Eye Blink Spelling Device as a Brain Computing Interface Using EEG

Survey Paper on Eye Blink based Spellers for the disabled.

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Abstract: Brain Computer Interfaces or BCI's are a type of human-machine interfaces which allow us to interpret the electrical activity taking place between the dense interconnected clusters of neurons or brain cells. Although it is extremely difficult for us to detect a single neuron's impulsive activity, we can easily collect signals arising from result of thousands of neurons firing in synchronization. The human brain and a computer can thus communicate using this new medium. It acquires signals from the human brain, processes and transforms them into machine instructions in order to do specific actions. Not only the visually impaired but also patients suffering from neurodegenerative disorders like amyotrophic lateral sclerosis (ALS), Alzheimer's disease, Huntington's disease and Parkinson's disease can be benefited if their eyes could become another way of communication instead of just visionary aids. The goal of this paper is to throw light on some of the notable interactive systems based on EEG (electroencephalogram) focusing mainly on virtual keyboards and spelling devices.

Keywords: Brain Computer interface, EEG, ALS (Amyotrophic lateral sclerosis), Parkinson's disease, Huntington's disease, motor neuron, virtual keyboard.

1. Introduction

The evolution of technology leads to significant changes in the way we use interactive systems. With increasing consumption of tablets and smartphones, it can be observed that interaction between users and applications will eventually take place only through smaller displays and touchscreens. With the advent of new technologies, different human body parts can interact with machines. For example: D.Srinath demonstrated the possibility of using human skin as a touch interface [1], Pablo Diez presented a wheelchair controlled by brain waves[2], and Kara Pernice proposed an eye-tracking system [3].Joseph Murphy proposed to control a television using a muscle above the ear ,which lost its function along with human evolution.[4]

2. Literature survey

2.1 Brain Computer Interface

BCI or MMI (Mind Machine Interface) revolves around reception of signals captured directly from our brain and processing them further. So far three techniques are known to carry out the same namely:

1. Invasive technique
2. Partially Invasive technique
3. Noninvasive technique

Invasive capture involves introduction of implants into user's encephalic mass [5], directly through the skull, providing high quality signals. This however causes great inconvenience and poses great risks to the human health. In case of partial invasive capture, implants are placed under the skull without drilling the brain (as in case of invasive capture). Given the fact that it does not harm the human health in any way, the reduced quality of signals obtained, can be to some extent neglected. Noninvasive capture on the other hand gathers information without any implant since sensors are placed on the scalp, fully external to the body. Noninvasive BCIs prove to be more convenient and easier to use and at the same time provide reasonably acceptable signal capture. Moreover it is the only technique imposing no threat whatsoever. For the same reason, this paper focuses only on the noninvasive BCIs.

Cerebral information can be obtained using three techniques:

1. Electroencephalography(EEG) [6]
2. Magnetic resonance imaging (MRI) [7].
3. Near-Infrared Spectroscopy (NIR).

2.2 Electroencephalography and its Application

Electroencephalography is a method in which the voltage fluctuations (electroencephalograms) arising from ionic current within the neurons are recorded over a period of time using electrodes placed on the scalp (hence is noninvasive).Along with cerebral activity however, it tends to record electrical activities arising from sites other than the brain. Such recorded activity, which is not of cerebral origin, is termed artifact. These artifacts can be divided into two types: physiologic and extra physiologic artifacts. Extra physiologic artifacts arise from outside the body (like equipment, environment). While physiologic artifacts are generated from the patient, they arise from sources other than the brain (other body parts like eyes). Of the eye induced artifacts, the most significant are caused by the potential difference between the cornea and retina. This is in fact quite large as compared to cerebral potentials. When the eyes and eyelids are completely still, this cornearetinal dipole does not affect EEG. Electrooculography [8] revolves around detection, identification and measurement of the potential difference (electrical) which is believed to be existing between the front and back of the human eye. The resulting signal is thus called the Electro-oculogram and the technical term foe their magnitude measurement is called Electrooculography or EOG. Primary applications of EOG include diagnosis of eye disorders and recording eye movements.

