Computer Access Using Electrical Signals From The Forehead: The Cyberlink™ In Action

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ABSTRACT

Computers can substantially improve the quality of life for people with disabilities. However, for the potential of computers to be fulfilled, adequate input systems to enable computer access are crucial. Individuals with disabilities affecting manual control can use modified or alternative keyboards and mice, alternative input systems using output from effectors other than hands, or brain-computer interfaces directly linking brain activity to computer actions. The Cyberlink™ is a hands-free system that uses electrical signals from the forehead to control a computer. Research has shown that the Cyberlink™ can serve as an alternative input system for people with multiple disabilities and it is often recommended as a last resort when other alternative input system cannot meet the user's needs. Advantages of the Cyberlink™ include its little reliance on head position, its clicking speed, and its therapeutic value. Disadvantages include its sensitivity to users' overt emotional reactions and its dependence on not fully understood and difficult-to-control brain signals. Undergoing and planned research is expected to improve our understanding of brain signals and guide the development of new software applications and the improvement of the current ones, making the Cyberlink™ more usable and accessible and a more valuable tool for all potential users.

INTRODUCTION

Computers can substantially improve the quality of life for people with disabilities. For example, computers may provide non-verbal individuals with type-to-speech systems and allow blind users to hear written text using a screen reader. The ability to perform these actions (i.e., speak and read) with the help of a computer can greatly improve the independence and opportunities for social interaction of these individuals. However, for individuals with motor disabilities, these benefits will be thwarted if they do not have an easy and reliable way to access computers. Thus, adequate input systems to enable computer access for individuals with motor disabilities are crucial for the potential of computers to be fulfilled.

Most commercially available computers use a keyboard and a mouse as input devices. However, individuals with motor disabilities (e.g., cerebral palsy) may have difficulty or may be unable to use traditional input systems (i.e., keyboard and mouse). Fortunately, there are numerous alternatives to the traditional input systems and individuals with motor disabilities can choose to use modified versions of the traditional input systems or alternative input systems (e.g., eye tracker) to access computers.

In this paper, we discuss the potential of the Cyberlink™, a hands-free system that uses electrical signals detected at the forehead, as an alternative input system for people with motor disabilities. Some of the research exploring the potential of the Cyberlink™ (e.g., Marler, 2004) is reviewed and some advantages and disadvantages of the Cyberlink™, when compared to other alternative input systems, are presented. We conclude the paper by describing some of the research we are currently performing using the Cyberlink™, as well as the research projects we plan to undertake in the future to improve the usability, accessibility, and general value of the system.

COMPUTER ACCESS FOR INDIVIDUALS WITH MOTOR DISABILITIES

Traditional input systems require individuals to use their hands in order to control the computer. Therefore, any disability that affects manual control will affect the ability of that individual to access computers. Technological aids available for individuals that have difficulty using traditional input systems can be divided into three categories, depending on the motor control available to the user:

1. *Alternative or modified keyboards and pointing devices* are designed to aid users who have difficulty using traditional keyboards or mice, but who have at least limited use of their hands. Examples of these technologies include: the StickyKeys, FilterKeys, and ToggleKeys options (available in the Accessibility section of every Windows 2000 or XP operating system); special keyboards that facilitate typing by limiting the amount of fine control needed (e.g., IntelliKeys®) or the amount of gross control needed (e.g., USB Mini®); and joysticks or trackballs sometimes used instead of mice to minimize the range of movement (Cook & Hussey, 2002).
2. *Alternative input systems that use motor output from effectors other than hands*. Example of these systems include those tracking eye or head position to control the cursor on the computer screen, speech-recognition systems that use voice input for typing and other computer functions, and switches that are activated with different body parts (e.g., mouth, chin, head).
3. *Brain-computer interfaces* (BCI) use sensors to detect brain signals (e.g., electroencephalogram, EEG) and use them as input signal for a computer. Brain-computer interfaces can be divided into three groups depending on how invasive they are:
    a. *Non-invasive BCIs* use sensors placed outside the skull to detect brain activity.
    b. *Partially invasive BCIs* use sensors placed under the skull on the surface of the cortex.
    c. *Invasive BCIs* use sensors placed within the cortex.

    Wolpaw et al. (2002) also distinguished between *dependent* and *independent* BCIs. The main difference between these two types is whether motor output of effectors is necessary to generate the detected brain activity. Thus, *dependent BCIs* measure brain activity resulting from effectors' motor output whereas *independent BCIs* measure brain activity that does not depend on effectors' motor output.

Although the systems in each category require a different level of motor ability from its users, it is possible that a person with motor abilities adequate to use devices from a category (e.g., limited use of the hands) prefers using a system that does not use these abilities (e.g., a speech-recognition system). Similarly, when detecting motor output from alternative effectors becomes difficult (e.g., due to spastic movements), users may find it more efficient to use brain signals instead.

