Implementing a Brain-Computer Interface Wheelchair in Home-Care Setting: Preliminary Result

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Abstract. This main aim of this study is to implement the brain-computer interface wheelchair in a home-care setting for the occupant’s benefit. Two patients suffered from motor neuron diseases (MND) and were recruited from local elderly home care. The wheelchair was set-up and test trials were conducted prior to the data collection. All the challenges faced during the process of implementation were recorded. Solutions were suggested accordingly.

1. Introduction

Brain-Computer Interface (BCI) is a system which acquires and analyzes the brain signals and translates them into commands which later will be transferred into the desired action by an output device [8]. BCI wheelchair research records a rapid growth in the last two decades, however, studies with actual patients are limited compared with healthy subjects towards a new modality-independent interface for a robotic wheelchair [1].

Researchers studied applying the BCI system on patients suffering from chronic diseases [2]. Motor Neuron Disease (MND) is a collective term for a progressive neurological disorder that affects efferent neurons which control the voluntary muscles [4]. These MND sufferers will experience gradual atrophy and weakness of muscles which cause body stiffness leaving optic muscle movement control as last to be damaged [5]. Few types of MND include Amyotrophic Lateral Sclerosis (ALS), spinal cord injury, multiple sclerosis, and stroke. Approximately, there are greater than hundred million motor neuron diseased patients around the globe could be benefited from the BCI technology, with many affected with stroke [2].

Statistics showed that the incidence of MND worldwide is found 2/100,000 cases annually while there are about 600 new cases reported each year in Malaysia [6]. Almost 50% of MND patients are unable to control an electric wheelchair through a common method which is wheeling by hands and walking with the wheelchair by feet. Particularly, these patients are only able to exercise their willpower in the presence of vision and brain signals [3].

BCIs has been developed as neurorehabilitation tools for paralysis patients with an aim to improve their quality-of-life (QoL) and to allow them to live in a normal and comfortable life [7,8]. However, there is a lack of BCI study in the home-care setting. Thus, the present study intends to
implement the BCI-wheelchair in the home-care setting for the occupant’s benefit. However, there were many challenges encountered during the process of implementation. All the challenges were identified and addressed. The potential technical solutions found in this study may contribute to the future problem-solving in the BCI research.

2. Materials and Methods

2.1 Participants

This case study obtained an ethical approval both from Universiti Tunku Abdul Rahman (UTAR) Scientific and Ethical Review Committee and Jabatan Kebajikan Masyarakat Malaysia (JKMM) respectively. Two subjects were recruited from JKMM and informed consent is obtained prior to data collection. The inclusion criteria were the mentally stable patients who suffer from motor neuron disease and wheelchair bound with voluntary participation.

2.2 Equipment

2.2.1 Steady-State Visual Evoked Potential (SSVEP) and Electroencephalogram (EEG) Electrode. SSVEP is used to record a person’s visual frequency with the aid of the EEG electrode. Three standard 10mm gold-plated EEG electrodes are placed on the participant’s scalp: Oz as the signal channel, A1 (left mastoid) and A2 (right mastoid) as reference and ground channels, respectively. Initially, pre-test practice is conducted and followed by the selection practice. The stimulus frequency tested were: 7, 8, 11, 12, 13, 14, and 15 Hz.

2.2.2 SSVEP Test. SSVEP test is conducted using 2 types of selection modes which are (1) SSVEP PreTest and (2) SSVEP Selection. First, a brief on SSVEP PreTest, it starts with 5 seconds of rest/black screen and 5 seconds of flashing and was repeated for 7 times. The test lasts for more than 1 minute. Next, is the SSVEP Selection mode. In this mode, there will be 6 flickering boxes appear at the same time with an arrow pointing to one of the boxes. The end user is required to focus at the pointed box.

2.2.3 Wheelchair Navigation. An autonomous wheelchair is used in this study. Each of the stimuli or flashing box represent a pre-set location which aids in wheelchair mobility. The navigation software will drive the wheelchair to the destination once it is selected. The top laser, SICK NAV350 laser navigator is used for localization and navigation purposes. NAV350 is capable of localizing its current location through the use of reflectors which serves as fixed landmarks [13]. In this study, a total of 32 reflectors (Figure 1) were placed along the navigation pathway. 32 reflectors were pasted on the pillars along the navigation pathway. The reflectors were pasted at the height of 158cm from the base or ground. Length and width of each reflector is 37cm and 8.5cm respectively. The path planning and navigation can be conducted with a predefined map and its known current location. A second laser which is the front laser is used for more accurate measurement of the surrounding obstacle(s). The obstacles can be living or non-living things. Once an obstacle is sensed, the wheelchair will stop
immediately and only moves after the obstacles have been removed. The wheelchair preset navigation route (Figure 2) is set for 46.0m (one-way) and a total of 92.0m (two-way).

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Reflectors pasted on the pillars along the wheelchair route.  
**Figure 2.** Wheelchair Route Map.

### 2.3 Experiment Setup

The experiment was conducted with the participant sat on their wheelchair (Figure 3). The laptop screen was closely aligned in a range of 30-50cm from the subject’s eye level. The trial session was allowed for the subjects to familiarize with the system. Before each trial session, instructions were given in the verbal form.

To be specific, the actual study was intended to be conducted as: The subject will be instructed to select their preset destination just by looking at the flickering box displayed on the selection menu (Figure 4). Each of the flickering boxes represents a preset location which aids in the BCI wheelchair mobility. The selection confirmation will appear as in a binary choice of flickering boxes which are “Yes” and “No”. Once the selected destination is confirmed, the wheelchair will drive them. There is no exact preset duration for steady-state visual evoked potential (SSVEP) selection using an EEG electrode as it solely depends on the users’ will to move around to the preset destination. Furthermore, once the subject makes a selection, the wheelchair will start to move and the subject is free to rest, sightseeing or do any other activities of their interest until they reach their destination.

