# Accuracy of a P300 Speller for different conditions: A comparison

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**Abstract**

When using a Brain-Computer Interface (BCI) as a spelling device, the P300-based BCI is mostly common, because of its high speed and accuracy, compared to other BCI paradigms. During the last years many studies have been performed to optimize the single spelling parameters, the stimulation frequency and stimulation intensity. Also different options for the electrode position and classification algorithm were analyzed intensively. But most of these studies were tested on healthy, young participants, subjects who may achieve better results than the people BCIs are mainly thought for: people with motor impairments. The tests were performed in a quiet laboratory environment were all possible outer distractions were filtered out. The aim of this publication is to take the results of a previous study, performed on healthy people within a laboratory (Group A) and to compare them to measurements on two other groups. Group B were healthy people that tested the device in a noisy environment, group C in contrast consisted of people with motor impairments. The conclusions deliver valuable results towards bringing BCIs to the end-user.

## 1 Introduction

A Brain-Computer Interface (BCI) provides a new output pathway and so an additional technology to control external devices. Exploring the possibilities of BCIs, many studies e.g. for controlling virtual environments [1], robots [2], games [3], wheelchairs [4], spelling devices [5], orthotic [6] or prosthetic [7] arms or legs were performed during the last years. To control a BCI different EEG signals can be used, for example slow cortical potentials [8], event related (de)synchronization [9], steady-state visual potentials [10], or the P300 event related potentials [5, 11]. For spelling devices a P300 based BCI is most common, due to its higher number of characters it is leading to a higher communication rate [12]. The P300 is part of the visual evoked potential (VEP). It elicits when an unlikely event occurs randomly between events with high possibility and was the first time described by Farwell and Donchin [13] in 1988.

In a previous study [5] we examined the overall accuracy of a P300 speller for healthy subjects. After five minutes of training the subjects were asked to spell 5 characters. It was up to the subjects to choose between a row/column (RC) speller and a single character (SC) speller. 72.8% (N=81) were able to spell with 100% accuracy in the RC paradigm and 55.3% (N=38) spelled with 100% accuracy in the SC paradigm. Less than 3% of the subjects did not spell any character correctly. Members of group A are the 81 subjects that tested the RC speller. Following this first study, we tested the RC speller with exactly the same settings but different conditions. For group B the environment was changed into a setting that resembled a possible "everyday situation". For that we asked visitors of the g.tec exhibition booth during the CeBIT 2011 in Hannover to instantly test the speller. During the session many other people were walking around, talking to

| Accuracy level (%) | Group A (%) | Group B (%) | Group C (%) |
|---|---|---|---|
| 100 | 72.8 | 62.0 | 30.0 |
| 80 | 88.9 | 18.0 | 30.0 |
| 60 | 6.2 | 12.0 | 10.0 |
| 40 | 3.7 | 6.0 | 0.0 |
| 20 | 0.0 | 0.0 | 10.0 |
| 0 | 1.2 | 2.0 | 20.0 |
| Average accuracy of all subjects (%) | 91.0 | 86.0 | 62.0 |

Table 1: Accuracy levels of the single groups

the subject and also to each other. No exclusion criteria were given, apart of the anonymized EEG data no further information about the subjects (e.g. age or sex) was noted.

The measurements of group C were done at the Fundació Privada Institut de Neurorehabilitació Guttmann, Barcelona, Spain. Here, 10 people with motor impairments, two of them suffering locked in syndrome (LIS), used the device. Inclusion criteria were: Cervical Spinal Cord Injury (SCI) (between C2 and C6) and massive subcortical stroke patients with preserved cognitive function.

# 2 Paradigm and data recording

The EEG data were acquired using eight active electrodes (positions: Fz, Cz, P3, Pz, P4, PO7, Oz, PO8; according to the international 10/20 system) made of sintered Ag/AgCl material. The ground electrode was located on the forehead; the reference was mounted on the right earlobe.

