EEG AS COMMAND SIGNAL IN REHABILITATION DEVICES

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Abstract: A BCI real-time system using Steady-State Visual Evoked Potentials generated by stimulus via a standard CRT-computer screen is discussed. The system is working in the synchroneous mode, i.e. using visual input-stimuli. Detection performance is within the range [58–100%] thus rather large differences between subject performances are seen. Also results from basic EEG-research investigating the cortical modulation of movement-related EEG-parameters are presented. The long-term aim is here to recognize cortical activity related to force, velocity and direction in the EEG with the purpose of more advanced orthosis control in rehabilitation.

Keywords: EEG, Rehabilitation, Brain Computer Interface, SS-VEP, Motor Coding

Introduction

Several bio-signals can be used for control and communication, e.g. speech, EMG, EOG, EEG etc. [1] Our focus on EEG-based brain-computer interfaces (BCI) is so far directed towards communication applications using the Steady-State Visual Evoked Potentials (SS-VEP) [2, 3] and towards basic motor-EEG research aiming at applications using the EEG from the primary motor cortex. SS-VEP is shown to provide a fast and "ready to use" communication paradigm which we see as a feasible tool for communication for patients disabled of movement due to e.g. stroke or ALS. In the lane of basic research we have been investigating the cortical modulation of movement-related EEG-parameters. The aim is to recognize cortical activity related to force, velocity and direction desired by the patient for a determined action.

The control of these parameters may be of great importance when performing complex tasks like overcoming obstacles during walking, controlling pedals etc using a future advanced orthosis. In this presentation the performance of our SS_VEP based online communication system will be described (I) also results from our experimental work of decoding cortical motor commands in controlled ankle plantar flexor movements (II) will be described.

Methodology

I)

Specific frequency components can be distinguished in EEG signals recorded over the visual cortex when subjects gaze at blocks flickering at certain frequencies on a standard computer screen.

Seven healthy subjects were presented to a matrix of 3 by 3 flickering squares numbered from 1 to 9 (area: 4 cm², stimulation frequencies: 5.0, 7.08, 7.73, 8.5, 10.63, 12.14, 14.16, 17.0, and 9.44 Hz) shown on a 21'' CRT standard screen with a refreshment rate of 85 Hz. The subjects was seated 50 cm from the computer screen. The subject was instructed to "dial" his/her phone number , birth date, and the numbers from one to nine, by gazing at the different numbered squares on the computer screen, see Figure 1.

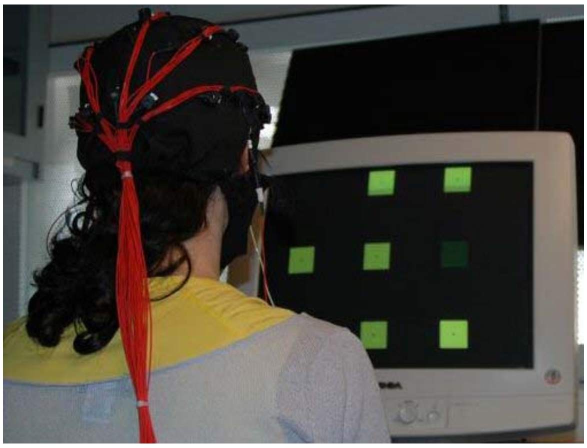

Figure 1: Recording session using SS-VEP

Subjects were instructed to pass to the next number after they heard a computer generated spoken number, whether or not it matched with the desired. Each phone number and birth date was dialed three times and numbers from one to nine were dialed four times, giving a total of 81-85 numbers depending on the phone number and if the month of birth had one or two digits.

The EEG signal was recorded from the Oz electrode, referenced to the left ear lobe sampled at 500 Hz using a 0.5 Hz high pass filter, a 75 Hz low pass filter and a 50 Hz notch filter.

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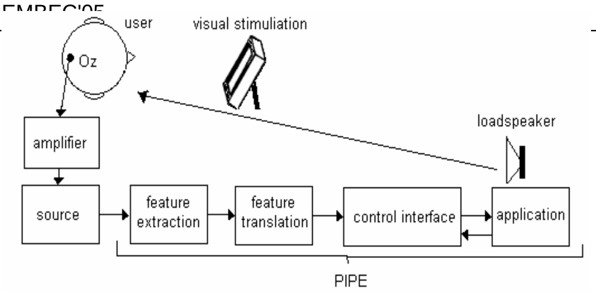

Figure 2: SS-VEP system diagram. The loudspeaker gives audiotive feedback about the detected symbol.