Since severely disabled people are more or less a burden on the society and families, they couldn’t perform their daily life regularly. Assistive technologies have been therefore developed to play a vital role in helping paralyzed persons. It will not only improve the ability to control their environment, but will also assist them to be employed, reduce the workload of family members and reduce their health care cost. One such disease being the ALS (Amyotrophic lateral sclerosis)[9]. Most of the affected individuals have to rely on others for simple everyday tasks. This also includes, for some cases, the usual communication with the environments. Hence they mostly require personal assistants who interpret their motordisabled gestures to communicate with the outside world. The parts of the body which don’t get affected are the muscles which simulate eye movements, bladders and bowel sphincters.

There are no scientific evidence to prove the usability of BCI’s for ALS patients. Although many communication systems have been developed for physically challenged individuals, the research for spelling devices and virtual keyboards still remains obscure. This study scrutinizes the usability of different BCI systems for text typing for people with ALS and similar disorders. Surprisingly the EEG-receptions from ALS patients are found to have the minimum amount of artifacts i.e. EMG’s (Electromyography) [10]. BCI Applications can therefore make use of the controlled eye event signals as valuable inputs.

2.3 Brain waves

Brain waves [11] (EEG signals) are differentiated into five different categories depending upon the different frequency ranges associated with them:

Table 1. Types of Brain Waves

Type	Frequency Range	Dominance/Association
Infra Low	Below 0.5 Hz	Brain timing and network function
Delta (δ)	0.5 Hz to 3Hz	Deep restorative sleep and healing process
Theta (θ)	3 Hz to 8 Hz	Sleep, deep meditation, gateway to learning, memory, and intuition
Alpha (α)	8 Hz to 12 Hz	Mental coordination, calmness, alertness, mind/body integration and learning.
Beta (b)	12 Hz to 38 Hz	Problem solving, judgment, decision making, focused mental activity
Gamma (ɤ)	38 Hz to 42 Hz	States of universal love, altruism, and the higher virtues

3. Survey

This section briefly describes various endeavors to develop a spelling device (virtual keyboards) for physically disabled people. In most of the attempts, different patterns based on these signatures were used to map alphanumeric characters on a virtual keyboard and words were generated. Multiple samples were collected from different subjects with voluntary eye blinks. Experiment based analysis of these samples shows that a human eye blink lasts for 500 milliseconds (ms) and the time gap between the two voluntary eye blinks is less than 1000 ms. The average movement of the eye was monitored using a timer with a waiting period of 1000 ms.

3.1 Virtual T9 Prediction Keyboard

T9 [12] stands for Text on Nine keys, uses nine keys to represent all English alphabets as shown in Figure 1.Multi-tap approach used in traditional mobile phones is not used at all. The virtual T9 keyboard consists of four regions, namely keypad region, current word region, suggestion region, and phrase region. In equally timed cycles of three seconds, each of the keys is highlighted. The highlighting process begins from the keypad region and navigates to other regions based on the user input. By blinking twice the user can select the highlighted key. Once a character is chosen, the character is appended to current word region, and five suggestion words are displayed in the suggestion region. In three second intervals the words in the suggestion list will also be highlighted. Again the user can select any one of the highlighted words from the suggestion list with two eye blinks, thus sending the words to the phrase region. Backspace button will be highlighted for three seconds. The user, if wishes to clear the last character will have to blink twice in this time period. Same highlighting and selection cycle is used for sending the word in phrase region to TTS, which ultimately plays a synthesized speech for that respective word. This process repeats till the application exits.

3.2 Virtual ABC Prediction Keyboard

The design of virtual ABC [13] keyboard, shown in the Figure 2 is more or less similar to the design of the virtual T9 keyboard. All the features of the virtual T9 keyboard are implemented in ABC Keyboard as well, along with the accessibility to speak non-dictionary words, speaking out names and a few other features.

