Project Summary

BREAK Computer Accessibility

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The subject surrounded by his retinue and BREAK team during testing.

1.0.0 Abstract

Cerebral Palsy is caused by damage to the motor control center of the brain during early childhood. This permanent disease impairs the fine motor skills of a person, rendering what most would could consider simple daily tasks impossible. While the body of a person with cerebral palsy may not function properly, many people still have full cognitive function, leaving them trapped inside a body that acts as a prison. For this reason, the objective of this project was to provide the project recipient (boy with athetoid cerebral palsy, age 11) an assistive device system that would allow him to further his education, expand his means of communication, create a new avenue for recreation, and help provide a new sense of freedom. The final design consisted of a mounting system which attached to the wheelchair and placed the laptop computer in a suitable position for viewing and for supplemental eye gaze device, that allowed for the user to control a cursor and access multiple click functions solely with his eyes. The system was tested and refined before finally being turned over to the recipient for use. In order to receive optimal benefit from the system, The subject must continue to practice controlling the cursor position and selecting and executing different click commands. With practice, the Computer Access team believes the subject will be able to perform nearly all functions a normal user could on a computer.

1.1.0 Assistive Technologies Considered

The design team considered several assistive technology solutions for to address the disabilities of the recipient. These are briefly described below.

1.1.1 Mouth-Controlled Devices

Mouth controlled devices are commonly found in two forms: toggle or sip & puff switches. These assistive tools are normally mounted on the head or on a mechanical arm positioned near the user's mouth for access. Some systems use both a toggle and sip and puff switch in conjunction. A person will use the lips, tongue, or motions of the head to direct a toggle switch which steers a cursor; a second toggle may be used to select items or input data by linking the different directions to mouse clicks or keyboard input. The sip & puff switch operates via a straw-like device which the operator will blow or suck on to trigger computer commands. Sip and Puff switches require an interface to convert the sips and puffs into electrical signals (http://www.orin.com/access/sip_puff/).

There are benefits and drawbacks to mouth controlled devices. They allow users to accomplish tasks without moving their outer extremities. Users with highly dexterous lips and tongues will be able to use a toggle system easily. People with good breath control will have no trouble managing a Sip and Puff switch. In contrast people with weak facial muscles or poor control of their tongue will have difficulty using a toggle switch, and people who are short of breath or can't control their breathing will not be able to use a sip and puff switch easily. Any device placed in and/or around a user's mouth may impair their ability to breathe or swallow. Sip and Puff switches also have a very limited number of inputs as they can only register two inputs; blowing and sucking. Toggle switches may be capable of a wider range of inputs, but may be limited by time-sensitive input (such as selecting an item at an exact moment). Mouth controlled devices will also impede vocal communication while in use.

1.12 Speech-Controlled Devices

A speech control program will contain a list of commands which, when spoken correctly by the user, will carry out the specified prompt. Voice recognition has been incorporated into a range of devices, including phones, vehicle navigation, and entertainment systems. Voice control programs are available for download which will allow users to control their computer. A voice program may be used to open or close applications, perform calculations, or type solely with spoken commands. This allows for people who are unable to use a keyboard/mouse to interact with their computer.

Speech control has its own pros and cons. Speech control allows users to accomplish tasks on an electronic device by vocal input. This allows for seamless control between the user's words and computer interface. Because speaking is second nature to most people, this method can be very easy to pick up and implement. A microphone and the proper software is required in order to use voice recognition with a computer. Care must be taken by the user to properly enunciate when issuing voice commands. For people who have trouble speaking clearly and fluently, this method can prove frustrating and/or impossible, as the computer will not register their vocal input.

