates of engrossment; the subjective state of focused attention that occurs when one is absorbed in a specific task.

The purpose of the present study was to evaluate the frequency distribution and coherence values at a variety of scalp locations during a task involving intense focused attention, or engrossment, in a complex auditory task. During complex tasks, there are times in which individuals are completely engrossed or attentively locked into that material, and other times in which attention tends to drift and information processing is either diminished or extinguished. In this study, the power distribution and coherence at different frequencies were evaluated using a within-subjects design, during the engrossed and non-engrossed portions of an auditory task.

Method

Subjects

Subjects for this study were recruited from senior level undergraduate and graduate level classes from the University of Tennessee. All subjects were screened for neurological difficulties which may interfere with attentional mechanisms, such as attention deficit disorder and learning disabilities. A total of seventeen subjects participated, eight males and nine females, with a range of ages between 24 and 36 years.

Procedure

A quantitative referential 19-channel EEG (QEEG) was used to provide percentage and power data within the following frequency domains: delta1 (0.75-2Hz), delta2 (2-4Hz), theta (4-8Hz), alpha (8-13Hz), beta1 (13-21Hz), and beta2 (21-31Hz). The delta1 and delta2 bands were used to monitor eye movement artifact, and their data was not used in the final analysis. The QEEG was administered following the International 10-20 system for electrode placement. An earclip electrode was placed on each ear using Electrogel (Electro Cap Company) to improve conductance following preparation using Omniprep solution (D.O. Weaver, Co.). Connections were made using an electrode cap (Electro Cap Company) and Electrogel was inserted through each sensor to improve conductance. Impedance measures for all channels were less than 3.5K Ohms. Following preparation, data were collected for an eyes-open listening condition.

Because this was a within-subjects design, and we were specifically interested in examining the differences between subjectively reported engrossed and non-engrossed states, a baseline measure was not used for comparison. During the experimental session, subjects listened to a book on tape version of Michael Critchton's *The Lost World* (Crichton, 1995). They were instructed about the concept of engrossment, and were required to indicate when they were engrossed in the story by activating a small hand held rocker switch resting on their laps. When subjects felt they were no longer engrossed, they were to switch the rocker back to the original position. In this way, movements were brief and minimal, thus reducing any artifacts that might have been produced by motor activity. . This procedure was continued throughout the recording session. Following the session, subjects were questioned regarding their ability to differentiate between engrossed and non-engrossed states using the hand held switch.

EEG activity was recorded at a sampling rate of 128 samples per second. During the listening task, the EEG recording was annotated automatically for engrossed states by the action of the hand held switch. Recording was continued until approximately four minutes of engrossed and four minutes of non-engrossed EEG segments had been collected. Raw EEG was inputted through 19 matched 7P511 pre-amplifiers (Grass Instrument Co.), with band pass filters set to 0.5-70Hz. EEG activity was digitized on-line by a BMSI 519 ADC board. Following data collection, EEG segments were analyzed off-line using the Stellate Rhythm 9 system (Stellate Systems, Westmount, Quebec, Canada). The Stellate system was used first to remove specific artifacts such as EMG, eye movements and blinks, and then to combine artifact free EEG for QEEG analysis.

Results

Power Spectra

Paired t-tests (2-tailed) were performed using absolute power data, to compare engrossed and non-engrossed states within the theta, alpha, beta1, and beta2 frequency bands, for each of the 19 locations. Due to the large number of multiple comparisons, a conservative Bonferroni correction was used. Results showed significant differences between the means for F7, T5, O1, FZ and T4 locations ($p < 0.05$, after correction) within the theta band. A significant difference between the means was also found at the C3 location ($p < 0.05$, after correction) within the beta1 band. Figure 1 displays the locations where significant differences were obtained between the two states as a function of frequency.

Without exception, mean power was greater during the engrossed state than during the non-engrossed for each of the above results.