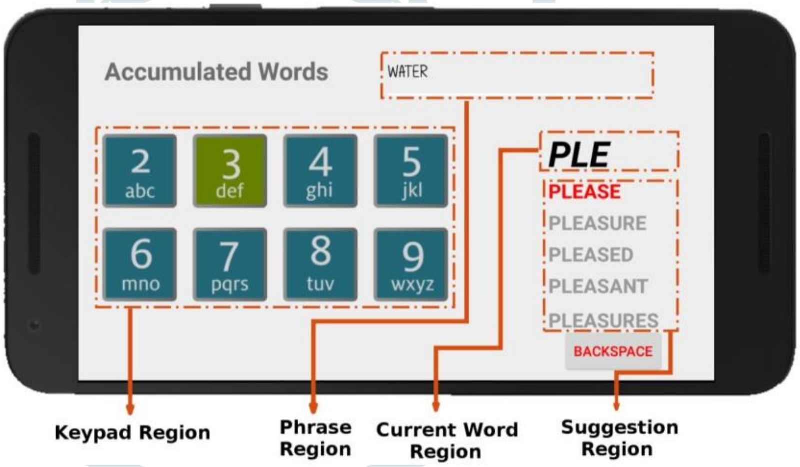

Figure 1: T9 Keyboard

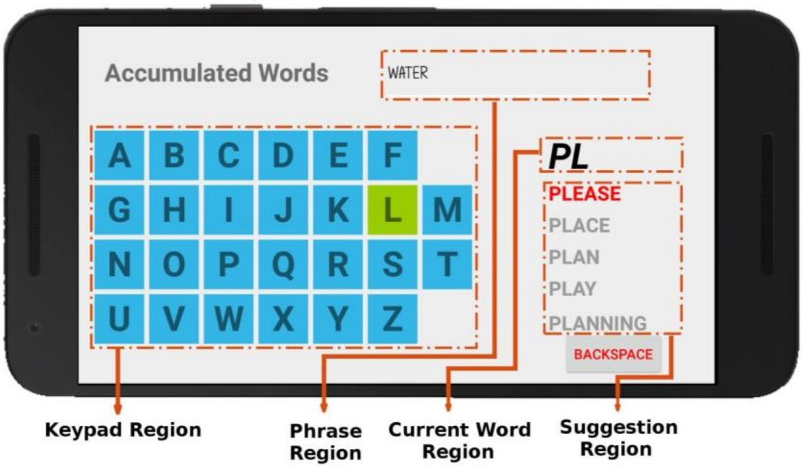

Figure 2: ABC Keyboard

In the proposed work, a BCI is developed for individuals with speech disability where EEG based eye blinks are detected to produce a sequence of English words that are finally synthesized to produce speech output. The next challenge was considered to be the design of similar keyboard and speech output interfaces for other languages.

3.3 P300 speller system

This speller device consisted of two entities: a “EEG acquisition software” and a separate keyboard which had 35 symbols and a backspace key composed in a 6 × 6 matrix. When focusing on a distinct object amid a collection of similar objects, the human brain is found to give rise to a P300 signal [14]. The positive voltage deflection lasting for 300 milliseconds is called a P300 signal which ascribes the name to this speller. To generate ERPs (Event Related Potentials), the rows and columns were intensified randomly, intensifications being block randomized in a number of events equal to the number of rows and columns. The selection of a particular character could be done by recording the P300 signal (if elicited for that character). The user on the other hand was made aware of that the reception for that character has started with the help of a smiley face. This smiley face was superimposed on the characters after equal intervals of time. Smiley faces were used instead of conventional glowing of characters as it was found during experiments that these could elicit stronger P300 signals.

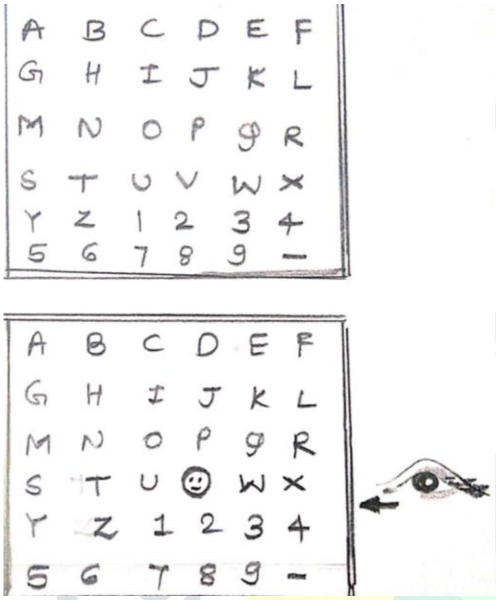

Figure 3

Machine Learning algorithms were used to train the system to predict the top 10 words that had the highest probability and maximum frequency of occurrence. The same flashing principle was used for full words as for characters, to allow their selection via the P300 detection, smiley faces were briefly overlaid on each word. A blank space followed each full word that was formed. One out of the 21 participants had fatigue during the experiment and hence could not be examined for observations. All of them had a normal gaze control when clinically examined. Out of those 20, 8 were able to use AAC (alphabet keyboard with a voice synthesizer) and gave positive results when neuropsychological tests were carried out.