THE CYBERLINK™ SYSTEM

The Cyberlink™ is an alternative input system developed by Junker (1997). Following the framework presented in the previous section, the Cyberlink™ could be categorized as a non-invasive BCI because it uses sensors placed on the skin to detect electrical signals. Although the Cyberlink™ is generally used as a dependent BCI, some studies (e.g., Doherty et al., 1999; Junker et al., 2001) have suggested that it can also be used as an independent BCI.

The Cyberlink™ consists of three components: a headband, an interface box, and a software application (i.e., Brainfingers™). The headband contains three sensors that are placed on the user's forehead and detect and amplify electrical activity at this site. The sensor in the center is placed directly above the nose and detects ground, while the other two sensors detect brain activity. A single "brain-body signal" is derived from these two inputs at the headband and sent to the interface box, which filters it into three different signals (i.e., frequency bands). The low-frequency band (0.2 – 3 Hz, EOG) is highly responsive to eye movements, the mid-frequency band (0.5 – 45 Hz, EEG) responds to brain activity that is relatively independent from external movements, and the high-frequency band (70 – 1000 Hz, EMG) is highly responsive to facial-muscle activity.

The software application which goes along with the Cyberlink™ system is called Brainfingers™ and it subdivides these three signals into a total of 11 *fingers* (i.e., frequency bands): 3 fingers in the EOG region, 7 fingers in the EEG region, and the EMG finger. Each of these fingers can be mapped to control one or multiple functions in the computer ranging from single and double clicking to one- or two-dimensional cursor movement).

Brainfingers™ also includes a series of games (e.g., Pong and Labyrinth) that users can play to practice using the electrical signals produced at their forehead to control the computer. Many different combinations of these 11 fingers can be used for two-dimensional cursor control with clicking capability (i.e., as replacement for a mouse). For example, when users have control over their facial muscles, EMG is often used to control vertical movement of the cursor and often also clicking. This signal is usually the easiest to control for these individuals. Then, one of the EOG fingers can be used to control horizontal movements of the cursor. Users with no control over the EMG signal can sometimes use alternative fingers in the EOG and EEG region to control cursor movement (e.g. Doherty et al., 1999).

Past research using the Cyberlink™

The Cyberlink™ was originally developed as an alternative input system for military use (e.g., Nelson et al., 1997). However, studies soon started to explore the feasibility of the Cyberlink™ system as an alternative input for individuals with motor disabilities. These feasibility studies (e.g., Junker et al., 2001) found that individuals with no documented means to access a computer could successfully input information to a computer using the Cyberlink™. However, these studies report that the system was not easy to control for most users, recommending it only as a last resort.

Doherty and his colleagues (2002) pointed out that, even though the Cyberlink™ improved the access of some individuals to recreation (e.g., playing Pong), it was difficult to use it for communication. In their studies, they explored different interface designs to allow users to reliably say yes or no without clicking. Their research led to the development of guidelines for the design of maze-like interfaces for individuals who can control two-dimensional cursor movement with EOG and EEG but cannot reliably produce mouse clicks.

Another group of studies explored the usefulness of the Cyberlink™ for students with multiple disabilities (e.g., Marler, 2004). Marler found that the system was very helpful for these individuals and her experience led to the development of a training tutorial to aid practitioners determine the best combination of fingers for each individual (Marler, Junker, & Lustre, 2006). In addition, Marler reported improvements in attention span, motivation, and mental-age diagnoses (upgraded from 6-18 months to 4-5.5 years of age) after her students used the Cyberlink™ twice a week for a period of eight weeks,.

The Cyberlink™ can also be used in combination with other input systems. For example, Junker and Hansen (2006) found that combining gaze input (for pointing) with the EMG signal (for clicking) led to faster and more accurate performance than using gaze-derived measures (e.g., blinking or dwelling) for clicking. In fact, Junker and Hansen pointed out that clicking with the Cyberlink™ is even faster than clicking using a manual control (e.g., mouse) and some gamers have used this faster EMG clicking to improve their gaming performance.

Advantages and disadvantages of the Cyberlink™ system

One of the advantages of the Cyberlink™ when compared to some of the other alternative input systems (e.g., eye or head trackers) is that it is less sensitive to spastic movements affecting head position (Marler, 2004). However, when using the EMG signal, overt emotional reactions resulting from the execution of successful actions (e.g., laughing) sometimes activate the Cyberlink™, resulting in involuntary clicks.

When compared to invasive or partially invasive BCIs, the Cyberlink™ has the obvious advantage that no surgical procedure is necessary. When compared to other non-invasive BCIs, it has the advantage that it is more aesthetically pleasing and easier to attach than BCIs that place electrodes all around the skull (e.g., Wolpaw et al., 2002). The placement of the sensors on the forehead is particularly convenient because it is one of the last areas affected by degenerative diseases (e.g., amyotrophic lateral sclerosis, ALS). However, the more aesthetically pleasing design has the downside that the signal detected by the sensors is less rich than the signal detected by more complicated arrays.

