

Development of a Brain Computer Interface (BCI) Speller System Based on SSVEP Signals

Movahedi M.M.¹, Mehdizadeh A.R.^{*2}, Alipour A.^{3,4}

ABSTRACT

BCI is one of the most intriguing technologies among other HCI systems, mostly because of its capability of recording brain activities. Spelling BCIs, which help paralyzed people to maintain communication, are one of the striking topics in the field of BCI. In this scientific a spelling BCI system with high transfer rate and accuracy that uses SSVEP signals is proposed.

In addition, we suggested that LED light sources can provide proper signals for speller BCIs and they can be used in future.

Keywords

BCI, SSVEP, Signal processing, Speller

Introduction

There are millions of people all around the globe who cannot communicate with other people because of their impaired their nervous system i.e. ALS1, Brain Stem Stroke, Cerebral Palsy, Muscular Dystrophies, Multiple Sclerosis, etc.

People who have sustained these diseases are generally called Locked in syndrome patients. These patients hold the required cognitive abilities for language comprehension and speaking, but they can't communicate with other people just because of few impaired nerve fibers.

Fortunately, this is not the end of the story for these people. It is possible to bypass the damaged neural fibers and connect them to a device which acts based on the user's intention and it's the basic concept of a BCI system.

This type of communication technology was available since 1970s when early models of this device developed for animals [1]. Eventually, in the 1980s the brain computer interface (BCI) technology, a particular type of human computer interface (HCI) was introduced.

A BCI system measures the neuronal activities in order to yield the proper response for the user based on their intentions.

A BCI system provides communication ability for its user, and it does not need the user's movements [2]. BCI's can be divided into two different types, invasive and non-invasive. In spite of the invasive BCIs that are considered as complex and impractical, on-invasive ones are as-

¹Faculty Member of Medical Physics and Medical Engineering, Department of Medical Physics and Medical Engineering, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran

²Assistant Professor of Medical Physics and Medical Engineering, Department of Medical Physics and Medical Engineering, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran

³Conscioustronics foundation, Shiraz, Iran

⁴School of pharmacy, Shiraz University of Medical Sciences, Shiraz, Iran

*Corresponding author: Mehdizadeh A.R. Department of Medical Physics and Medical Engineering, School of Medicine, Zand Blvd, shiraz, Iran
E-mail: Mehdizadeh@sums.ac.ir

sumed to be the most promising BCI systems.

Two different instruments are routinely used to measure neuronal activities, EEG and FMRI.

Generally a BCI system translates neural activities into computer commands and it has constituted from four main parts [3]:

1. Signal acquisition
2. Signal classification
3. Transfer classified signals to the output device
4. Integrate signals with an operating protocol

Although every year BCI technology finds new applications in wheelchairs, robotic arms, computer games, etc. its basic and major uses remain the same which is to make speller BCIs [2].

A speller BCI translates its user's intentions to a single character on the screen.

One of the challenges in contemporary BCI systems is to achieve higher transfer rates and accuracy.

When there is enough neural information present, the accuracy is guaranteed and the next important factor seems to be the temporal resolution.

Two different instruments are routinely used to measure neuronal activities, EEG and FMRI.

Taking these points to account, choosing EEG for most of the BCI systems sounds appropriate because it has enough neural information to achieve a reasonable accuracy and temporal resolution to provide appropriate transfer rate.

From 1998 when first speller device introduced, different kinds of BCIs were used. A quick review on the previous systems could be beneficial in this part.

In order to make a BCI spelling device, basically three types of signals are used:

- ERPs: event related potentials
- Motor Imagery

SSVEPs: steady state visual evoked potentials

ERP

ERPs are signals that could be detected after an event (or a specific process in the brain) with an EEG device.

The first speller device manufactured by Farwell et al in 1998 works based on P300 ERPs and oddball paradigm [4].

The system shows a row-column of characters which illuminate respectively and if the illuminated row of character has been intentioned by the user, the ERP is detected.