P3000 proved to be effective for the presented study as far as the communication for ALS patients with external environments is concerned. This system displayed high efficiency when it came to scheduling of the flashes. The consequent flashes were thus timed keeping in mind the time constraints of a hard real time system.

In 2012, Tobias Kaufmann [15] developed the Optimized Communication System, a P300 BCI speller where a single button automatically configures and adjusts the system. The user presses the button one time to start EEG signal capture, and a second time to stop the capture and use the data collected to configure and calibrate the system. The transmission speed was significantly improved using auto completion. Hence the speller was a distinctive enhancement over others.

3.4 EEG using Biopac MP36

This version captured EEG signals using “Biopac MP36” system. The electrodes were placed on the scalp using the International 10–20 system. The globally recognized method demands for the placement of scalp electrodes on specific regions of the scalp. Identification of these placement sites, also called lobes, is done using simple acronyms. For example letters F, T, FP, and O imply Frontal, Temporal, Pre-Frontal and Occipital respectively. Numbers following these letters could depict the further specification like (2, 4, 6, 8) i.e. even numbers less than 9, referred to the different lobes on right side of the head while the numbers (1, 3, 5, 7) i.e. odd, referred to those on the left side. The name 10-20 stems to the fact that the interelectrode distance is maintained to be either 10 percent or 20 percent of the skull length and skull width. For this speller; regions FP1 and F3 were used. As discussed earlier, noise being a significant EEG artifact had to be taken care of in order to obtain optimal recordings. For the same reason, two hardware filters were used. The setup was then used to test 14 subjects, asked to lie recumbent, but not completely horizontal, on a bed with their eyes closed. This was followed be EEG device calibration and the actual recording.

With intervals of 5 seconds the users were asked to produce sets of eye blinks. The interface was trained in such a way that it could learn to distinguish between the occurrence of single/two/three eye blinks. The entire alphabets containing the 26 letters and the space character (--) were the characters available in the Virtual Keyboard. These 27characters divided into three blocks having 9 characters each as shown in the Figure 4.The letters were inserted into the block as per row major rule which fills each row first before moving on to the next row. The first block thus had letters A to I, the second with J to R, leaving letters S to X with the space in the third one. Spelling out a word involved three selection phases: namely Block selection, Row/Column selection (can also be done if columns are preferred over rows). Lastly the exact Letter selection would take place. Figure shown below gives a clear idea of the selection of the letter “M”.

