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Button Accessibility Interfaces for the brain-injured and other disabled Users

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Abstract — The number of people with brain injuries is increasing, as more people who suffer injuries survive. Some of these patients are aware of their surroundings but almost entirely unable to move or communicate. Brain-Computer Interfaces (BCIs) can enable this group of people to use computers to communicate and carry out simple tasks in a limited manner. However BCIs tend to be hard to navigate in a controlled manner, and so the use of “one button” user interfaces is explored. It may be a useful “stepping stone” for a disabled person before he or she attempts to use a more sophisticated interface. This one button concept can not only be used brain injured personnel with BCIs but by other categories of disabled individuals too with alternative point and click devices. Hence this paper is written as a position on future research in this area of accessibility.

Keywords: Brain Computer Interface, One button interface, Brain Injury, Accessibility, Communication and Disability

1. INTRODUCTION

People who have suffered a brain injury or some other form of motor impairment may have difficulties communicating. In the most extreme case, the patient may be non-verbal and quadriplegic. Some patients are cognitively intact but unable to communicate at all, which condition is termed “locked in

syndrome". The authors are particularly interested in improving accessibility for this neglected group of people, in areas such as communication, recreation, controlling the environment, controlling games and accessing web and applications using a simplified button interface. This paper describes work, currently in its initial stages, which aims to provide access to off-the-shelf software, using a "one button" interface.

"One button games" are games in which the only control is a single button, which may be pressed or not pressed. At first, this seems a very limiting user interface. However, (Berbank-Green, 2005) discusses one-button games and lists many ways in which games can be played using only one button.

A one-button interface, as the name suggests, has only one control: a button which can be pressed or not pressed. This is the most minimal control a user can exercise, and so is the most "universal", in the sense of being accessible to the maximum number of users (Keates and Clarkson, 2004)

Such an interface clearly has its limits, and will not be suitable for all types of software. In this paper we discuss contexts in which a one-button interface will bring benefits to severely disabled people, by providing an immediately usable interface.

2. BRAIN INJURIES

A traumatic brain injury (TBI) is an acquired brain injury caused by trauma such as a blow to the head, an impact with a blunt object, or penetration by a sharp object [23]. Common causes of TBI are motor vehicle accidents; bicycle accidents; assaults; falls and sports injuries (Ponsford, 1995), (Lindsay and Bone, p.216, 2004).

The primary mechanism in many cases of TBI is diffuse axonal injury, i.e. widespread damage to axons (brain cells) caused by shearing or rotational forces [23]. At the microscopic level, the direction of the shear may be visible (Lindsay and Bone, p.218, 2004).

Other causes of brain injury which are not classified as TBI are called acquired brain injury (ABI). There are many possible causes for an ABI, including: stroke (cerebrovascular accident, CVA); Amyotrophic Lateral Sclerosis (ALS); brain tumour; haemorrhage; infection; encephalitis; and medical accidents (<http://www.birt.co.uk/>).

Powell (1994) reports that approximately one million people in Britain attend hospital every year as result of head injury. The incidence of disabled survivors is 100-150 per 100 000 – or more than 120 000 people in the UK suffering from long-term effects of severe head injury.

Improvements in road safety have reduced the number of people who suffer a head injury. For example, Cook and Sheikh (200) report a 12% reduction in bicyclist head injuries in England between 1991 and 1995, ascribed to the increased use of bicycle helmets over the period. Reductions in drink-driving and increased use of seat belts, crash helmets and air bags have reduced the incidence of head injury in many countries [(Lindsay and Bone, p.218, 2004).

However, as medical care has improved, the number of people who survive a brain injury has increased (Ponsford, 1995). Powell (1994), reports that the number of brain injured people has increased since the 1970s, because the mortality rate has dropped since that time.

When a person suffers a moderate or severe brain injury, they will enter a comatose state. During this period, it is possible to assess the severity of the injury by gauging the responsiveness of the patient. The Glasgow Coma Scale, developed by Jennett and Teasdale, is commonly used (Ponsford, 1995). Upon regaining consciousness, the patient will experience a period of post-traumatic amnesia (PTA). The period of PTA is judged to have ended when the patient is able to form new memories (Ponsford, 1995).

The periods of the coma and of the PTA give a reliable indication of the severity of the brain injury. A coma period of more than six hours, or PTA of more than 24 hours is classed as a severe injury, which accounts for 5% of all head injuries [24]. Other methods of evaluation are more suitable for assessing the patient's longer-term prospects of recovery. These include the Rancho Levels of Cognitive Functioning (Hagen, 1998).

Some patients remain in the comatose state, or transition to a persistent vegetative state (PVS). PVS patients are unable to move or communicate, and are not aware. Some other patients are cognitively intact and aware of their surroundings, but are unable to move or communicate. This condition is known as *locked-in syndrome*.