The BCI wheelchair was tested without the end user prior several times in order to check the safety, control, and its smooth running.
2.4 Data Collection

The challenges faced in terms of subjective, environmental and technical problems were addressed from a wide angle consist of the subject, researchers and the laptop or system. Verbal feedback was collected in terms of the face-to-face interview using pen and paper method.

3. Result and Discussion

3.1 Steady-state visual evoked potential (SSVEP) Response

Two elderly subjects with MND were recruited in this study. Their prominent frequencies recorded were: Participant A: 8 and 11 Hz and Participant B: 7, 8, 11, and, 12 Hz. Remaining other frequency hits were 0 respectively. These were weak brain signals recorded as true positive hits for at least once for each subject. A sum of more than 10 trial sessions was conducted for both pre-test and selection practice. These test trial were conducted with the SSVEP selection without the wheelchair. In this test, the subject has experienced the way to select when using a BCI wheelchair. In this trial, both subjects were unable to select the direction they want to move to for the first few attempts. The rest of their attempts land them to the wrong selection. Out of 10 attempts, Participant A has none correctly selected attempt while for Participant B has 2 correctly selected attempts. Many failed attempts made them tired and bored, these were expressed by the subjects after the attempts. As a matter of fact, for smooth control of EEG-based BCI wheelchair, there should be continuous sensorimotor frequency produced in order to select the wheelchair direction. An EEG-based BCI wheelchair does not ease a control to both elderly subjects in this study. Therefore, an alternate device is preferred for a smooth BCI wheelchair control.

3.2 Challenges/ Issues in Wheelchair Implementation

![Figure 3. Model sitting on a BCI wheelchair. The arrow signifies the distance between the model’s eye and the laptop screen.](image)
This current research studies on the challenges faced in implementing a BCI wheelchair in a home-care setting and its proposed solution. There are, indeed, challenges faced by many researchers [3,4,8,11] in applying a BCI system in-home setup. The challenges divided into three major factors which are subjective, environmental, and technical factors.

3.2.1 Subjective Factor. Subject factors result from the research subject themselves. It ranges from 1) unavailability of the subject due to hospital follow-up and in-house physiotherapy session, 2) poor health condition due to disease progress and illness, and, 3) unable to achieve a sufficient control level due to tiredness, discomfort and distraction were to influence the subject’s control over the BCI wheelchair navigation. As a matter of fact, the subject felt tired due to their sleepless night due to discomfort caused by pain, getting up earlier in the morning, and, lethargy due to aging as both were geriatric subject’s. Also, subjects felt discomfort when the EEG electrode removed together with the surgical tape. Plus, the elderly can be easily distracted with noise, movement by passerby or conversation happens around them. Besides, sweating leads to poor EEG signal as sweat loosens the EEG electrode connection on the subject’s scalp. Poor EEG signal results in destination selection difficulty and, thus, the wheelchair control is disturbed which is a major issue for BCI wheelchair implementation in the home-care setting.

3.2.2 Environmental Factor. The environmental factor is best explained by nature. Firstly, bright sunlight was a major issue there as the wheelchair navigation route is under a roofed walkway leaving the surrounding unroofed. In this case, the bright sunlight produced a glare on the laptop screen which acts as an obstacle for the subject to look and select their destination appeared on the screen.

3.2.3 Technical Factor

The technical challenges were contributed by the laptop or system. The current wheelchair only consists of a 2D laser mounted at 170cm and another 2D laser mounted at the height of 90cm. The position of the sensor limits the obstacle sensing capabilities of the wheelchair in a home care setting where there are multiple dynamically moving obstacles such as other patients on a wheelchair, food trolleys, and cats. The path that can be taken by the wheelchair is narrow and dynamic obstacle avoidance in such a small area by the wheelchair is not possible with the current sensor setup.

4. Proposed Solution

In this section, the potential solutions were listed out for the avoidable factors.

4.1 Subjective Problem-Solution

We are proposing solutions as stated: 1) unavailability of subject can be solved by checking the availability of the subject with their caregivers and draft a schedule accordingly, 2) taking a break from being the research participant is the best choice to offer when they are in ill health and tired body, while, and, 3) distraction can be reduced by reminding them to focus to select and once after the wheelchair starts to move they are free to do their own activities such as talking and sightseeing.
While the poor EEG signals made their selection difficult, therefore, switching EEG electrode to an eye tracker will be the best solution. Moreover, an eye tracker eases the subjects to make the selection as the eye gaze on the screen provides visual feedback to them. It also ensures whether the preset destination is focused and selected correctly. In this way, the end user will be certain with their selection.

4.2 Environmental Problem-Solution

On the other hand, environmental factors can be solved by fixing a black sheet on the navigation laser holding bars as it helps to block the direct sunlight from producing glare on the laptop screen.

4.3 Technical Problem-Solution

For the purpose of the experiment, the dynamic pathfinding feature of the wheelchair is disabled. Fixed waypoints are set as the trajectory for the wheelchair. The wheelchair is programmed to stop upon the detection of an obstacle. The wheelchair will resume movement once it detected that the path is cleared.

5. Conclusion

For a successful implementation of a BCI wheelchair in a home-care setting, there are, indeed, many challenges faced from subjective, environmental, and, technical aspects. However, poor EEG signal is a major issue in a BCI wheelchair control. Henceforth, in this article, the best solution proposed to replace the EEG electrode for end users with poor visual frequency is by substitute it with an eye tracker.

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