EEG data acquisition was done using a Nuamp 40 channel system (Neuroscan Inc.). Stimulation, data collection (via Scan 4.3), feature extraction and detection was controlled by a modular C++software system, developed at Aalborg University, running on a Windows XP platform, see Figure 2.

Online extraction of SS-VEP features and classification is accomplished by power spectral analysis using FFT-based periodograms on 4 sec EEG-data and detection of amplitudes in the first, second and third harmonics. The subjects were given feedback as an auditory playback of the detected number using a sampled voice [4, 5].

The required training time is negligible when using SS-VEP as compared to EEG-based methods using event-related desynchronization/synchronization (ERD/ERS) [6], for instance. Additionally, relatively high detection speeds are possible. Using SS-VEP based BCI some control of eye movements is still needed prohibiting use for subjects without eye motor control.

SS-VEP appears as a fast and “ready to use” potential communication tool for patients impaired by e.g. stroke or lesions on the spinal level.

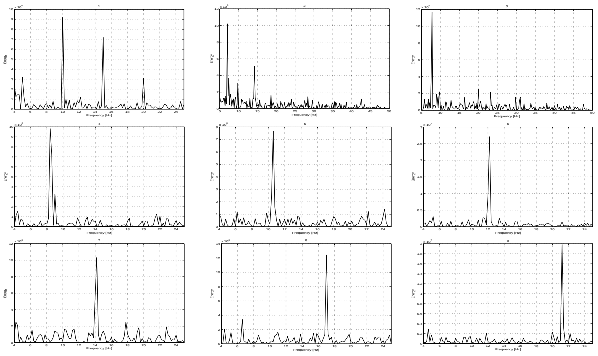

Figure 3: EEG power spectral densities from 9 SS-VEP symbols. Frequencies shown from 4-25Hz. Amplitudes in V^2/Hz

II)

One aim of our basic EEG research is to recognize cortical activity related to force, velocity and direction desired by the patient for a determined motor action. The control of these parameters may be of great importance when performing complex tasks like overcoming obstacles during walking, controlling pedals etc. using a prosthetic or neuroprosthetic device.

Ankle plantar flexor movements from nine healthy subjects were monitored by EMG and force recordings as the subjects followed a visual feedback instructing them about 6 different, measured by speed and force, executions of the flexions.

Surface EMG was recorded (Gain 1000, FS=2000Hz, LP=1000Hz, HP=10Hz), from Soleus (SOL) muscle and Tibialis Anterior (TA) using Ag/AgCl electrodes (Medicotest). Post-hoc, the raw EMG data was high-pass filtered at 10 Hz, rectified and low-pass filtered at 6 Hz. 24 EEG channels were recorded using a custom made cap with extra electrodes around primary motor cortex (FS=500Hz, HP=0.5Hz, LP=75Hz, Nuamp, Neuroscan Inc, Scan 4.2SW) at positions FC1, FC2, CF13, CF1, CFZ1, CFZ2, CF2, CF24, C3, C13, C1, CZ1, CZ, CZ2, C2, C24, C4, CP3, CP1, CPZ1, CPZ, CPZ2, CP2 and CP4 referenced to common reference (A1, A2). Four EOG channels were recorded for noise reduction purposes. Recording sweep started and lasted for 6 s (3 s before the platform trigger and 3 s after), see Figure 4. The ankle plantar flexor force was measured as the torque (expressed in Nm) exerted on a pedal, instrumented with strain gauges (10 mV/Nm) from which signals were input to an A/D board with a sampling rate of 500 Hz.

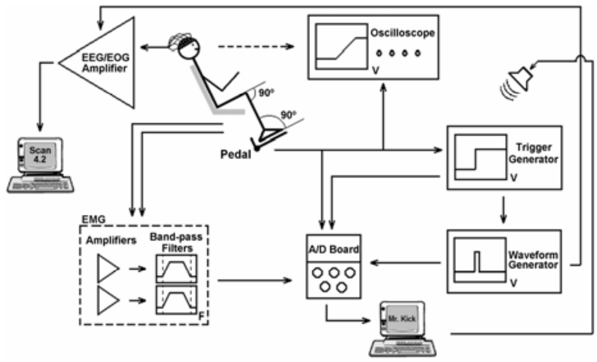

Figure 4: Setup for MRP-recordings [8].