As mentioned in the previous subsection, clicking using EMG is faster than clicking using the hand (Junker & Hansen, 2006). This is clearly an advantage of the Cyberlink™ (if the user is able to use EMG signals), not only in comparison to other alternative input systems, but also in comparison with traditional input devices.

Another advantage of the Cyberlink™, which is shared with other input devices that enable individuals to do things that were previously impossible, is its “therapeutic” value. That is, the positive effect that using the device has on the user’s cognitive abilities (e.g., increased attention span or estimated mental age), perceived control, and motivation. In addition, some studies (e.g., Doherty et al., 1999) have pointed out the diagnostic value of the Cyberlink™ in the case of individuals with locked-in syndrome.

Even though the Cyberlink™ has some clear advantages over its alternatives, it is usually only recommended to users with disabilities as a last resort (e.g., Doherty et al., 2002). That is, after all other alternative input systems (except invasive and partially invasive BCIs, which are not used regularly due to their obvious risk) have failed to meet the user's needs.

One of the main criticisms and limitations of the Cyberlink™ is that its EEG signals are currently poorly understood and difficult to control and, as a consequence, the usefulness of the Cyberlink™ as an exclusively independent BCI (i.e., for individuals with no motor output) is limited. In addition, the Brainfingers™ software is not as reliable as it would be desirable and necessary if the Cyberlink™ were to be used for daily use. However, some control is better than no control, rendering even major problems "acceptable" for users that have no other means to access a computer or exert an kind of control over their environment (Doherty et al., 2002).

Undergoing and future research using the Cyberlink™ system

Our lab is currently exploring the possibilities of the Cyberlink™ as an alternative input system for people with multiple disabilities. For example, we are currently studying its potential to help individuals with disabilities in the community by analyzing what obstacles they encounter when adopting Cyberlink™ as an alternative input system. We are using the experience derived from these case studies to design new interactive software programs that can be controlled using the Cyberlink™ and help to facilitate computer access and, ultimately, communication opportunities. Although the Cyberlink™ is described throughout this paper as a means to provide computer access, access as such is not always motivating to a person that has never used a computer before and, as a consequence, does not know what to do with it. Rather, we have found that the computer's potential to facilitate social interaction is a strong motivating factor for individuals previously unable to communicate. We have further found that software applications that use computer access as a tool to enable social interaction are preferred and more successful than those applications merely providing control over the computer and its functions.

In the future, we plan to combine the knowledge obtained from our case studies with more formal experimental studies in order to improve the Cyberlink™ system. For example, we plan to explore in more detail how the EEG signals change under different cognitive situations (e.g., mental arithmetic, pleasurable thoughts, relaxation) in order to create guidelines to improve and train voluntary control of EEG signals. As part of this effort, we also plan to explore more effective ways to use the EEG signal to control the computer. For example, one approach is to identify patterns across the activity of several fingers and map these patterns, instead of the activation levels of a single finger, to particular computer actions (e.g., move the cursor up).

We plan to conduct a usability analysis of the Brainfingers™ software in order to provide useful recommendations for future software upgrades. Currently, the Brainfingers™ interface is mostly visual. Auditory feedback is only provided to the users when threshold values are exceeded, while visual displays continuously show the level of the brain signals. This design makes the Cyberlink™ difficult to use for individuals who are blind or have low vision. We plan to explore auditory displays that could be used to improve the accessibility of the Brainfingers™ software to people with visual impairments.

Lastly, we plan to explore the possibility of using Cyberlink™ for environmental and wheelchair control.

SUMMARY AND CONCLUSIONS

Past and undergoing research suggests that the Cyberlink™ is a promising alternative input system to facilitate computer access for people with severe and/or multiple disabilities. This system has numerous advantages over other alternative input systems (e.g., fast clicks using EMG and less sensitivity to spastic head movements than other systems) but it also has some limitations (e.g., emotional reactions to the system, such as laughing, often trigger unexpected actions and brain signals are not fully understood). Understanding better how EEG signals from the Cyberlink™ can be used to control a computer could greatly improve the usefulness of this system for individuals with limited or no muscular control.

We expect current and future research to identify what type of difficulties current Cyberlink™ users experience in their everyday life and use this information in conjunction with more formal experiments to improve our understanding of how EEG signals can be used more effectively to control a computer. We expect to collaborate in the development of new interactive software applications to use with the Cyberlink™ that engage users in social interaction. As well, we hope to make the current Brainfingers™ software more usable and accessible for individuals who are blind or have low vision.

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