COGNITIVE NEUROSCIENCE LABORATORY

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1.0 Goals

Our initial interest in BCI-related work is to record movement-related electrophysiology (Mμ Rhythm, Readiness Potentials) and develop real-time recognition of EEG patterns in order to interface with machines and do practical work.

2.0 Current Work

2.1 Study 1: Effects of Self-movement, Observation, and Imagination on Mμ Rhythm

2.1.1 Introduction

The human mμ EEG rhythm is recorded in the 8-13 Hz range from the central region of the scalp overlying the motor cortices. This rhythm is large when a subject is at rest, and is well-known to be blocked or attenuated by self-generated movement. Indeed, the mμ wave is hypothesized to represent an "idling" rhythm of motor cortex that is interrupted when movement occurs. In this study, we show that the mμ wave is also attenuated when a subject observes a movement or when the subject imagines making the same, self-generated movement. According to Rizzolatti and colleagues, the responsiveness of the mμ wave to visual input may be the human electrophysiologic analog of a population of neurons in area F5 of the monkey premotor cortex (Fadiga et al., 1995). These cells respond both when the monkey performs an action and when the monkey observes a similar action made by another monkey or by an experimenter. Older studies have reported that a mμ-like wave is blocked by thinking about moving. For example, individuals with amputated limbs can block this rhythm by thinking about moving the amputated limb. The blocking of the mμ rhythm by visual and imagery input may have implications for understanding movement-related responses and for the rehabilitation of movement-related neurological conditions.

2.1.2 Methods

Subjects were 17 healthy volunteers (10 men, 7 women; age range 19-58 with a mean of 27.7 years). Most subjects were students or employees at the University of California, San Diego and naive to the purposes of the experiment. Only 10 subjects were used for statistical analysis because of problems with noise.

EEG signals were recorded from 6 electrodes placed over frontal (F3, F4), central (C3, C4), and occipital (O1, O2) sites according to the standard 10-20 International Electrode Placement System. Blinks and eye movements were monitored with an electrode in the bony orbit dorsolateral to the right eye. EEG was amplified by a Grass model 7D polygraph using 7P5B pre-amplifiers with bandpass at 1 and 35 Hz. EEG was digitized on-line for two minutes at a sampling rate of 256 Hz.

Subjects participated in four conditions: 1) *rest*: in which no particular task was required; 2) *self-generated movement*: subjects were asked to move their opposing thumb to middle fingers of the right hand ("duck" movement); 3) *observation*: subjects watched a confederate of the experimenter perform the "duck" movement; and 4) *imagination*: subjects were instructed to imagine performing the self-generated "duck" movement. The confederate faced the subject who was seated approximately four feet away throughout all conditions of the experiment.

2.1.3 Results/Discussion

During the rest condition, subjects exhibited significant power in the 8-13 Hz frequency range. This rhythm showed statistically significant changes during the various conditions ($F(3,27)=4.98$, $P<0.01$). Pairwise comparisons showed that the main differences were a reduction in power during the self-generated movement and the observation conditions. Post-hoc analysis of the data showed that during the imagination condition, mμ power decreased at frontal sites but was less affected at central and occipital sites (site x condition, ($F(15,135)=2.22$, $P< 0.01$).

2.1.4 Literature Cited

Fadiga, L.; Fogassi, L.; Pavesi, G.; Rizzolatti, G. (1995) Motor facilitation during action observation: A magnetic stimulation study. Journal of Neurophysiology, 73 (6): 2608-2611.

2.2 Study 2: Readiness Potentials (RPs) and Mμ Rhythm Changes to Spontaneous Overt Single and Multiple Limb Movements

2.2.1. Introduction

The imagination or performance of a movement is generally accompanied by a readiness potential (RP; also called Bereitshaftspotential or BP) which is most prevalent over cortical motor areas. The free running EEG also shows characteristic changes in mμ activity which are unique for movements of different limbs. These findings have proven useful in the construction of BCI systems based on movement related changes in mμ activity.

Numerous studies have explored the RPs and mμ changes associated with single movements of the finger and hand. However, the electrophysiology of left and right foot movement, and those preceding the voluntary simultaneous movement of multiple limbs, have not been thoroughly explored. This information is necessary to better understand how the brain's activity gives rise to different movements, and also expands the range of input signals which could be used in a BCI.

This study recorded EEGs from human subjects performing voluntary movements of either one limb or two limbs at self paced intervals. Results confirmed that each type of movement is associated with unique EEG characteristics which could be categorized artificially.

2.2.2 Methods

A total of 18 subjects (mean age 23.7 +/- 2.8) were run in this experiment. Seven subjects were female and 3 of the female subjects and two males were left handed. Most were undergraduate students at UC San Diego and were compensated with either credit toward an undergraduate course or monetary payment. All subjects were native English speakers with no sensory or motor deficits and no history of psychological disorder. Subjects signed a consent form and research was approved by the Human Subjects Committee at UC San Diego.

EEG activity was recorded monopolarly with Ag/AgCl electrodes over nine sites: F3, Fz, F4, C3, Cz, C4, P3, Pz, and P4 (according to the International 10-20 system of electrode placement), referenced to linked mastoids. All scalp sites had were amplified 10,000 times and bandpass was .1-100 Hz. EOG activity was recorded through an electrode placed over the right orbital bone. Eye activity was magnified 5,000 times and filtered from .3-100 Hz. All electrode sites had an impedance of less than 5 kOhms. Subjects' hand movements were detected through two joysticks (Gravis), while a foot pedal device (CH Products) recorded foot movements. All data (subjects' movements and electrode data) were sampled at 256 Hz and were recorded using the ADAPT software package.

In single movement trials, subjects performed 10 minute long trial blocks during which they made voluntary movements of either hand or foot with at least a five second delay between movements. The movements could be of any one limb, and they were instructed not to worry about randomizing which limb was moved or ensuring a fair distribution of different limb movements. Instructions were identical for multiple movement trials except that subjects were asked to move any two limbs simultaneously.

2.2.3 Results

The data obtained in this study remain under investigation. It is clear that the RPs preceding 2 types of combined movement (left foot/right hand movement and right foot/left hand movement) have a significantly larger peak amplitude than any other single or combined movement. In addition, each of the four single movement types show unique RP and mμ rhythm characteristics. Research is currently directed toward further data analysis and toward exploration of different mechanisms of artificially categorizing the different movement types.

3.0 Future Work

3.0 Classification of RPs using Thoughform (a proprietary software) and other techniques (e.g., PCA, ICA).

3.1 RPs to imagined single and multiple movements.

3.2 Classification of signals using neural networks.

3.3 Detect changes in biorhythm signals, e.g., sleep-wake cycles.