Early Experiences Using Visual Tracking for Computer Access by People with Profound Physical Disabilities

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ABSTRACT

A dozen people who cannot speak and have very limited voluntary muscle control because of cerebral palsy or traumatic brain injury have tried using a new technology called the Camera Mouse to access the computer. Nine of the people were successful, in many cases being able to spell words or run commercial software or access the internet for the first time. The Camera Mouse is non-invasive and uses a standard video camera and room lighting to track slight movements of the head or thumb or toe, whatever part of the body a person can control. The Camera Mouse acts as a mouse substitute.

1. INTRODUCTION

We work with people who are excluded from access to computers and the internet and even from communication with fellow human beings. These people have severe physical disabilities either from birth or from accidents or from degenerative diseases. They are unable to speak and have very little or no voluntary muscle control. Their level of mental functioning might not be known because of their inability to communicate. Children with severe physical disabilities but fully functioning minds can go uneducated. People with severe physical disabilities often are isolated, spending hours in bed or in a wheelchair at home or in an institutional setting staring at the wall or at the television.

Computer and communications technology can make all the difference in the world for people with profound physical disabilities. Our approach has been to develop technologies that allow people to control the mouse pointer on the screen by moving their eyes or by small movements of their head or toe or thumb. If people can control the mouse pointer and issue clicks then they can use the computer to communicate with people, to run educational software, to access the internet.

We have developed two technologies to provide access to the computer for people with severe physical disabilities. The first technology, EagleEyes [1,2], uses five electrodes placed around the eyes to allow a person to control the mouse pointer by eye movement. More recently, we have developed the Camera Mouse, a technology that uses a standard video camera to allow a person to control the mouse pointer by slight movements of the head or any other portion of the body. In [3], we introduced the Camera Mouse technology (patent pending). Here we report on our experiences with the first dozen people, mostly people with severe cerebral palsy, in using the Camera Mouse for computer access.

Several other assistive technology products allow people to control the computer through head movements. The Tracker 2000 from Madentec (www.madentec.com) and the HeadMouse from Origin Instruments (www.orin.com) use near infrared light to track a reflective dot placed on the head. The HeadMaster 2000 from Prentke Romich (www.prentrom.com) mounts the light source on the head

instead of near the monitor. The Gyro-HeadMouse from Advanced Peripheral Technologies (www.advancedperipheral.com) embeds mercury switches in a hat to measure head angles. People have benefited enormously from these products. The Camera Mouse uses existing light and has nothing placed or mounted on the person's head. We hope a product based on the Camera Mouse technology will be easier to use, less invasive, more flexible, and much less expensive and thus will be of wide benefit.

2. THE CAMERA MOUSE

The Camera Mouse uses a video camera to capture images of the part of the body being moved and uses the computer to track the movements in the images in real time. These body movements are converted into mouse pointer movements on the screen. The result is that the Camera Mouse is a completely non-invasive, easy-to-use access device. A video camera sits on top of the monitor or below the monitor pointed towards the user. The user moves his head slightly. The mouse pointer moves accordingly. As an option to the user, selections can be made using "dwell time." For example, a mouse click can be generated if the user keeps the mouse pointer at a given location for some settable time, usually 0.7 seconds. As an additional option, a double click can be generated if the mouse pointer is held in the location for a longer period of time. The Camera Mouse is a general mouse replacement system that works with commercial software, including communications software, educational software, and web browsers, and with custom-developed software.

The initial version of the Camera Mouse [3] used two computers: one for the visual tracking and one for the user application program. The current version of the Camera Mouse uses a single computer. The Camera Mouse program runs in the background while the application program runs in the foreground. The Camera Mouse works by taking in 30 frames of video per second. Initially a person clicks on the feature (for example the tip of the nose or the middle of the lower lip) to be tracked. The Camera Mouse then tracks that feature by finding the portion of the next frame that most closely matches it. The process is repeated for each frame. An example of visual tracking is shown in Figure 1.