Coherence

Coherence was computed for 26 longitudinal pairings (FP1-F7, FP1-F3, FP1-T3, FP1-C3, FP1-T5, FP1-P3, FP1-O1, FP2-F8, FP2-F4, FP2-T4, FP2-C4, FP2-T6, FP2-P4, FP2-O2, O1-F7, O1-F3, O1-T3, O1-C3, O1-T5, O1-P3, O2-F8, O2-F4, O2-T4, O2-C4, O2-T6, and O2-P4) for each of the four frequency bands. Coherence for each subject was calculated for both the engrossed state and the non-engrossed state. Differences between these levels were then analyzed for statistical significance using a 2-tailed t-test ($\alpha = 0.05$). Once again, a conservative Bonferroni correction was used. Following this correction, none of the differences in mean coherence proved significantly different.

Supplemental Results

The above results were based on an extremely conservative multiple comparison Bonferroni correction. Significance was lost for a substantial number of locations and coherence pairings due to this correction. The following details our results before correction – information that might prove valuable for future investigations and pre-planned comparisons.

Power Spectra (Uncorrected): Results showed significant differences between the means for all locations in the theta band: (C3, CZ, PZ, C4, T6, $p < 0.05$), (FP1, F3, P3, FP2, F4, P4, O2, F8, $p < 0.01$), and (F7, T3, T5, O1, FZ, T4, $p < 0.001$). Within the alpha band, significant differences between the means ($p < 0.05$) were found for 8 of the 19 locations (F7, T3, T5, FP1, F3, FZ, FP2, C4). The beta1 band showed significant differences at 7 locations (F7, FP1, F3, CZ, PZ, $p < 0.05$), (P3, $p < .005$), and (C3, $p < 0.001$). Beta2 showed significant differences for FZ and C3 ($p < 0.05$). Without exception, mean power was greater during the engrossed state than during the non-engrossed for each of the above results.

Coherence(Uncorrected): Results showed significant differences within the theta band for the following six pairings: FP1-F7, FP1-T3, O2-F4, O2-C4, O2-T4, and O2-P4. For each of these pairings, the engrossed state showed greater coherence than the non-engrossed state. Within the alpha band, significant differences were shown for the FP1-F7, O1-T3, and FP2-C4 pairings. Coherence was greater during engrossed states for pairings FP1-F7 and O1-T3, but lower during engrossed states for pairing FP2-C4.

Discussion

Our study was exploratory, without a priori hypotheses as to the locations and bands that might prove important. As with any area of investigation, importance should be placed on adequate replication. Although significance was lost for many of our results following the conservative Bonferroni correction, we believe certain trends were apparent which could prove most useful for pre-planned comparisons in future studies investigating the processes of engrossment.

