

# Transferring BCI skills to successful application controls

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**Abstract.** The goal of our research is to enable various end-users to control applications by using a brain-computer interface (BCI). Since applications—like telepresence robots, wheelchairs or text entry systems—are quite demanding a good level of BCI control is needed. However, little is known on how much training is needed to achieve such a level. A second open issue is, if this can be done at rehabilitation clinics or user-centers, without BCI experts present? In this work we wanted to train BCI-naïve end-users within 10 days to successfully control such applications and present results of 23 severely motor-disabled participants.

**Keywords:** BCI, EEG, motor imagery, application control, end-user, single trial performance, technology transfer

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## 1. Introduction

Brain-Computer Interfaces (BCIs) are no longer only used by healthy subjects under standardized laboratory conditions, but are also introduced to end-users controlling applications in their homes. A challenge in the application of BCIs is the need of training. However, in end users a sufficient level of BCI-performance should be achieved quickly. In this work we want to share the experiences we gained, by starting with BCI-naïve participants, teaching them first to achieve BCI control, evaluating the performance through online BCI experiments and finally controlling applications (like a telepresence robot, a wheelchair and a text entry system). The aim was to do this in 10 days, together with therapists at a rehabilitation clinics or user-centers, and without any BCI experts present.

## 2. Material and Methods

All participants had to start by left hand, right hand and foot motor imagery during calibration recordings. Afterwards the 2 most discriminable tasks were used for controlling the online feedback or the application.

### 2.1. Brain-Computer Interface and signal processing

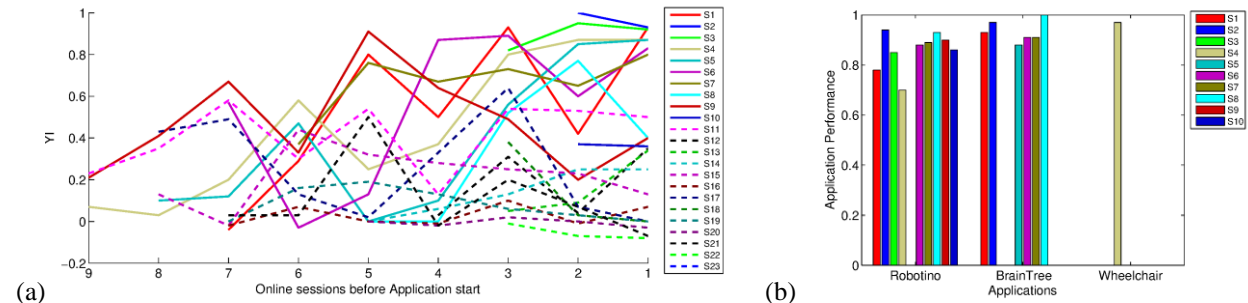
The brain activity was acquired via 16 EEG channels over the motor cortex. From the Laplacian filtered EEG, the power spectral density was calculated. Canonical variate analysis was used to select subject-specific features, which were classified with a Gaussian classifier [Galán et al., 2008]. Decisions with low confidence on the probability distribution were filtered out and evidence was accumulated over time. The BCI training was performed at the clinics without BCI experts present. Only the classifier setup was done remotely by the BCI expert.

### 2.3. Test of different application prototypes

The first application was a text entry system called BrainTree [Perdikis et al., 2012]. Using a series of left and right BCI commands the participants could select letters out of an alphabetically sorted tree. The visualization implements a so-called Hu-Tucker binary tree (based on a language model) which ensures an optimal but not equal number of commands to reach each character. The second application was a telepresence platform based on the Robotino robot [Carlson et al., 2012]. The subject remotely controlled the robot, steering it to the left or to the right within an office environment. In addition, the subject can intentionally not deliver any mental command to activate the default behavior of the robot, which consists on moving forward and avoiding obstacles with the help of a shared control system using its on-board sensors. The subjects saw a video-transmission from an on-board camera of the robot in parallel with the BCI output. The third application was a powered wheelchair equipped with sonars and webcams, which movements can be controlled similar to the telepresence robot, except that the subject is co-located with it. The subject had to drive the wheelchair to reach several targets. All applications were quite demanding for the subjects, since besides the increased workload and the split attention between the BCI and the application [Leeb et al., 2013], it was also necessary to perform the requested BCI action with certain temporal precision.

### 3. Results

Up to now, 23 end-users aged  $42 \pm 14$  years (4 female) have participated once every 1–2 weeks for up to 3 hours/day. Ten subjects (S1-S10; re-ordered in descending BCI performance) achieved a very good level of control and could test the applications. Since the whole experiment was limited to 10 sessions (days), not all subjects could test all applications, or train enough to increase their BCI performance. In one subject we had technical problems; two subjects had to be excluded because of inherent muscular artifacts due to their impairments; and one subject decided to stop participating. The subjects are affected by different levels of myopathy (5), spinal cord injury (13), spino-cerebellar ataxia (1), amputation (1), cerebral palsy (1), or locked-in (2). Figure 1.a shows the performance of the online BCI runs before application start using the Youden index (YI), whereby  $YI=1$  means perfect control and 0 equals chance level. The performances of the applications (see Fig.1b) are reported for the text entry as the percentage of correctly written characters to the total number of written characters [Perdikis et al., 2012], and for the telepresence platform and for the wheelchair as the ratio between the time needed to reach the targets with manual control vs. BCI control [Carlson et al., 2012], all resulting in 1 for perfect and 0 for no control.



**Figure 1.** (a) Performance values (YI) of all online runs averaged per session for all subjects. (b) Application performances of the three applications (Robotino, Braintree, Wheelchair) for the remaining subset.

### 4. Discussion

All subjects who achieved good BCI performance could also control the applications successfully (see Fig.1). Especially whenever end-users reached a  $YI > 0.6$ , they mastered the applications equally well as healthy subjects. This is very important, because having a good BCI control does not guarantee good control over the application, due to the necessary split attention between the application and the BCI. Furthermore, BCI training does not require users to achieve 100% performance every trial, but most applications demand almost perfect performance all the time [Leeb et al., 2013]. Unfortunately only half of the participants could test the applications. Due to the strict time limitations of our experimental protocol, we had to stop the training process of those end-user who didn't reach a  $YI > 0.4$  over two consecutive sessions within 10 sessions (days). However, for some subjects a longer training would have been preferable. The performance drop of subject S4 in case of Robotino resulted from one single run, in which she intentionally delivered wrong commands believing that the target was somewhere else. Finally, control of the applications could be improved by the use of a hybrid BCI, where key commands (e.g. correction of text-entry errors, pausing the movement of the robot...) are delivered through other channels such as residual muscular activity, which can be controlled reliable but not very often (because of quick fatigue) [Perdikis et al., 2012].

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