The same sort of process is used to determine the column of the characters and characters will be typed in the screen.

From that time, a few attempts have been devoted to expand the device.

Motor Imagery

In this type of BCI the user imagines the limb movements and with imagination he could define the intentioned character. The Airlab speller device is a model of this kind [5].

SSVEP

When somebody looks and focuses on a flickering light source, a specific type of signals starts to elicit in parietal and occipital cortex. These signals are called "steady state visual evoked potentials" [6].

The signals' frequency depends on the source's flickering frequency and the SSVEP signals could be acquired with a flickering light source in the range of 1-100 Hz frequency [7].

Although SSVEP signals are mostly used for neural pathways damage diagnosis, but they can be used in BCI systems [8, 9]. In addition to this point, VEP based BCIs have been used with several processing techniques such as ICA [10], wavelet and furrier transforms [11, 12] or EEG spectral analysis [13].

VEPs are divided in three categories based

on their amplitude. There is a reverse relationship between the frequency and amplitude for these signals [11] i. e. a 9 Hz flickering source

elicits a wave which has two times more amplitude than a 59 Hz flickering light source. Besides, signals with higher amplitudes can

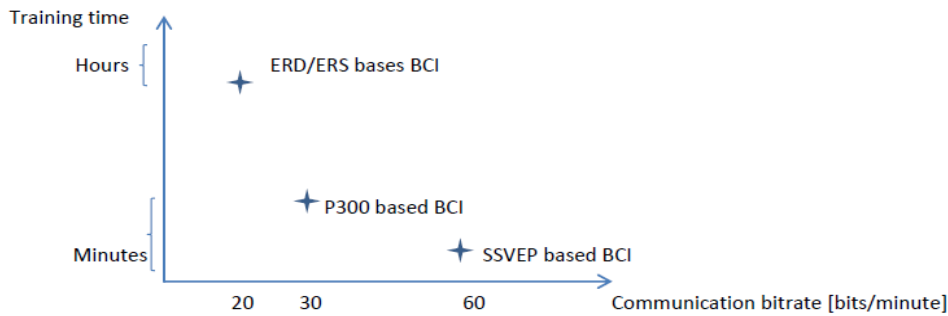


Figure 1: A comparison between three types of BCIs based on their communication bitrate and training time [8].

be used more efficiently than low amplitude signals.

The first BCI which used SSVEP was introduced in 1996 [8]. The advantageous point of SSVEP BCIs is their high speed and the low training time among other BCIs, as demonstrated in figure 1.

Cecotti made a spelling device which works based on SSVEPs and it needed a four parted flickering screen [14]. His spelling system had a hierarchical paradigm in the program that restricted the user to select his intentioned character through three consecutive steps.

Gao et al reported that they have built an “environmental controller” system with SSVEP

which could provide each of its 48 commands just at one single step (high transfer rate)[15].

Gao’s device uses a LED plate of 48 commands instead of a screen therefore it gained a better speed. Although a SSVEP BCI is capable of achieving high transfer rates because there is only four options in each step for the user in the Cecottie’s system, the capability of a SSVEP based BCI remained unused.

Putting all information together, we suggest a new spelling BCI by combination of LEDs (as stimuli) and SSVEPs (as signals). This BCI is capable of providing fast and accurate communication for its users due to providing the user with the characters just in one-step.

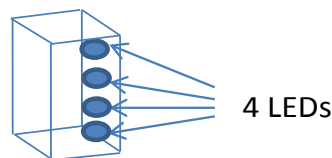


Figure 2:
 a) Schematic picture of the character (one of Arabic capital letters),
 b) 3D scheme of a character, the visual keyboard constitutes from 34 of these characters.

Methods

Stimuli

A visual keyboard is used to provide the desired stimuli. The visual keyboard constitutes of 34 Flickering light sources representing 34 characters (32 Farsi alphabets, space and backspace). Each character comes with a group of 4 green LEDs covered by the character scheme in a way that the light beams could pass through the hollow space of the character covering. Details are depicted in figure 2.