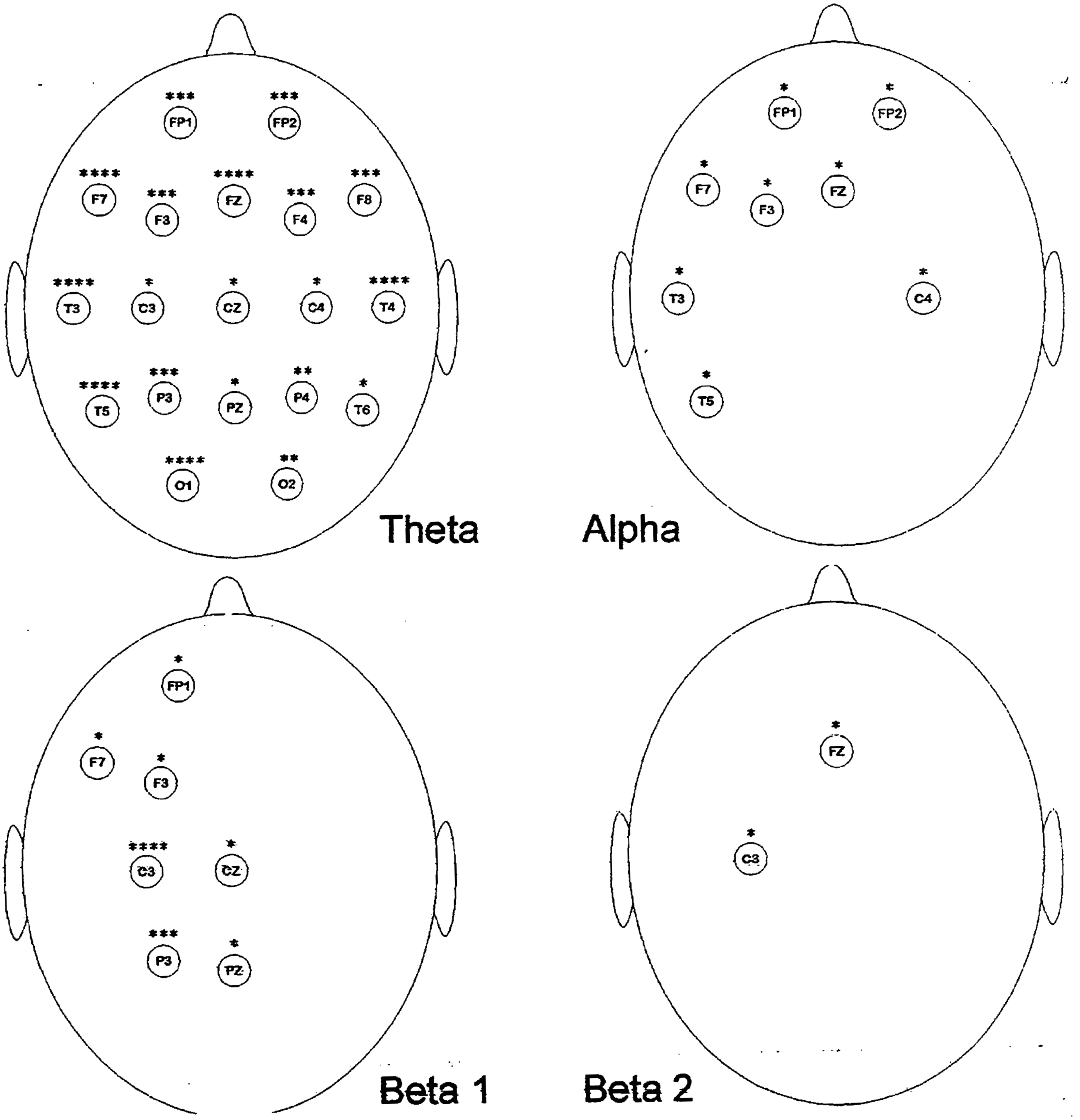
While all subjects did not activate the hand-held switch indicating engrossment during identical sections of the story, there was a consistent pattern in the responses. Nearly all subjects transitioned between non-engrossed and engrossed states throughout the story. Consistent with the variability in state, the time spent within each state also varied throughout the story.

In order to provide an example for a typical subject, subject S3's data was evaluated to demonstrate the transitions between states and also show the sections. S3 had a total record time of 7 minutes and 55 seconds variability during the non-engrossed and engrossed. Of this, 37 artifact-free epochs (of 8 second duration) were used for analysis, providing a total of 4.93 minutes of data. Within this data there were six sections of non-engrossed states and six sections of engrossed states, thus indicating 11 transitions between non-engrossed (starting section) and engrossed states. The non-engrossed states comprised a total of 112 seconds or 1.87 minutes. The longest section was 24 seconds, the shortest section was 8 seconds with a mean of 18.67 seconds. The engrossed states comprised a total of 184 seconds or 3.07 minutes. The longest section was 48 seconds, the shortest section was 16 seconds with a mean of 30.67 seconds.

A gross analysis of transitions for the various coherence pairings showed that changes in subjective engrossment were associated with shifts in coherence levels. Evaluating the transitions between non-engrossed and engrossed sections for the coherence pairing Fp2-C4 a consistent pattern was observed. This pairing represents one in which higher coherence was observed during the non-engrossed compared with the engrossed state. This would imply that during the

Figure 1

Significant Difference in Power Specta Between Engrossed and Non-Engrossed States



Legend: * = p<0.05, ** = p<0.01, *** = P<0.005, **** = p<0.001

transitions between the two states, there would be lower coherence when a subject transitioned from non-engrossed states to engrossed states and higher coherence when transitioning from engrossed into non-engrossed states. For subject S3, this pattern was observed in 10 out of the possible 11 transitions, indicating that changes in engrossment were consistent with changes in coherence.