Results

I)

Experimental SS-VEP results from 7 healthy subjects show correct detection in 79.7% [57.7-100%] of the trials using on-line SS_VEP. The effective signaling rate is 9.3 [7.2-11.5] symbols per minute. The detection is implemented using a conservative strategy favoring true detections on the price of speed, see Figure 3.

II)

EEG were analyzed using averaging (30-50 sequences) and the amplitude of the MRP's in the RP, MP and MMP windows (Readiness -, Movement - and Movement Monitoring Potentials) [8], were compared.

The main observations from the analysis, see fig. 5, of the MRPs were that the readiness potentials (RP) demonstrated a statistically significant discrimination between low and high torque amplitudes and that the RP, the motor potentials (MP) and the movement-monitoring potentials (MMP) could be statistically differentiated among the different rate of torque developments (RTD).

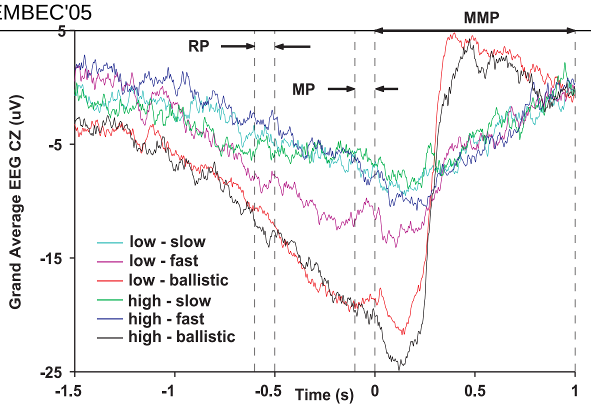

Figure 5: EEG grand average data of CZ electrode including 9 subjects performing six different isometric tasks. RP: Readiness Potential, MP: Movement Potential, MMP: Movement Monitoring Potential. The different traces illustrate foot movements with different velocities and amplitudes. [8].

Discussion

I)

The required training time is negligible using SS-VEP compared to alternative EEG-based methods using e.g. ERD/ERS as principle, and relatively high detection speeds are possible, even though some control of eye movements is still needed [6]. The current efforts on this kind of BCI are directed towards the implementation of the “multi-tap” alphabet (like those used in text messaging of mobile phones) in connection with predictive text input in order to speed up the information transfer rate and promote an efficient communication tool for patients.

II)

The results from analysis of the MRP's indicate that RP is a suitable parameter for differentiation between levels of isometric plantar flexion torque and MP and MMP are sensitive to a differentiation between RTDs. The correlation between MRPs and motor tasks involving different rates of torque development and levels of torque suggests that MRPs may comprise a potential solution for programming of intended movements to be executed by systems based on neural rehabilitation technology.

Conclusion

The studies presented here shows that a simple yet relatively fast BCI's can be obtained using the synchronized method of SS-VEP utilizing EEG as a command signal. This BCI based on SS-VEP appears to be a promising approach since accuracy of up to 100% can be achieved with symbol signaling rate of 12 chars per minute. Besides, the required training time seems to be negligible. Higher detection speeds are possible, even though some control of eye movements is still needed in this synchronized paradigm. The current efforts on this kind of BCI are directed towards the implementation of the “multi-tap” alphabet (like those used in text messaging of mobile phones) in connection with predictive text input in order to speed up the information transfer rate and promote an efficient communication tool for patients.

Our study of MRP's shows that it is possible to obtain relatively complicated information from EEG recorded over primary motor cortex pointing towards more complicated control strategies using EEG in rehabilitation devices in the future [8, 9].

Moreover, the resemblance of this cortical modulation in imaginary movements has also been investigated, to be reported elsewhere, looking to the application of BCIs in patients which are deprived of normal neural pathways.

A major challenge in using the MRP is if relevant components can be detected from the raw EEG recordings online. Presently it is needed to average several responses before the MRP becomes detectable in the EEG signal. One of the major challengers in systems using asynchronous EEG based command signals is the low information transfer rates of maximum 5-25 b/min [7] Achievement of greater speed and accuracy depends on improvements in signal processing, translation algorithms, and in certain cases user training. These improvements depend on increased interdisciplinary cooperation between neuroscientists, engineers, psychologists, and rehabilitation specialists. But the EEG certainly seems to have potential for being the command signal for user interfaces for disabled without motor functions and thus no alternative signalling capabilities.

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