Recent cases have been reported of patients who were misdiagnosed as being in PVS, when they were in fact locked in (New York Times, 2010). Monti and team (2010) describe patients who are outwardly non-aware and non-communicative, but who can answer questions using MRI scanning. As patients

diagnosed as PVS are more routinely scanned for cognitive activity, so the number of diagnosed locked-in patients may increase, and the number of PVS patients decrease correspondingly (Monti *et. al.*, 2010). The consequences of brain injuries fall into three general categories: cognitive effects; emotional and behavioural effects; and physical effects (<http://www.birt.co.uk/>).

Powell (1994), lists the effects of brain injury most often noted by relatives of the injured person. These effects include personality changes, slowness, poor memory, irritability, bad temper, tiredness, depression, rapid mood changes, tension and anxiety, and threats of violence.

As medical technology advances, more people survive brain injury. However, survival is not the same as quality of life. Rehabilitation is the process of regaining lost skills, or developing coping mechanisms to replace them.

Rehabilitation has two stages: the acute stage, where medical professionals stabilise the patient. The second stage is where family and carers take over. Broadly, successful rehabilitation depends on the severity of the brain injury. However, every patient responds differently to treatment, and different skills may be regained at different times (e.g. regaining walking and remembering skills), (www.birt.co.uk). Full recovery (to the same state as before the injury) is a reality for mild injuries, but “as a general rule the more severe the injury, the longer recovery may take, and the less complete it may be” (www.birt.co.uk). However, on a positive note, some patients continue to improve, even years after the brain injury (<http://www.birt.co.uk/>).

3. BRAIN COMPUTER INTERFACES

A Brain-Computer Interface (BCI) is a system for controlling a computer that does not depend on the brain's normal output pathways such as speech or gestures. Instead, a BCI will use any of the *bio-potentials* which are under the conscious control of the user (Gnanayutham and George, 2006). For people with extremely limited motor ability, a brain-computer interface is the only way in which they can use a computer.

3.1. Bio-Potentials

Bio-potentials are electrical signals originating in the brain and nervous system. The existence of electrical currents in the brain was first discovered in 1875 by Richard Caton (Teplan, 2002). These can be detected and used to control hardware and software.

Bio-potentials may be detected in two ways: invasive and non-invasive. Invasive methods involve surgery to place electrodes within the body or brain; non-invasive methods take measurements from the surface of the body. Invasive techniques provide higher amplitude signals with improved signal to noise ratio, but carry the risks of surgical procedures. In this study, we consider the use of only non-invasively measured bio-potentials: electroencephalography (EEG), electromyography (EMG), and electrooculography (EOG).

Electroencephalography (EEG) is the measurement of electrical waves produced by the brain. The existence of these regular waves was first published by Hans Berger in 1929 (Bickford, 1987).

These waves have amplitudes ranging from approximately 1 μ V to 100 μ V at the surface of the scalp. The frequencies measured range from approximately 1Hz – 30Hz, the dominant frequency depending on the person's mental state (Bronzino, 2000), (Teplan, 2002).

Electromyography (EMG) is the measurement of electrical signals originating from muscle movement. These signals have the same frequency range as EEG and an amplitude range of 0.2 to 2000 μ V (Gnanayutham and George, 2009).

Electrooculography (EOG) is the measurement of electrical activity caused by eyeball movements. The range of frequencies is relatively low, from 1.1 to 6.25 Hz. The amplitude is higher than EEG, around 1 - 4mV (Gnanayutham and George, 2009).

Other non-invasively measured bio-potentials may be used for BCIs, but are not used in this study. These include evoked potentials, (e.g. P300 and N400); steady-state visual evoked potentials; and slow cortical potentials (Gnanayutham and George, 2009).

3.2. Commercially available Brain-computer interfaces

BCI hardware ranges from devices intended for playing computer games through to medical-grade EEG machines. Table 1 shows currently available consumer-level BCI hardware (non-invasive) which make it easier to purchase a BCI and the cost of such devices also have become much more affordable in comparison to previous years.

Table 1: Commercially available BCI hardware

Name	Manufacturer	Approx Cost in £
Cyberlink™	Brain Actuated Technologies Inc [3]	£1400
Neural Impulse Actuator™	OCZ Technology [22]	£85
Enobio®	Starlab [26]	£3150
EPOC	Emotiv [8]	£200
Mindset	Neurosky [19]	£130

3.3. Discussions - Usability for Accessibility

In this position paper, the Cyberlink™ BCI hardware with Brainfingers software has been used as the BCI. This follows in the footsteps of successful studies (Gnanayutham *et. al.*, 2004), which have enabled locked-in patients to communicate using the button interface on-screen keyboard (Fig 1). The on-screen keyboard was a series of buttons, the users choose the appropriate key using the chosen bio-potential. This process uses the human computer interaction principles on usability and makes complicated software/hardware into accessible software.