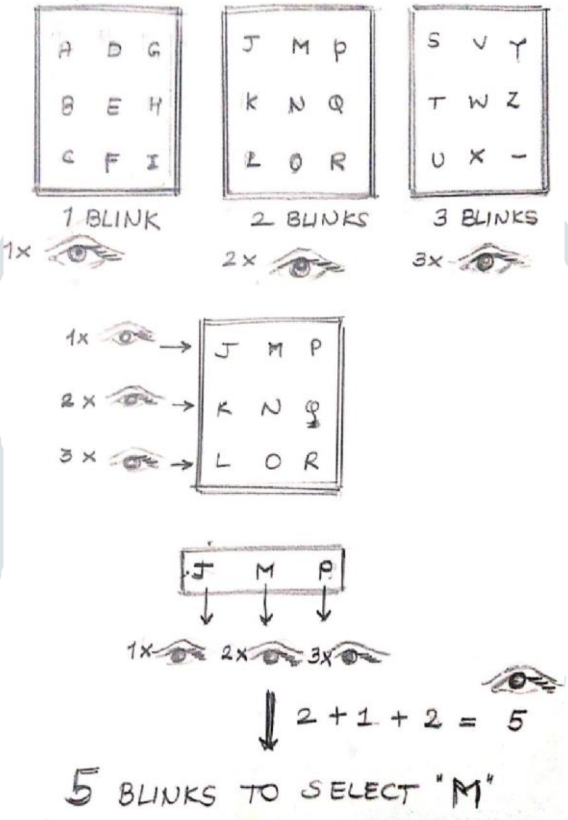

Figure .4

During the first phase i.e. the Block Selection phase, one eye blink resulted in glowing of the first block, informing the user that the first block has been successfully selected. As shown in the figure, same was applicable for the remaining blocks except the fact that these need 2 and 3 eye blinks respectively. First glowing also marked the end of phase 1. The next two sets of eye blinks which correspond to the row/column and individual element selection respectively. The second phase had two options namely row or column selection, the decision for which was not decided by the user but by the system designers themselves. The decision didn’t affect the end result due to the fact that each row and each column had equal number of elements. Same principle (1, 2 or 3 blinks and subsequent glowing of that respective row/column/element) was used to select the first, second or third row/column and the individual first, second or third element from this row/column. In the above example: The second block is selected by eliciting two eye blinks followed by its glowing, the first row(J, M and P) using a single eye blink and finally the desired letter i.e. “M” using two blinks. The required input for this letter was thus 5 voluntary eye blinks. Such a communication system, though inefficient with respect to time, could be valuable for severely disabled people when it comes to expressing deep thoughts, emotions and strong feelings. Reduced eye blink time can be a deciding factor for the efficiency improvement.

4. Challenges

After thorough survey of the BCI systems and their literature, we identified several challenges with implications for user interaction. Most of the existing BCIs result in a high level of fatigue and often are demanding high concentration or attention to quick and intermittent stimulus. In addition to fatigue and inconvenience, BCI may not work since user cannot reach enough level of concentration. Any BCI system is no doubt challenging to put under the right application. One has to take into consideration the underlying cerebral matrix before placing the electrodes on the scalp. The choice of the technology also plays a crucial role.

Furthermore, BCIs restrict the mobility of users .They have to necessarily remain quiet, most preferably sitting down, or in reclined position during any test. In real world applications, using a BCI may require user to walk or run on the street in order to avail the services of the system. In addition, BCIs must also provide comfort to user. An EEG headset must be as easy to carry and use as a headphone to listen to music. The weight of the EEG headgear influences not only the user's mobility but also affects the overall experience with the system and hence must be considered during development. During the EEG signal capture electrolytic gels or conductive pastes are used to increase efficiency of the system. Although these gels and pastes ensure lowest possible resistance to optimal signal capture, they prove to be highly undesirable when it comes to user's comfort. Choosing an EEG headset thus becomes a challenging task if we consider mobility and comfort requirements. In BCIs, systems are required to constantly update and modify themselves to user's signals. These adjustments therefore must be quick and precise. Some of these challenges have been recently overcome with the introduction of advanced BCI's like the XWave by Apple. The new accessory device allows users the control applications like Media Player, Call Receivers, and Texting on their iPhones using brain waves or EEG signals. The technology is very inexpensive and is very beneficial to the organizations as it would improve productivity and efficiency across the globe. XWave Tunes which is a very productive and time saving app, programs songs from an individual's music library in synchronization with their brain wave pattern and how his or her brain responds to different genres. This device is a technology break through; being the first BCI which is available to consumers on such an enormous scale.

Figure 5

5. Conclusion

This paper presented a survey BCI's along with several review-based challenges for BCI in the context of interactive systems. These challenges must be addressed in order to make BCIs adopted in interactive systems more effectively. Furthermore, due to advancements and price reduction of headsets, BCIs will be common in the near future as the kinds of interfaces and interactions are today. Communication through spelling is still one of the main challenges in BCI applications, especially for people with severe disabilities. The BCI literature has exponentially increased in the past few years. Although the BCI's discussed so far are based on only one type of brain activity, the future generations of BCIs will combine the detection of several brain responses with other automated systems and embedded systems. Hardware as well as software enhancements can be made. Gel-free electrode usage, wireless signal transmission are some of them. This can further enhance performance and usability. The spelling devices developed so far have considerable efficiency. Optimization techniques like time reducing devices, use of powerful sensors could improve the efficacy. Although the BCI's are restricted to certain languages like the English or Chinese (in case of P300), the advancements are likely to cover accent specific languages like German, French, Italian etc. along with those having Indian origin.

6. Acknowledgement

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