1.1.3 Eye-Controlled Devices

Eye controlled devices use eye movement to determine mouse cursor position and selection. These can be mounted on headgear/glasses or a surface facing the user. Tracking is accomplished via video capture or other sensor pointed at the operator's eye. When the operator looks at one area of the screen the cursor or indicator follows his or her gaze. The selection itself can be performed either by blinking, or by maintaining the user's gaze, causing the cursor to hover over an application until an automatic timer triggers the click . A few eye gaze technologies already in use as assistive technology include the Quick Glance, MyTobii, and Grinbath Eyeguide. Eye gaze can also be used in conjunction with brain computer interfaces, enabling the click mechanism to be independently controlled via thought; this has been shown to possibly be a more reliable alternative to the "lingering" method.

Ideally, controlling the pointer is a simple as looking at the item to be selected, but the system is not without it's flaws. Eye gaze technologies are advantageous due to their effectiveness resulting from natural and fast input, and the absences of any attachments to the individual. The downsides of eye gaze technology is that it can be extremely tiring to the individual, especially during early stages of use, inaccurate in small areas, and difficult because the eyes are used for both output and input. Proper environments are also necessary for optimal use of eye gaze technology. It has been found that fluorescent lighting provides the best results, while incandescent lighting, halogen lighting, and direct sunlight can provide difficulties. Combining eye gaze with brain computer interface headsets would afford the user the advantage of controlling mouse position with their eyes, along with the advantage of having multiple instantaneous inputs from the brain computer interface headset. Although combining eye gaze and brain computer interface provides the advantage of both systems it can also be expensive because it requires that both systems be purchased. This increase in cost may not be outweighed by the added benefits of having both systems.

1.1.4 Brain-Computer Interface Devices

The brain is the primary organ behind the complexity of the human body's functions. It is a triple threat of information handling, capable of receiving and processing, deciphering and orchestrating, and storing and recalling. It is the epicenter for the regulation and control of functions within the human body.

Electroencephalography (EEG) is the record of electrical activity manifesting on the scalp, due to the underlying activity of the 80 billion neurons that compose the human brain. Electrodes are selectively placed above regions of the brain to monitor both local and global activity. These records contain the spatial distribution of the electric field flux, in real time.

Typically, EEG is used to:

- Diagnose and monitor seizures,
- Conduct invasive research on the brain,
- Analyze the brain activity of coma patients.

However, as neurology, the study of the neurons, the nervous system, and the brain, has advanced, EEG has had some success predicting and interpreting local and global neuron activity. This is the foundation for the brain-computer-interface (BCI), a direct communication pathway from the brain to an external device. In June of 2013, researchers at the University of Minnesota flew a remote control quadricopter, through an obstacle course, based on motor imagination registered and transmitted by a non-invasive EEG BCI.

The outward, physical symptoms of cerebral palsy begin as irregular noise in the electric activity of the neurons. Using traditional methods of harmonic analysis, the fast fourier transform (FFT) method, for an EEG BCI system would be susceptible to the same spastic activity. However, Siddiqi et al have demonstrated that the spasms of epilepsy patients can be predicted using an EEG system that employs the wavelet transform (WT) method. WT is a modern branch of mathematics that extends harmonic analysis to transient systems. If noise can be predicted in a transient system, filters can be designed that activate during neurological spasms to reduce the impact on the BCI behavior.

2.0.0 The Process of Elimination

Though the subject has some tongue control, because of his limited muscular control, mouth-controlled devices were not pursued. The subject would not have sufficient input degrees of freedom to control the computer. Similarly, though the subject can speak, his inflection and the interrupted nature of his speech made speech-controlled devices unlikely to work. This left two primary technologies, eye gaze and brain-computer interface devices.

2.1.0 EEG Evaluation

One distinct advantage of the brain-computer interface is that no physical movement would be necessary for use, as the only input needed are the user's brain activity. Thus, the team chose to evaluate the Emotiv EPOC and associated Cognitive Suite software, as this was also a relatively inexpensive option. However, three problems were found in initial use of the Emotiv EPOC: 1) The sensitivity of the system for EEG was low and was being swamped by

EMG signals from facial musculature, 2) The CP subject's brain waves contained in inordinate amount of noise compare to normal brain waves, and 3) much of the control seen in demonstrations was actually coming from gyroscopic measurements of movement by the device. In addition, though it was relatively low profile, the wireless transmitter on the back of the unit interfered with the subject's wheelchair headrest. It became quite clear the data from the Emotive EPOC would not be sufficient to control a computer.

