Graphical Neurofeedback Interface for the Non-pharmacological Intervention in Attention Deficit/Attention Deficit Hyperactivity Disorder

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Abstract ***A graphical neurofeedback interface is described which is employed in the non-pharmacological intervention in Attention Deficit/Attention Deficit Hyperactivity Disorder (ADD/ADHD). The interface is used in conjunction with the New England Neuroebehavioral (NE Neuro) CorTekScan electroencephalographic amplifier to administer neurofeedback to patients who suffer from ADD/ADHD.***

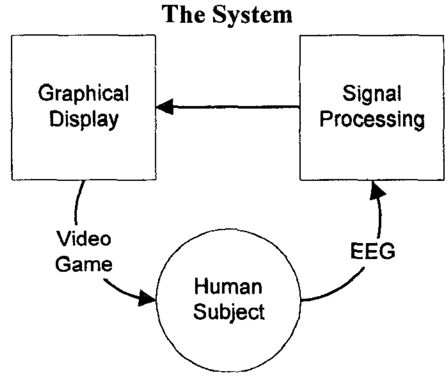
Background A review of the literature establishes the fact that the power spectrum of the electroencephalogram (EEG) can be used to assess the functional status and maturational development of the brain. Published works have provided a substantive body of documented evidence relative to the use of the EEG as a diagnostic tool in the study of the brain function of both normal and learning disabled children [1,2,3,4,5,]. There is a body of data which describe age specific normative values for the (EEG) [6], and studies that relate certain EEG abnormalities to learning disabilities [1,2,3].

Lubar established the predominance of theta (4-7 Hz) EEG activity, with decreased beta-1(13-21.75 Hz) activity in children with ADD [7]. Lubar also showed that the administration of biofeedback, to increase beta and decrease theta, can lead to very significant changes in the EEG as well as improvements in psychometric test measures and school performance [8]. M. Tansey recorded significant, long term beneficial results from the administration of 16 Hz sensorimotor rhythm (SMR) biofeedback in the treatment of ADD [9]. Tansey also asserts that there are electroencephalographic "signatures" peculiar to learning disabled children[10].

In 1996, Miles, Smith and LaCourse described the NE Neuro CorTekScan(CTS) and its use in a specific non-pharmacological intervention protocol [11]. The CorTekScan processes the EEG signals from a subject, and in conjunction with the graphical neurofeedback interface, facilitates the transformation of the subject's EEG power spectrum from the low frequency, pediatric profile typical of ADD, to more appropriate, age specific normative values.

Material and Methods

The System



The system provides biological neuro-feedback to subjects so that they may be able to control the EEG power spectrum and overcome ADD/ADHD. The three main components of this system are (1), a subject to generate an EEG; (2), a Signal Processing component to monitor and process the EEG; and (3), a Graphical Display component to give the subject feedback with respect to the EEG.

Implementation

The Signal Processing component of the system is made up of two parts: A "CorTekScan" (CTS) device, which samples the voltages of the EEG, and a Texas Instruments "Evaluation Module" (EVM), which processes the voltage signals of the EEG. The two devices communicate via an RS-232 serial port. The Graphical Interface component is comprised of an IBM Pentium PC, with two different types of graphical displays: numerical graphs and a video game. The PC receives the results of the EEG processing via its own program bus since the EVM is installed in one of the PC's expansion slots.

Signal Processing

Data Flow

The purpose of the Signal Processing system is to

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process the subject's EEG signal so that it may be displayed by the Graphical Interface system. It must sample and digitize the voltage of the EEG, calculate the power spectrum, and transmit the results to the PC. This is done by the CTS and EVM.

The sampling instrumentation, the CTS, consists of a 5 channel EEG amplifier and computer interface. The unit is able to detect, amplify and filter 1 electrooculographic (EOG) channel and up to 4 EEG channels simultaneously. Scalp locations F3, F4, C3, and C4 in the International 10-20 System have been chosen as appropriate at this time but may change as research proceeds. Each channel amplifies the signal approximately 30,000 times and filters out signals above 32 Hz with an 8th order Bessel low-pass filter. Low frequencies are attenuated with a high pass filter with a 3 dB point of 0.4 Hz. After amplification and filtering, the signal is sampled and digitized with 12 bit resolution by a microprocessor sampling at 128 Hz. The digitized data is sent to the serial port of the EVM at 19,200 baud.

The EVM is equipped with a TMS320c30 Digital Signal Processor (DSP), a PC bus interface, and a serial port. The EEG voltages are received via RS 232 serial port, processed by the DSP, and the results are sent to the PC bus upon request by the PC. These three tasks are accomplished by three routines: Serial, FFT, and Sender, which operate on four memory blocks: Voltage, Process, Spectrum, and DataOut.

Serial handles the data coming in through the EVM's serial port. Serial shifts out the oldest voltage data and writes in the newest voltage data. The Voltage memory block contains the sampled voltage from the four EEG signals and the EOG channel. The EEG voltage blocks contain 256 points per channel.

