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BCI Telepresence: A Six Patient Evaluation

T. Carlson[1], L. Tonin[1], R. Leeb[1], M. Rohm[2], R. Rupp[2], A. Al-Khodairy[3] and J. del R. Millán[1]

[1]EPFL, Lausanne, Switzerland; [2]Universitätsklinikum Heidelberg, Germany; [3]Clinique Romande de Réadaptation Suvacare, Sion, Switzerland

Correspondence: T. Carlson, Ecole Polytechique Fédérale de Lausanne, 1015, Lausanne, Switzerland. E-mail: tom.carlson@epfl.ch

Abstract. In this paper we present the results of six motor-disabled patients manoeuvring a telepresence robot via a BCI. Remarkably, although five of the patients had never visited the location where the telepresence robot was operating, they achieved similar performances to a group of four healthy users who were familiar with the environment. In particular, the experimental results confirm the benefits of using shared control for brain-controlled telepresence robots. Shared control empowered all subjects (including the less experienced motor-disabled BCI subjects) to complete a complex BCI task in a comparable time and with a similar number of commands to those required for a manual condition.

Keywords: BCI, Motor Imagery, Telepresence Robot, Shared Control, Assistive Robotics

1. Introduction

BCI telepresence aims to enable people with severe motor impairments to explore environments and interact with friends and relatives remotely. We have already shown that healthy subjects are able to manoeuvre a telepresence robot efficiently using a BCI combined with shared control [Tonin et al., 2010] and that two patients exhibited the same trends [Tonin et al., 2011]. In this paper we confirm that a total of 6 patients achieved a similar performance using a BCI as opposed to a manual input and moreover, that shared control reduced the workload required to maintain such a performance.

2. BCI Telepresence Platform

To drive our telepresence robot (Fig. 1), subjects use a two-class asynchronous sensory-motor rhythm-based BCI [Millán et al., 2004]. The robotic platform and BCI system (pre-processing, feature extraction and classification methods) are described in detail in [Tonin et al., 2011]. In brief, we record 16 EEG channels over the motor cortex and use discriminant power features with a Gaussian classifier. Continuous driving of a mobile robot using discrete commands is a demanding task. Therefore, we use shared control to reduce the burden on the user and to compensate for any inaccuracies in command decision or timing [Carlson et al., 2011]. The default behaviour of the robot is to move forward and avoid obstacles where necessary. The user can then voluntarily deliver one of the two classes (turn left or turn right), or decide not to issue a turning command, which yields an implicit third class known as intentional non-control (INC). These commands are interpreted given the context of the surroundings.

3. Experiment Participants and Protocol

Six motor disabled patients (*d1*–*d6*, see Table 1) and four healthy subjects (*s1*–*s4*, all males) took part in the experiment. The healthy subjects were located in a different room, approximately 15m from the robot, whereas five of the patients were located more than 100km away from the remote

Table 1. *Profiles of the motor-disabled patients, including the motor imagery tasksets*

Patient	***Class 1***	***Class 2***	***Distance from robot***	***Gender***	***Condition***
d1	*both feet*	*right hand*	*~100km*	*Female*	*Myopathy*
d2	*left hand*	*both feet*	*~100km*	*Male*	*Myopathy: spinal amyotrophy-type 2*
d3	*left hand*	*both feet*	*~440km*	*Male*	*C4 tetraplegia*
d4	*left hand*	*both feet*	*~100km*	*Male*	*C6 tetraplegia*
d5	*left hand*	*both feet*	*~15m (different room)*	*Male*	*C5-C6 tetraplegia*
d6	*left hand*	*right hand*	*~100km*	*Male*	*C6 complete tetraplegic*

environment, with one of them even taking part from another country. All subjects were previously trained with the BCI (achieving >70% accuracy over 2 consecutive sessions); none had previously driven a telepresence robot. In the experiment, each subject had to drive along 3 different paths, passing pre-defined target locations [Tonin et al., 2011]. This was done under two conditions: first using a BCI coupled with shared control and second using a manual two-button input without shared control; this order prevented the results from being biased towards the BCI condition, due to learning effects.

4. Results

As a benchmark of task complexity, the average time for healthy subjects to complete a single path in the manual condition was 257±34 seconds, whereas for patients it was 287±61 seconds. Due to personal reasons, subject *d2* was unable to finish the experiments. During the second path of the experiment, subject *d1* delivered a number of incorrect mental commands, believing that the target was elsewhere; hence it took some time and additional commands to bring the robot back to the correct target, therefore this data point can be considered an anomaly and is excluded from our analysis.

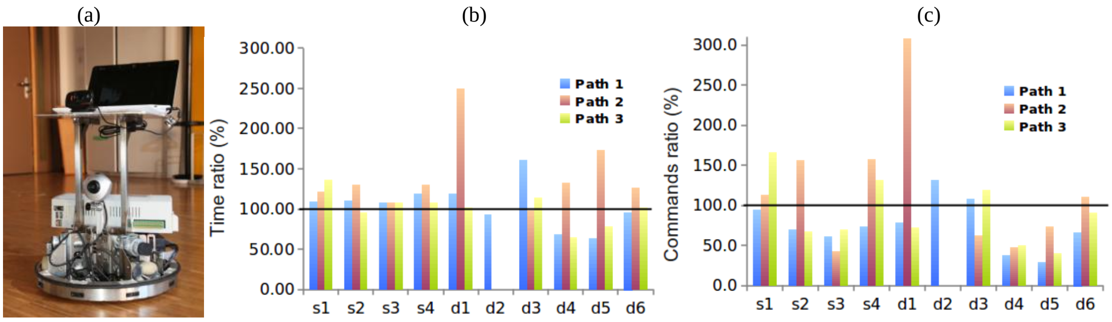

Figure 1. *(a) The telepresence robot, equipped with a camera and screen for interaction; (b) the ratio between the time required to complete the task when using BCI and when using the manual input device;(c) the ratio of the number of commands required to complete the task between the BCI and manual conditions.*

Interestingly, on average, the motor-disabled patients seem to perform better with the BCI than the healthy subjects. First, the mean ratio of time to complete the task for the BCI condition compared with the manual condition is only 105% for the patients, as opposed to 116% for the healthy subjects (Fig. 1); this indicates a lower time penalty for patients to use the BCI. Second, the mean ratio of the number commands required to complete the task for the BCI condition compared with manual condition is only 81% for the patients as opposed to 100% for the healthy subjects (Fig. 1). The number of commands to complete the task can be considered an indirect measure of workload, which indicates that the patients exploited shared control more than the healthy subjects to help reduce their workload.

5. Discussion

In the context of manoeuvring a telepresence robot, these results, which include three times as many patients, add compelling evidence that continues to support our initial findings [Tonin et al., 2011] that: i) when a BCI is combined with shared control, users can achieve a similar level of performance as is attained with a manual (2-button), no shared control condition; and ii) patients are able to attain a comparable level of performance to healthy subjects.

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