The speller showed a matrix, consisting of 26 characters (A, B,... Z), 10 numerical characters (0... 9), 5 punctuation marks (,.:!?) and 9 extra token (e.g. for ringing an alarm) on the computer screen. The RC speller highlighted a whole column or row for 100 ms (flashing time). The pause between the flashing was 75 ms each time (dark time). Each row and column was flashed fifteen times in a random order before a classification was done. After that the signal processing unit calculated the evoked potential for each character and performed a linear discriminant analysis (LDA) classification to determine which matrix item the subject was attending to. Then the highlighting sequence started again and the subject was prompted to attend to the next character. The subject's task was to attend to (or look at) the character she/he was prompted to spell and count how many times the character was highlighted. The BCI system was trained first on individual EEG data and therefore the subject was asked to "select" (or attend to) the word WATER, one letter at a time. This process took about 5 minutes. After training the BCI using this calibration data, the subject was asked to write the word LUKAS, one character at a time, taking about 5 more minutes. The spelling accuracy of each person was calculated by looking at the number of correctly spelled characters of the word LUKAS. When one person misspelled one character (e.g. LUFAS instead of LUKAS) then 4 out of 5 characters were correct and the accuracy was 80%.

In a second step the accuracy versus the number of flashes were calculated for each classifier, using the validation run of the copy spelling task, where the subjects were asked to spell the word LUKAS. These plots show the reached accuracy for every single number of used flashes. This means that for the accuracy level at flash number one only the data of the first flashing event (each row and each column flashes one time) for each of the single characters was used for classification. For the level at flash number two the data of both, the first and second flashing event was taken, and so on.

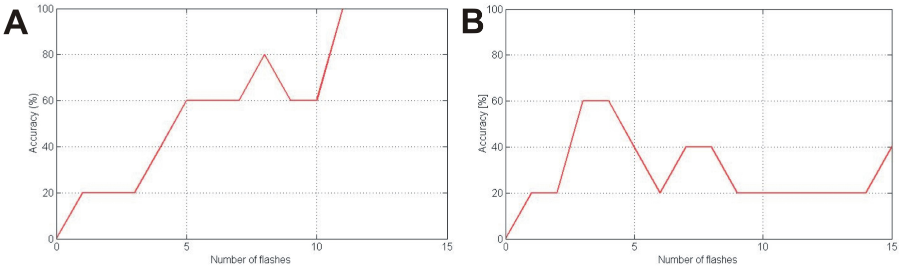


Figure 1: Plot of accuracy versus number of used flashes.

## 3 Results

Table 1 shows the accuracy levels of the single groups. The average accuracy of group A was 91%. In group B were 31 persons able to control the speller with 100% accuracy, 9 persons reached 80%, 6 persons 60%, and 3 persons 40%. Only one participant of this group was not able to spell one single character correctly (accuracy: 0%).

Three out of ten people in group C controlled the speller with 100% accuracy, another three subjects spelled one of five characters wrong (80 %). One person achieved an accuracy of 60%. One subject had to stay in bed during the measurement. However, the monitor was placed on the desk as we did for the other patients, so the configuration did not fit the special needs of this patient. Due to this, the accuracy obtained by him was poor (20%). Two subjects suffered LIS and were not able to control the speller with the given settings. These results were filled in the table for comparison of the accuracy. Nevertheless afterwards another measurement was performed, applying different settings (flashing time: 150 ms, dark time: 100 ms). Here the subjects reached an accuracy of 40% and 20%, respectively.

Figure 1 shows two plots of accuracy versus the number of used flashes for two subjects out of group C. In Figure 1A the patient reached an accuracy of 100% when using 11 or more flashes. Using less flashing events would lead to a faster spelling rate, but produces errors. Of special interest is the plot in Figure 1B, because it was processed out of the data of one of the patients suffering LIS. As aforementioned, we changed the settings and performed the same paradigm again. Here the accuracy is best with only three or four flashes, using more of them even decreases the accuracy.

## 4 Discussion and Conclusion

In this study we compare data from 141 people, divided into three groups. As expected, the overall accuracy of group A, were healthy subjects sat in a laboratory environment, was best. The overall accuracy of group B (healthy people, noisy environment) is only five percentage points lower than in group A. This shows clearly that the device is also practicable within ”everyday life”. The accuracy of group C, is very heterogeneously.Two people suffering LIS were not able to control the speller with the predefined setting. However, changing the settings to a slower spelling rate (flashing time: 150 ms, dark time: 100 ms) resulted in at least one correct spelled character for each patient. Therefore, tuning these parameters seems to be necessary. Giving into account that not more time than two hours was given with each subject, we think that with more training time and different settings it might still be possible to use the device for LIS patients. One important hint for this assumption is the fact that for one of them the accuracy reached 60% (see Figure 1B) when using only three or four flashes (and setting the flashing time and dark time to higher values). We believe that the decrease of the accuracy for an increasing number of flashes is due to the fact that this patient suffers from diplopia so it was difficult for him to concentrate on one character for a longer period of time.

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