Our results raise some interesting points regarding the neurological correlates of attentive mechanisms involved in engrossment in a complex auditory task. First, it must be emphasized that although the frequency related power differences between the engrossed and non-engrossed state were significant, the findings from this study do not necessarily generalize to auditory engrossment in all forms of complex cognitive activity. The particular passages in this task were taken from portions of the Michael Crichton's book, *The Lost World*, in which there were vivid action oriented scenes. The specific content to which individuals listened involved characters who were trapped in a tree while being attacked by carnivorous dinosaurs known as Velociraptors. One portion of the scene involved an individual falling out of the tree and being devoured while the others observed and expressed fear and terror. What is particularly noteworthy in Figure 1, is that during the engrossed state there was a considerable increase in theta activity in frontal-central, temporal, and temporal-parietal locations. The greatest significant differences occurred frontally and in the left hemisphere in temporal and parietal locations, whereas in the right hemisphere the differences were primarily frontal and temporal.

Theta activity has generally been considered to be associated with visualization (Niedermeyer and da Silva, 1993) which would be consistent with the storyline of the text. These researchers also point out that alpha activity, which we found primarily frontally and in the left hemisphere (though significant differences were lost following Bonferroni correction), is typically associated with a relaxed non-judgmental state. Alpha activity is often significantly increased in situations where there is either mastery of a task or relatively little significant mental effort associated with the task. Beta activity, particularly between 13 and 21 Hz., is associated with active processing of information and focused attention (Niidermeyer and da Silva, 1993). Beta activity in this study was significantly increased in the left hemisphere, and to some extent centrally. The largest increases were seen in areas that are involved in visualization, the extrastriate cortex, approximated by location P3, and at C3, an area that lies over the motor cortex. Some beta activity was seen in the higher band pass of 21-32 Hz.

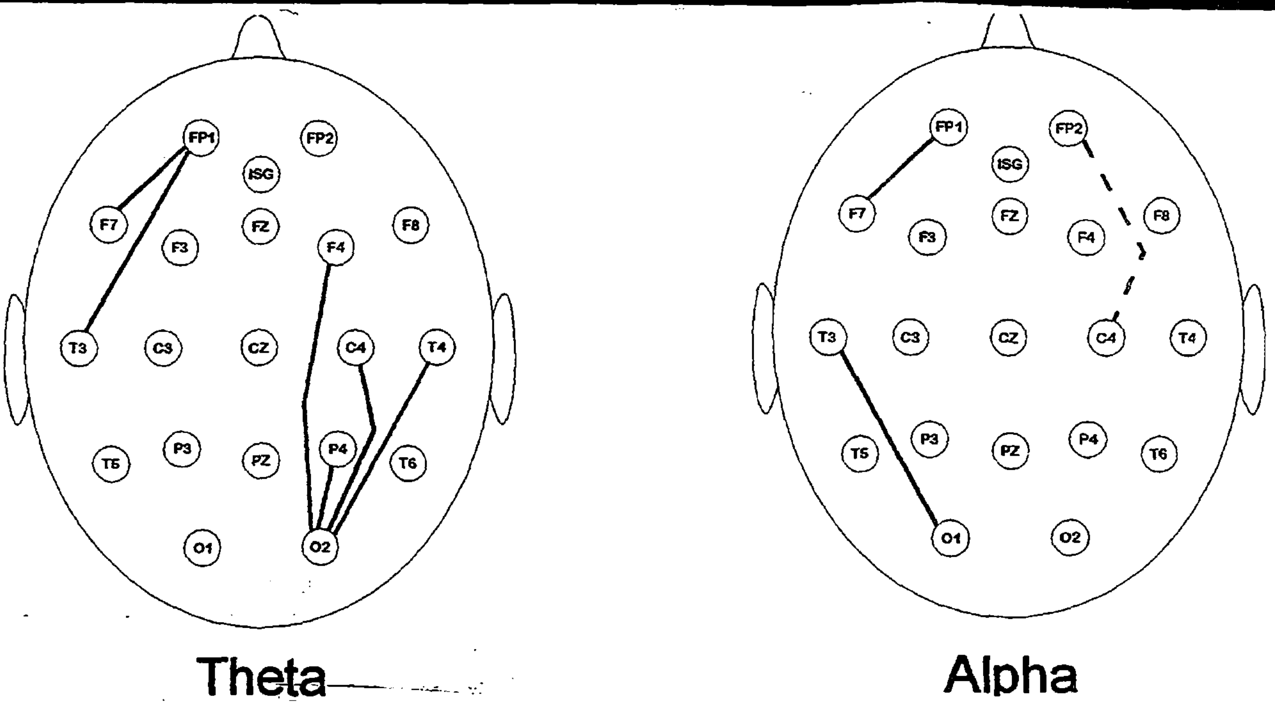
Post-session interviews revealed that subjects responded to different aspects of the scenes that they were listening to. Some individuals were particularly intrigued by the visual aspects of the action taking place, some were more involved in the feelings and emotions experienced by the characters being attacked, and others were more involved in the setting of the scene (i.e., object details and placement). Visualization of the scene may be associated with the increased theta activity as indicated above. The evaluation of the emotional components of the scene are more likely associated with the increases in beta activity. As pointed out by Pilgreen (1995), increased arousal is associated with increased desynchronization of cortical activity, reflected by higher frequency beta. The increased alpha activity, which was predominantly located in left frontal regions, possibly reflects an impersonal, detached type of processing. This activity would be consistent for those individuals who were more concerned with the object details and placement of the scene.