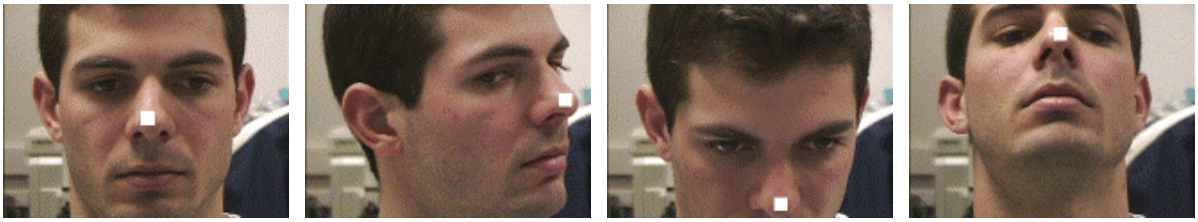

Figure 1. Automated visual tracking.

The window with the image of the user is minimized while the user runs the application program. In the current version, the tracking program is given control of the mouse pointer by pressing the CapsLock key. Control is returned to the mouse in the same way.

With the support of the Camera Mouse both commercial software and custom-developed software can be used. The Camera Mouse enables people to use Internet Explorer and Netscape Navigator to access the web. We use a wide variety of educational software. We use both custom-developed spelling programs and Clicker 4 for communication. We use both commercial and custom-developed entertainment software to develop skill control and just for fun.

3. JORDAN USING THE CAMERA MOUSE

The first person to have her own Camera Mouse system was Jordan – a thirty-three month old girl with severe cerebral palsy. Jordan can't talk but she can move her chin up and down a little and her head from side to side a little. Here is Jordan in her wheelchair trying a system in our lab. Her mom is next to her. The camera is black and below the monitor.

Figure 2. Jordan controls the mouse pointer by moving her chin.

Jordan is moving her chin to move the white arrow (mouse pointer) to pop the bubble that contains a bird. With the help of the Camera Mouse she regularly uses this commercial program for children.

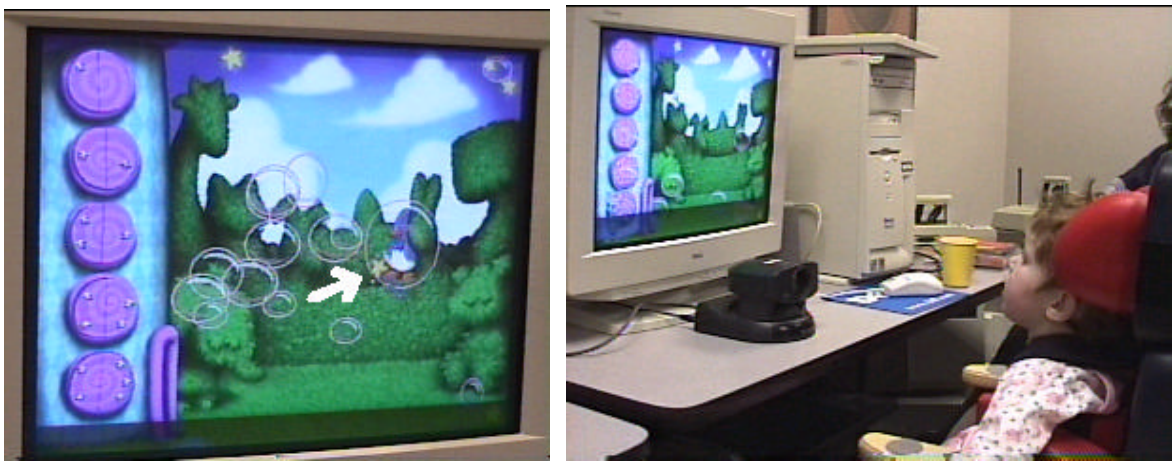

Figure 3. Jordan uses the Camera Mouse to run commercial software.

4. RESULTS

People without physical disabilities quickly learn to control the computer through the Camera Mouse by moving their head.