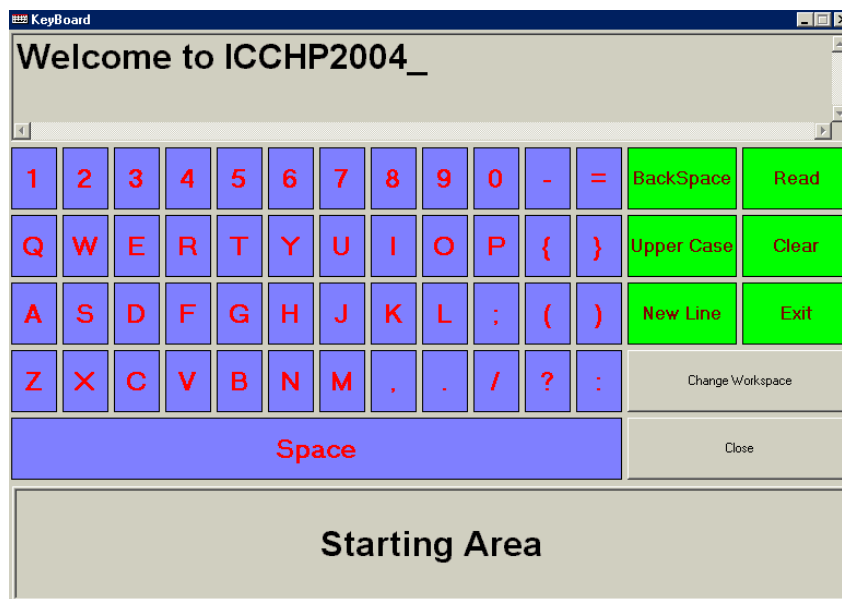


Fig. 1. Online Keyboard Research Using Button Interface

To move the mouse cursor at will at any direction, the user must be able to consciously control four separate 'channels' of bio-potential: one channel to move the cursor up, one to move it down, one for left, and one for right movement. Adding the ability to generate mouse button events further complicates the task facing the user. This difficulty means that in practice BCIs are difficult to use.

Typically when using Cyberlink, the mouse cursor moves quickly to a corner of the screen and then stays there. This frustrates users, making it even harder to bring the cursor back under conscious control.

These difficulties have been addressed by developing the novel User Interface paradigms, *Discrete Acceleration* and *Personalised Tiling* (Gnanayutham *et. al.*, 2005). Another approach, discussed here, is to make the interface even easier to use by reducing the number of channels, which the user must control. The simplest possible configuration is a one-button interface, requiring only one channel of information. To use this kind of interface, the user only needs to be able to consciously control one bit of information over time. The advantage of such an interface is its simplicity. Being the simplest kind of interface, it is as “universally accessible” as possible. Cyberlink/Brainfingers lets the user control the mouse cursor and mouse button clicks using bio-potentials. The software is configurable, so that different users can control the mouse using different EEG frequency bands, and also EOG and EMG, if appropriate.

Hence we can,

1. Translate web links into buttons that opens in a window that can be used to navigate a website (work in progress);
2. Translate application menu into buttons that open in a window and enable the user to choose various options(work in progress);
3. Translate game control keys into buttons that can enable the user to play a game (Coleman and Gnanayutham 2010);
4. Have optional text-to-sound added for visually impaired users (Gnanayutham *et. al.*, 2004);
5. Enable the buttons to be chosen one by one or scanned at a convenient speed (Gnanayutham *et. al.*, 2004).

Button interfaces not only can be used by BCIs but also by mouse, joystick, switch, voice recognition, etc. Thus we can enable brain-injured, motor impaired and other motor impaired disabled individuals to access mainstream software, web and games with ease so that we can have an inclusive society which doesn't alienate the brain injured from the general public.

4. CONCLUSIONS AND FUTURE WORK

This position paper described the use of Brain-Computer Interfaces (BCIs) that can enable a disabled person to access mainstream software. This may be a useful “stepping stone” for a disabled person before he or she attempts to use a

more sophisticated interface. This one button concept cannot only be used by brain-injured personnel with BCIs but also by other categories of disabled individuals with alternative point and click devices. This paper doesn't advocate changing the most commonly used applications or games but discusses how it can be made accessible thereby making it possible for wider audiences. Hence this paper is written as a position paper on future research on accessibility and usability of main stream software for the brain injured and motor impaired personnel. Hence this paper is written as a position paper on future collaborative research with other institutes.

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