There was relatively little artifact in our EEG recordings and any eye movement artifact was easily removed from the analysis. No observable muscle activity contributed to the higher frequencies, i.e., the beta activity, and no significant body or eye movements contributed to the theta activity. Additional band passes were also analyzed, specifically 0-2 Hz. and 2-4 Hz. Any significant eye movements would have been registered in these band passes. No significant differences were found between the two conditions in those frequency domains.

Based on the work of Thatcher and colleagues (e.g., Thatcher et al., 1987) increased coherence represents increased linkages between brain areas. Thatcher would interpret the increased coherence in theta activity between FP1 and F7, and FP1 and T3, as being associated with the analytical aspects of the scene, that is, what is happening, how many people were involved, how many dinosaurs, the actual details of the setting. The tendency for increased coherence in the right hemisphere between O2 and a number of locations is associated with self appraisal or interpretation. In other words, "What would I be feeling, and what would I experience if I were placed in he same situation as the characters in the story?" The increased coherence between FP1 and F7 in alpha is also associated with analytical appraisal of the scene. The increased coherence between O1 and T3 is associated with visualization of the scene. The decreased coherence between FP2 and C4 is not interpretable at the present time based on existing information.

Since linkages between different brain areas and different situations change depending on the demands of the tasks employed, it is reasonable to propose that different relationships would be obtained in a study where individuals might be reading factual information or information devoid of emotional content. This would result, perhaps, in different patterns of coherence and spectral power as a function of frequency than those obtained in this very vivid, scenic experience. Engrossment was typically linked more with the action or emotional components of the setting. The statistically significant differences that were obtained – particularly for theta and beta in a number of locations -- attest to the consistency of the results in this group of individuals who are relatively closely matched for age, all of normal intelligence, and all able to clearly differentiate between engrossed and non-engrossed states during this auditory experience. Requiring subjects to report their ongoing state of awareness possibly introduced an additional cognitive process -- that of self monitoring and assessment –

Figure 2
Significant Differences in Coherence Between Engrossed and Non-Engrossed States



Solid arrows illustrate significant difference (0.05) in a positive direction
Dotted-line arrows illustrate significant differences (0.05) in a negative direction

which could limit the interpretation of these results purely as neurophysiological substrates of engrossment. This requirement may have resulted in a less than complete absorption in the material presented (Polkinghorne, 1989). Future studies designed to eliminate reliance upon self monitoring, such as presenting material prejudged to be engrossing/non-engrossing by an independent subject group, could help control for possible alternative explanations.

The further significance of this study is that the measurement of frequency and coherence differences when one is in a focused attentive and engrossed state, as compared with a non-engrossed state, may provide insight into how the brain processes information involving intense concentration or focusing. These results have implications as a methodology for assessing such factors as interest or absorption in particular materials, and perhaps for the assessment and treatment of attention deficit disorders where the ability to sustain attention and concentration is reduced in many cognitive situations.