2.2.0 Eye Gaze Evaluation

Eye-gaze systems are advantageous because there is no required physical movement aside from the user's eyes. Fortunately, the subject has good eye control. Some eye gaze systems do not require anything to be worn by the user, and the eye gaze sensor typcially takes up very little space. Set-up time for eye-gaze systems is also minimal, as the sensor is mounted on the screen and may be left in place between uses. A major advantage of eye-gaze technology compared to the neuroheadset is the technology has already been proven an effective means for use in the assistive device field. The major disadvantage of plug-and-play eye-tracking systems (such as the Tobii PCEye Go which was selected), is they tend to be significantly more expensive.

Eye-gaze systems are set up so they project across the user's line-of-sight to the screen. They work by capturing images of the user's eyes and deducing an intended target on screen from their orientation. This allows the user, through cursor control, to select and drag icons on the screen by simply changing where they are looking. Clicking is performed by blinking or dwelling, (where the user holds their gaze on a certain object for a set period of time) giving the user nearly all the same functions and controls as someone using a traditional two-button mouse would possess.

Right away, it was clear that Tobii PCEye Go system was much more plug and play, and the Tobii communicated and interacted flawlessly with the current operating software and applications of the computer. During initial testing with the subject, the team encountered unforeseen problems during this first set of tests. The subject had never done more than observe the interactions of others with computers, and was unfamiliar with basic operations. More importantly, the team discovered that the subject's head tended to turn away from the computer with increasing effort—apparently due to contraction of neck muscles as effort increased. When the computer was placed on the subject's left, he would have trouble keeping his head from rotating to the right until he could no longer view the screen. The team has instructed the subject's support group to help the subject learn to look and hold his gaze in a given direction. If necessary a padded brace could prevent this rotation. In subsequent testing (with fewer people and less "pressure"), this rotation was not an issue. An adjustable mount will allowed the Tobii and laptop computer to be positioned in an optimal manner for observation and interaction, as well as allow for easy storage when the system is not in use.

3.0.0 Final Design Summary

3.1.0 Computer

Providing a dedicated computer would eliminate the need for the eye tracker to be installed and calibrated on multiple computers. Using the PCEye Go requires installation of software on the respective computer and eye-tracking piece in front of the monitor; the eye tracker must also be calibrated for each different device on which it is installed. The subject is likely to be using the device in multiple locations, such as at home and school. The options considered were a laptop or tablet computer. Major contributing factors to the decision were operating system, screen size, weight, battery life, and budget. Because of the desire for the Windows 7 operating system and larger screen size of laptop computers, the final decision was to purchase a Dell Inspiron 17 inch laptop.

3.2.0 Mounting system

To support the computer and allow for flexible positioning, the team purchased an automotive laptop mount that was several hundred dollars cheaper than wheelchair mounting systems. They produced a custom adapter that mounts to the wheelchair rails and mates with the automotive laptop mounting system.

3.3.0 Eye Gaze Techology

The team chose the Tobii PCEye Go eye-gaze system for its robustness and user support. It has worked seamlessly with the operating system and other computer programs.

3.4.0 Software

The subject will be interacting with software standard for a school curriculum, but his introduction to the various program options should be tailored to suit his needs via gaze interaction. Iniitially, the team would like the subject to be able to use educational software for English, math and science. Eventually, he should be able to use word processing, spreadsheets, internet browsing, social media and more. The computer was provided with all basic Window 7 programs and Microsoft Office 2013.

4.0.0 Conclusion

The large laptop screen provided a good enviroment for the Tobii device to be used. The subject's determination and the progress he made during the relatively short amount of time spent testing was extremely promising. After discussing the issue of head drift, it was agreed upon between the team and project liaison that implementing some sort of device to prevent the subject's head from drifting could be helpful in the future..