FFT extracts the frequencies of the raw Voltage using a Fast Fourier Transform and then calculates the power spectrum of those frequencies. FFT first copies the voltage data from the Voltage memory block to the Process memory block. FFT then performs a Fast Fourier Transform on the Process memory block and calculates the power spectrum on the transform results. With 256 voltage points sampled at 128 Hz, the FFT routine provides a resolution of ½ Hz.

Sender provides the PC with voltage or power spectrum data upon request. It can provide EEG 1-4 (voltage or power spectrum) data, or EOG (voltage only) data.

Graphical Display The purpose of the Graphical Display is provide the human subject feedback with respect to his/her current EEG. The graphical display system is made up of three different process threads running on the PC: Getter, Plotter and Game, which operate on two data structures, Voltage and Spectrum, having the same function as the EVM blocks, but located differently.

The function of the Getter thread is to get voltage and power spectrum data from the EVM, and store the data in the corresponding data structures on the PC. It does this by interacting with the Sender routine of the EVM.

Plotter is the thread which displays the voltage or power spectrum data in the form of graphs. The graphs that will be displayed are Power Spectrum with full ½ Hz resolution, Bar Graph Power Spectrum with 4 Hz resolution, Voltage vs. Time, and Compressed Spectral Array (CSA).

The innovative component of this system is the Game thread. It translates the power spectrum values to one value, the ratio of the high (beta) frequency component of the EEG, to the low (theta) frequency component, and then uses that value as the input to a graphical video game. The game's style is that of flight simulation with the beta/theta ratio controlling the height of the airplane. The goal of the video game is to fly to a certain destination, while clearing obstacles of a certain height. In order for the subjects to be successful, they must have a high beta component and a low theta component.

Game is also where the EOG voltages are utilized. If the EOG reaches a certain threshold set by the operator indicating that the subject has blinked or moved his eyes, corrupting the EEG data, Game simply stops computing a new beta/theta ratio and uses the newest, non-corrupted ratio as input to the game. After a period of acceptable EOG levels, Game resumes the calculation of the beta/theta ratio. Game also computes the various objects in the video game and draws them in their proper location.

This video game has no joystick or manual controls. The subject flies the plane with his/her brainwaves and successful completion of a flight depends upon the frequency of the subject's emitted EEG, as controlled by feedback. The difficulty of the task is set by the operator at the beginning of the session in relation to past performance. "Flight" data in the form of achieved beta/theta ratios is saved in files for periodic review to determine subject progress.

Discussion Lubar's research showed that when subjects diagnosed with ADD/ADHD altered their EEG to higher beta and lower theta components, the cognitive and behavioral symptoms of ADD/ADHD were reduced, or eliminated entirely. This neurofeedback system is designed to facilitate a similar change in the EEG power spectrum of persons suffering from ADD/ADHD, provide a reduction in symptoms and relief from dependence on such drugs as Ritalin, with their problematic side-effects..

References

[1] LUBAR J, "Differences in Semantic Event-Related Potentials in Learning Disabled, Normal and Gifted Children" Biofeedback and Self-Regulation,17:41-7,1992.

[2] SHUCARD DW et al. "Event Related Brain Potentials Differentiate Normal and Disabled Readers" Brain and Language, 21:318-334, 1984.

[3] MONTGOMERY RICHARD, GUISADO R, "Electroencephalographic Scalp-Energy Analysis as a Tool for Investigation of Cognitive Performance" Biomedical Instrumentation & Technology, Mar-April:137-149, 1993.

[4] KAYE H, JOHN ER, et al. "Neurometric Evaluation of Learning Disabled Children" International Journal of Neuroscience,13:15-25,1981.

[5] JOHN, ER et al. "Neurometrics: Computer-Assisted Diagnosis of Brain Dysfunctions" Science, 29:162-169 1988.

[6] GASSER,T et al. "Development of the EEG of school-age children and adolescents. I.Analysis of band power" Electroencephalography and Clinical Neurophysiology, 69:91-99 1988.

[7] LUBAR J, "Discourse on the Development of EEG Diagnostics and Biofeedback for Attention-Deficit/Hyper-
activity Disorders" Biofeedback and Self-Regulation, 16, #3: 201-222, 1981.

[8] MANN CA, LUBAR J, et al. "Quantitative Analysis of EEG in Boys with Attention-deficit-hyperactivity Disorder: Controlled Study with Clinical Implications" Pediatric Neurology, 8,30-36,1992.

[9] TANSEY M, "Ten Year Stability of EEG Biofeedback Results for a Hyperactive Boy Who Failed Fourth Grade
Perceptually Impaired Class" Biofeedback and Self-Regu- lation,18:23-44, 1993.

[10] TANSEY M, "Brainwave Signatures-An Index of the Brain's Functional Neuroanatomy: Further Findings on the Effect of EEG Sensorimotor Rhythm Biofeedback on the Neurological Precursors of Learning Disabilities"
International Journal of Psychophysiology, 3:86-99,1985.

[11] MILES RK, SMITH WJ, LACOURSE JR "A System for the Non-Pharmacological Intervention in Attention Deficit/Attention Deficit Hyperactivity Disorder" IEEE 22nd Annual Bioengineering Conf, 101-102, 1996.