Pre-print: Krishnaswamy, K. & Kuber, R., 2012. Toward the Development of a BCI and Gestural Interface to Support Individuals with Physical Disabilities. In proceedings of the 14th International ACM Conference on Computers and Accessibility – ASSETS'12, Boulder, USA, 229-230.

Toward the Development of a BCI and Gestural Interface to Support Individuals with Physical Disabilities

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ABSTRACT

In this paper, we describe a first step towards the development of a solution to support the movement and repositioning of an individual's limbs. Limb repositioning is particularly valuable for individuals with physical disabilities who are either bed or chair-bound, to help reduce the occurrence of contractures and pressure ulcers. A data gathering study has been performed examining attitudes towards using BCI and gestural devices to control a robotic aid to assist with the repositioning process. Findings from a preliminary study evaluating a controller interface prototype suggest that while BCI and gestural technologies may play a valuable role in limiting fatigue from interacting with a mouse or other input device, challenges are faced accurately identifying specific facial expressions (e.g. blinks). Future work would aim to refine algorithms to detect gestures, with a view to augmenting the experience when using a BCI and gestural device to control a robotic aid.

Categories and Subject Descriptors

H.5.2 User Interfaces – *Input devices and strategies*

General Terms

Human Factors.

Keywords

BCI, Gestural interfaces, Physical disabilities.

1. INTRODUCTION

Robotic interfaces offer considerable promise to individuals with physical disabilities. Examples include solutions designed to support the retrieval of objects [2] and to assist with household chores [5]. However, research has yet to extensively focus upon the ways in which physically-disabled users can independently control robotic support aids, and the ways in which interaction potential can be maximized during this process. Brain Computer Interfaces (BCI) have been developed to support individuals with neuromuscular disorders, when other methods of interaction (e.g. eye gaze, speech input) may not be feasible for use. In this paper, we describe an exploratory study examining attitudes to the use of non-invasive BCI and gestural technologies to support tasks such as repositioning limbs. A prototype of a controller interface has been evaluated. The long term goal of the research would be to interface a robotic aid with the controller, to assist the process of repositioning limbs, thereby reducing the likelihood of developing stiffness in the muscles and pressure ulcers.

2. RELATED WORK

Assistive robotic interfaces have been developed to aid individuals with physical disabilities to perform tasks which others take for granted. Examples include Robovie R3, a robot designed to behave as a guide in a grocery store, carry shopping items, and locate nearby products [3]. In contrast with other solutions, it is able to assist the user to express emotions or sentiments. For example, the robot is able to grasp the hand and hug others. In terms of BCI-controlled interfaces, the FRIEND robot provides individuals with severe physical disabilities with 90 minutes of temporary independence from caregivers [1]. EEG signals can be used to generate the task sequences necessary to perform robotic operations. To gain a deeper understanding of the ways in which BCI and gestural technologies would benefit physically-disabled users, a data gathering study was performed.

3. DATA GATHERING STUDY

Due to the difficulties identifying individuals with severe physical disabilities, three participants were recruited for the study. Participants were asked to describe the ways in which they currently interact with computing technologies, and their attitudes towards using BCI and gestural interfaces to support limb repositioning. Their case studies are presented below.

Case Study #1: Alex is a 43 year old computer teacher with Limb-Girdle Muscular Dystrophy and Polio. Alex needs help with typing to reduce fatigue because he can only use the keyboard for half-an-hour per day. He has never tried using BCI and gestural technologies, but envisions these technologies could assist him when navigating through a graphical interface or when entering data. As he has the ability to make facial gestures and head movements, he is keen to use BCI and gestural technologies to aid him when interacting with the Web. He suggests that mapping mouse movements to facial gestures (e.g. by turning the head slightly either left or right to move the cursor in the respective direction) would reduce the physical strain on him. Alex limits his sitting time to 2 to 3 hours because he is unable to find a caregiver to help him to reposition himself, or to assist him with his physical therapy. He would be interested in using BCI technologies to gain assistance on demand for repositioning his arms to stretch above the head, and aiding him to perform leg stretches, when a caregiver is not available.

