Driving a BCI Wheelchair: A Patient Case Study

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Abstract. Our brain-actuated wheelchair uses shared control to couple the user input with the contextual information about the surroundings in order to perform natural manoeuvres both safely and efficiently. In this study, we investigate the feasibility of using our brain–controlled wheelchair with patients in a rehabilitation clinic. Both user and system performance metrics are analysed. We find that the driving performance of a motor-disabled patient at the clinic is comparable with the performance of four healthy subjects. All five participants were able to complete the driving task successfully.

Keywords: BCI, Motor Imagery, Wheelchair, Shared Control, Assistive Robotics

1. Introduction

Brain computer interfaces (BCI) offer the possibility to overcome the barrier of physical interaction when controlling a powered wheelchair, which could be vital in providing independent mobility to the severely motor-impaired. In this paper we describe how shared control can assist users in performing manoeuvres, such that they can achieve similar levels of performance with a BCI as they can in a manual control condition. Moreover we demonstrate that a motor-disabled patient is able to perform at least as well as four healthy participants.

2. BCI Wheelchair

We have equipped a powered wheelchair with wheel-encoders, 10 sonar sensors, a computer vision system for detecting obstacles, and an 8” screen to display feedback to the user, as shown in Fig. 1 [Carlson et al., 2011b]. Since it is difficult to achieve precise and sustained control over a wheelchair using a BCI directly, we blend the user input with the automatic capabilities of the wheelchair, by employing shared control [Carlson et al., 2008]. In this proactive shared control paradigm, the wheelchair’s default behavior is to move forwards and, where necessary, automatically slow down and turn to avoid obstacles as it approaches them. To implement the shared control policy, a number of detection zones were defined in the area around the wheelchair. The user input (“left/right”, to turn; or “no command”, to go straight) determines the high-level initial direction for the wheelchair, then the obstacle densities in the detection zones apply virtual forces that affect the rotational and translational velocities of the chair to avoid potential obstacle, as discussed in [Carlson et al., 2011a].

3. Experiment Participants and Protocol

Four healthy subjects (*H1-H4*), aged 23–28 years, participated in this study. All subjects were experienced BCI users, who had participated in at least 10 hours of motor imagery BCI training, online sessions and other BCI experiments. Furthermore, subjects *H3* and *H4* had previous experience of driving the BCI wheelchair, whereas subjects *H1* and *H2* had no previous experience of driving a BCI–controlled wheelchair. Importantly we also recruited a 34 year old myopathy patient (*P1*) to participate in the study. She was wheelchair–bound and had some previous experience of driving joystick–operated powered wheelchairs.

Before the experiment, participants were given a 30-trial online BCI session (where *H1-H4 and P1* achieved 93.3%, 90.0%, 96.7%, 100.0% and 86.7% accuracy respectively) followed by 15–30mins to familiarise themselves with the wheelchair. The experiment itself consisted of driving a predefined route (~34m) in a rehabilitation centre, passing through one doorway and reaching two separate tables. This was performed in a counterbalanced manner between the BCI condition and a manual (2-button) condition; the same proactive shared controller was active under both conditions. All subjects performed at least two runs of each condition, as can be seen in Fig. 1.

4. Results

In the BCI condition, the patient completed the task in 276±50 seconds, which was 142 seconds faster on average than the healthy subjects (418±108 seconds), as shown in Fig. 1. For the participants that had *no* previous experience of driving the wheelchair (*H1*–*H2*), there was an increase in the time required to complete the task under BCI condition, compared with using manual control. However, for *H3*–*H4*, this increase was only marginal, whereas the patient actually completed the task more quickly in the BCI condition. Moreover, the healthy users issued an average of 51±13 BCI commands to complete the task, whereas the patient completed the same task successfully using only 26±7 BCI commands. Despite an online BCI accuracy of 93.3%, healthy subject *H1* found it difficult to refrain from delivering commands, e.g. when the wheelchair should drive straight. Consequently *H1* unintentionally issued substantially more commands under the BCI condition, which also resulted in a higher task completion time (Fig. 1).

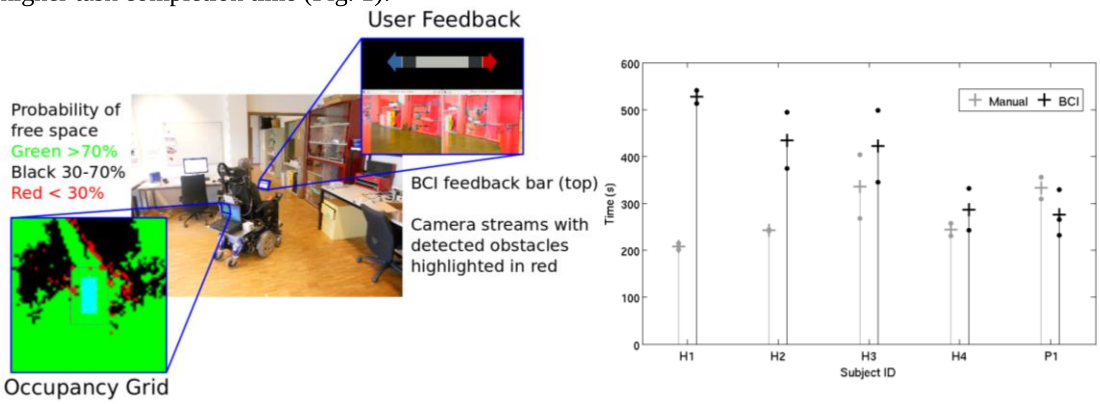

Figure 1. *Left: the wheelchair represents its knowledge of the environment as an occupancy grid, whilst the user is given feedback about the state of the BCI system and the percieved obstacles in the environment. Right: Task completion time (dots are individual trials, crosses are means for each subject/condition).*

5. Discussion

Transferring BCI skills from one task to another is not straightforward; however shared control can help to ease the transition. When a subject progresses from using a BCI to move a cursor on a screen to controlling a mobile robot platform, there is an increase in task complexity, such that more information needs to be processed by the subject and command-timing becomes more crucial. Shared control has been shown to help ease the user workload and allow the user to complete the task successfully and efficiently [Tonin et al., 2011]. We have seen that despite subject *H1*'s good online accuracy, involuntary commands reduced the efficiency when driving the wheelchair. Currently, shared control is can only compensate for such commands that would be inadvisable (or unsafe) to execute. Furthermore, in this study the user is co–located with the robotic device and is therefore subject to many external factors (motion, perceived risk of delivering an incorrect command etc.). Despite this, we have shown that both healthy subjects and a patient have been able to overcome these difficulties, and with the help of a shared control system, were able to navigate successfully and safely in a rehabilitation centre.

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