Each group of LEDs flicker in a pre-determined frequency between 6-18 Hz, therefore each character has its particular flickering frequency. (Based on Gao's report, distinction between 0.5 frequency differences is possible, thus each group has at least 0.5 Hz frequency

difference.)

Then the visual keyboard which is a compact set of the mentioned 34 characters provides the required stimulation module for SSVEP signals.

User's protocol

The user of the system is supposed to sit still and focus on each intended character so that the system can detect and process the characteristics of each SSVEP signal.

Signal acquisition

The EEG machine, nr sign 3840 used to acquire SSVEP signals from the O1 and O2 electrodes with the sampling rate of 1000/sect then the signals transferred to the computer for the processing stage.

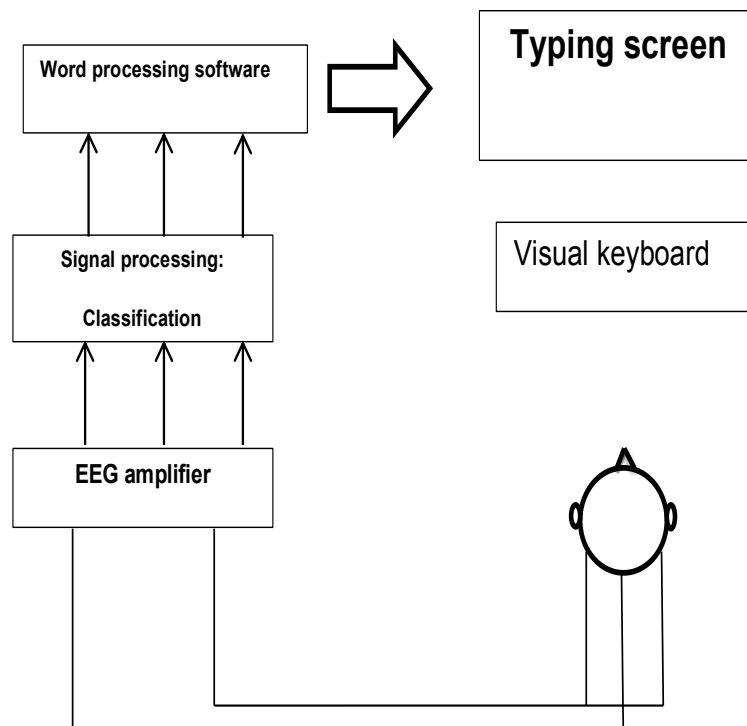


Figure 3: Schematic demonstration of the speller BCI system.

Signal Processing and word processor unit

Signals need a low and high pass filter of 5 and 20 Hz then the fast Fourier transform is used to determine the SSVEP signal's power and frequency.

Signal processing program classifies the detected SSVEP to its character and then sends it to the word processing unit. Word processing unit shows the classified character on the typing screen. A schematic demonstration of the speller BCI system is provided in figure 3.

Discussion

In comparison between different types of brain activity signals, SSVEPs are easier to use and process.

This advantage seems to origin from characteristics such as high signal to noise ratio, large amplitude and easy acquisition setup in SSVEP waves.

However, SSVEP based BCIs are losing their popularity because of gaze tracking systems [3].

Gaze tracking systems can find the user point of gaze and they can do the same thing as speller BCIs at a lower cost and complexity. By the way, BCIs still have their intriguing characteristics mainly due to the "brain activity measurements".

One of the interesting points in SSVEPs is the processing algorithms.

Processing algorithms of SSVEP BCIs can be used for many purposes beside their own purpose i.e. a speller system would readily be converted to a wheelchair by slight changes in algorithms.

They have this merit because they work based on flickering frequencies not mental tasks and Flickering lights could represent almost any kinds of commands.

The proposed SSVEP based BCI speller could be used as a language communication provider for locked in syndrome patients. De-

velopment of this system is an attempt to assist patients with the communication problems to find their role in the society and feel more independent during their daily activities.

Conflict of Interests

None declared.

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