References

Beaumont, J.G., Mayes, A.R., and Rugg, M.D. (1978) Asymmetry in EEG alpha coherence and poser: effects of task and sex. *Electroencephalography and Clinical Neurophysiology, 45*: 393-401.

Beaumont, J.G. and Rugg, M.D. (1979) The specificity of intrahemispheric EEG alpha coherence asymmetry related to psychological task. *Biological Psych, 9*: 237.

Born, J., Fehm-Wolfsdorf, G., Lutzenberger, W., Voigt, K., et-al. (1986) Vasopressin and electrophysiological signs of attention in man. *Peptides, 7*:(2) 189-193.

Busk, J. and Galbraith, G.C. (1975) EEG correlates of visual-motor practice in man. *Electroencephalography and Clinical Neurophysiology, 38*: 415-422.

Cantor, D.S., Thatcher, R.W., McAlaster, R., Lester, M.L. and Horst, R.L. (1982) Topographic distribution of EEG hemispheric coherence related to cognitive functioning in children. *Southeastern Conf. Human Develop, abstr.*

Crichton, M. (1995) The Lost World. New York: Alfred A. Knopf, Inc.

Dalbokova, D. and Kolev, P. (1992) Cognitive and affective relations in perception of auditory stimuli in the presence of music. *Psychomusicology, 11*:(2) 141-151.

Flor-Henry, P., Kiles, Z.J. and Tucker, D.M. (1982) Studies in EEG power and coherence (8-13Hz) in depression mania and schizophrenia compared to controls. *Advances in Biological Psychiatry, 9*: 1-7.

Giannitrapani, D. (1971) Scanning mechanisms and the EEG. *Electroencephalography and Clinical Neurophysiology, 30*, 139-146

Harmony, T., Fernandez, T., Rodriguez, M., Reyes, A., Marosi, E. and Bernal, J. (1993) Test-retest reliability of EEG spectral parameters during cognitive tasks. *International Journal of Neuroscience, 68*(3-4): 263-71.

Makeig, S. and Inlow, M. (1993) Lapses in alertness: Coherence of fluctuations in performance and EEG spectum. *Electroencephalography and Clinical Neurophysiology, 86*: 23-35.

Molle, M., Marshall, L., Pietrowsky, R., Lutzenberger, W., et al. (1995) Dimensional complexity of the EEG indicates a right fronto-cortical locus of attentional control. *Psychophysiology, 9*: (1) 45-55.

Niedermeyer, E. and de Silva, F. (1993) *Electroencephalography: Basic Principles, Clinical Applications and Related Fields.* Baltimore: Williams and Wilkins.

Nunez, P.L. (1995) *Neocortical dynamics and human EEG rhythm.* NY: Oxford Press.

O'Conner, K.P., Shaw, J.C. and Ongley, C.O. (1979) The EEG and differential diagnosis in psychogeriatrics. *British J Psych, 135:* 156.

Petsche, H., Pockberger, H. and Rappelsberger, P. (1986) EEG Topography and Mental Performance. In: F. H. Duffy, (Ed.), *Topographic Mapping of Brain Electrical Activity*, Butterworth Pub, Stoneham,63-98.

Pligreen, K.L. (1995) Physiologic, medical, and cognitive correlates of electroencephalography. In: P.L. Nunez (Ed.), *Neocortical dynamics and human EEG rhythm.* NY: Oxford University Press.

Polkinghorne, D. (1989) Phenomenological Research Methods. In: R. Valle and S. Holling (Eds.), *Existential-Phenomenological Perspectives in Psychology*. New York. Plenum Press.

Rasey, H.W., Lubar, J.F., McIntyre, A., Zoffuto, A.C. and Abbot, P.L. (1996) EEG Biofeedback for the Enhancement of Attentional Processing in Normal College Students. *J. of Neurotherapy, 3*: 15-21.

Ray, W. J., & Cole, H. W. (1985) EEG Alpha activity reflects attentional demands, and beta activity reflects emotional and cognitive processes. *Science, 228*, 750-752.