Case Study #2: Betty is 28 years old and has been diagnosed with Spinal Muscular Atrophy. She has full control of facial muscles, but has difficulty turning her head to the left side. She often sits in a reclined position to maximize neck control and reduce the occurrence of pressure ulcers. As her range of movement is limited, she requires assistance for personal care (e.g. bathing, feeding). She is able to interact with a laptop and touchpad mouse, using two fingers from each hand. While Betty is excited

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that BCI may provide an alternative to the slow process of typing and traversing hierarchical menus, she is eager to use this technology to gain more independence, by controlling a robot to assist with limb repositioning and personal care. She hopes that the same technologies can be used to non-invasively monitor her physiological condition and alert caregivers when a problem is detected. BCI offers her more potential compared to using an eye-gaze system, as she finds it difficult to visually focus for long periods of time. Her poor level of neck control can make the process of keeping her head upright challenging. Breathing issues have caused her difficulty to use speech-input solutions. However, a solution able to monitor the user's EEG activity or facial/lip movements when silently mouthing words is thought to offer considerable potential to improving her communication with caregivers and medical professionals.

Case Study #3: Tim is a 31 year old entrepreneur with Duchenne Muscular Dystrophy. He has full control of facial movements but finds tilting his head difficult. He uses voice-recognition to access his computer. He can move his hands once they are situated in specific locations, but often experiences muscle stiffness. He relies on caregivers to help reposition his limbs, but can only do this during the day, when they are around to assist him. He limits trips to the bathroom because of difficulty with obtaining assistance transferring himself to the patient hoist lift. Tim has not used BCI and gestural technologies before, but hopes these will assist him to control a robotic aid to perform personal care tasks. He suggested that performing a gesture, such as looking up or down, could convey to a robotic aid to help him transfer to the lift, while looking left or right would execute the necessary series of actions to assist him when using the bathroom. Actions could be confirmed by performing a nodding gesture.

Findings from the interviews have revealed that BCI and gestural interfaces could offer considerable potential to support individuals with physical disabilities to achieve greater levels of independence. This would provide an alternative when caregivers are unavailable or when respite is needed.

4. PROTOTYPE DESIGN & EVALUATION

A controller interface prototype was developed for limb repositioning using the Emotiv Epoc headset[1] (Figure 1). The device is able to detect emotional information, facial expressions and conscious thoughts. The user is able to control the on-screen avatar's limbs (Figure 2) by issuing a set of specified facial gestures that are detected using EEG sensors embedded within the device (Expressiv suite). A future robotic aid will be able to reposition the appropriate limb based on these commands. Examples of gestures created include looking left or right to raise the left or right arm, or blinking to lower either arm. The solution is customizable, enabling users with limited physical capabilities, to perform the gestures available to them. Commands are also accessible through keystrokes, for users with some level of movement in one or both arms.

An exploratory study was performed to determine the feasibility of using BCI technologies to control the on-screen avatar's limbs. We aimed to determine the effectiveness of detecting the following facial gestures: smiling, winking, blinking, looking left and looking right. Three participants without disabilities (2 male, 1 female, aged 24-58) were selected to execute ten randomly-presented arm tasks using the keyboard and performing facial gestures with the headset, to determine the feasibility of the solution.

[1] Emotiv Epoc - http://www.emotiv.com

Preliminary results have suggested that while all participants were able to interact with the avatar using both methods of input, participants spent 90.3s (SD: 123.1s) longer performing tasks using BCI and gestural technologies compared with the keyboard condition. Certain facial gestures were detected within a shorter time period compared with others. Examples including looking to the left or right to raise the avatar's arms (Left Arm: Keystroke: 1.8s (SD: 1.0s), BCI: 9.3s (SD: 6.2s); Right Arm: Keystroke: 3.8s (SD: 1.5s), BCI: 33.5s (SD: 24.8s)). The greatest difficulties were experienced when detecting blinks to lower the arms (M: 136.4s, SD: 188.3s). Findings contrasted with those of Lievesley et al. [4], whose participants found the blink action easiest to perform during their training process. The researchers also suggest the headset itself can be cumbersome to use, and is not recommended for individuals who retain a small amount of head movement. Our future work would examine ways in which these algorithms could be refined to ensure that gestures are more accurately detected.

Figure 1: Emotiv Epoc Headset

Figure 2: Robot Controller interface accessed using BCI

We also aim to develop the system to cater to the needs of individuals who are not able to make fully expressive facial gestures (e.g. small raises of the brow which may not be visually detectable), prior to more extensive evaluations with target users. Further study is also needed to identify ways to maintain levels of comfort, particularly for longer periods of device usage.

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