Shaw, J.C., O'Conner, K.P. and Ongley, C.O. (1977) EEG coherence as a measure of cerebral functional organization. In: M.A.B. Brazier and H. Petsche (Eds.). *Architectonics of the Cerebral Cortex*, Raven Press, NY, 245-256.

Shaw, J.C. and Ongley, C. (1972) The measurement of synchronization. In: H. Petsche and M.A.B. Brazier, (Eds.), *Synchronization of EEG Activities in Epilepsies*, Springer, New York, pp. 204-214.

Shaw, J. C. (1981) An introduction to the coherence function and its use in EEG signal analysis. *J. of Med Engineering & Tech*, 5, 279.

Tecce, J. J. (1972) Contingent negative variation (CNV) and psychological processes in man. *Psychological Bulletin, 77*, 73-108.

Thatcher, R.W. (1992) Cyclic cortical reorganization during early childhood. Special Issue: The role of frontal lobe maturation in cognitive and social development. *Brain and Cognition, 20*: 24-50.

Thatcher, R.W., Cantor, D.S., McAlaster, R. and Geisler, F. (1991) Comprehensive predictions of outcome in closed head-injured patients: The development of prognostic equations. *Annals of the NY Academy of Sciences, 620*: 82-101.

Thatcher, R.W., McAlaster, R., Lester, M.L., Horst, R.L. and Cantor, D.S. (1983) Hemispheric EEG asymmetries related to cognitive functioning in children. In: A. Perecman (Ed.), *Cognitive Processing in the Right Hemisphere*, Academic Press, NY, 125-146.

Thatcher, R.W., Walker, R.A. and Giudice, S. (1987) Human cerebral hemispheres develop at different rates and ages. *Science*, 236, 1110.

Tucker, D.M., Dawson, S.L., Roth, D.L., Blair, T.B. and Sawler, B.G. (1982) Regional changes in power and coherence during cognition: longitudinal study of individuals. In: *International Neuropsychology Society, Pittsburgh, PA. abstr.*

Valentino, D. A. & Dufresne, R. L. (1991) Attention tasks and EEG power spectra. *Int. Journal Psychophysiology, 11*, 299-302.

Grant Benham, B.Sc. is a Ph.D. student in experimental psychology at the University of Tennessee, Knoxville. His research insterests include biofeedback, hypnosis and psychosomatics. He is currently investigating the efficacy of hypnosis in altering autonomic physiology, and is Managing Editor of the International Journal of Clinical and Experimental Hypnosis.

Howard W. Rasey, earned his B.A from the University of North Florida with a major is psychology and a minor in behavioral medicine. He completed two years of graduate study at the University of West Florida during which he worked with Dr. Frank Andrasil and Dr. Thomas Budzynski at the Center for Behavioral Medicine. Currently, he is working on doctoral study at the University of Tennessee, working toward a degree in experimental psychology. Research interests include attentional processes, applied psychophysiology and the use of EEG biofeedback for ADD/ADHD individuals.

Joel F. Lubar, Ph.D., is a full professor at the University of Tennessee. Dr. Lubar has published more than 70 papers, many book chapters and eight books in the areas of Neuroscience and Applied Psychophysiology. He Dr. Lubar was responsible for developing the ise of EEG Biofeedback as a treatment modality for children, adolescents, and adults with Attention Deficit Hyperactivity Disorder starting with controlled studies in the mid-1970's. Dr. Lubar and his collegues are currently developing data bases for the assessment of individuals with ADD/HD. Dr. Lubar has seved on the Biofeedback Certification Institute of America Board and on the executive committee of the AAPB. He has been co-director of the Southeastern Biofeedback and Neurobehavioral Institute, Knoxville, Tennessee since 1979. This institute offers training for professionals in the area of neurofeedback as well as research and patient treatment.

Jon A. Frederick, M.S., is a graduate student in the Department of Psychology, University of Tennessee, Knoxville.

A. Charles Zoffuto earned his B.S. in secondary education from the Citidel in 1994. He is currently a master's student in the University of Tennessee's experimental psychology program. Following receipt of an M.A., he plans to continue his education at the doctoral level, focusing on neurosciences applications.

Please address all correspondence to: Grant Benham, Department of Psychology, University of Tennessee, Knoxville, TN 37996