We have tried the Camera Mouse with a dozen people who have severe physical disabilities. Each person cannot speak and has very little voluntary muscle control. Ten have cerebral palsy. Two have traumatic brain injury, one from an automobile accident, one from a motorcycle accident. Nine of the people are continuing to use the Camera Mouse. Six can use the Camera Mouse to spell using an onscreen keyboard system. Three of the people did not have sufficient muscle control to use the Camera Mouse. They are using EagleEyes to control the mouse pointer by moving their eyes. One of the people who was not successful was close and will be given additional opportunities to try the Camera Mouse in the future. The results are summarized in Table 1.

Table 1. Summary of results for the first dozen people with disabilities to try the Camera Mouse.

Age	Gender	Condition	Continuing to Use?	
2	M	Cerebral Palsy	Yes	Obtaining a system for home.
3	F	Cerebral Palsy	Yes	First with home system.
6	F	Cerebral Palsy	Yes	Spelled name. Obtaining a home system.
8	M	Cerebral Palsy	Yes	Spells naughty words and laughs.
11	M	Cerebral Palsy	Yes	Obtaining a home system.
14	M	Cerebral Palsy	Yes	Spells words. Obtaining a home system.
15	M	Cerebral Palsy	No	Close, but could not control reliably.
19	M	Cerebral Palsy	No	Does not have sufficient muscle control.
23	M	Traumatic Brain Injury	No	Does not have sufficient muscle control.
31	M	Traumatic Brain Injury	Yes	Spelled "TAKE OFF DAD"
37	M	Cerebral Palsy	Yes	Spelled "MERRY CHRISTMAS"
58	M	Cerebral Palsy	Yes	Spells, explores internet on home system.

Some of these people were unable to unequivocably demonstrate their level of mental functioning before trying the Camera Mouse. Often the parents were convinced of their child's intelligence and perhaps had found subtle ways to communicate within the family, but the authorities were doubters. Spelling using an onscreen keyboard with no outside intervention provides a definite proof of a level of mental functioning and a level of learning. It obviously is a critical step in providing contact and communication with the outside world and in beginning to formulate a coherent plan for education and intellectual development.

The dozen people have a high level of difficulty in controlling their head (or thumb or toe). With a traditional onscreen keyboard, where the keys are right next to each other and the keyboard fills much of the screen, they run into the Midas Touch problem described by Jacob [4]; everything the mouse pointer touches and rests on is selected. People without physical disabilities have no trouble spelling with a traditional onscreen keyboard. For people with more limited control we usually use a custom-developed two-level spelling program. The first screen shows five large buttons, each with a group of letters (ABCD, EFGH, etc.). The person clicks on the group containing the letter desired. The next screen shows a button for each letter in the selected group. There is plenty of resting area between the buttons. We are still experimenting with the optimal configuration of these screens.

The Midas Touch problem also occurs using Internet Explorer or Netscape Navigator with the Camera Mouse. As the person is reading the text on the webpage, the mouse pointer is resting somewhere. If it rests on a link for 0.7 seconds (a typical threshold for triggering a mouse click) then the link might be activated and the user is off in an unintended direction through the web. Our future work will explore better ways to navigate through the web using a technology like the Camera Mouse.

There is an important story to be told about each of the dozen individuals listed in the table. The gentleman who is 58 with cerebral palsy spends his time in bed at home in New Jersey. He had no expressive language ability and no voluntary movement below the neck. We were approached by his 80+ year old father who wanted his son to be able to communicate before he died. We set up a prototype system in the home. The gentleman is now using the Camera Mouse to communicate with his father and access a variety of software.

Here is a portion of an email sent by Jordan's mother, Cheryl. (Cheryl has given full permission to use the pictures and email.)

> We are a family of four. What makes us different is that we have a daughter who is three and has Cerebral Palsy … we had no idea if or how much Jordan understood. To our amazement she followed every direction that was given her. Can you just imagine the joy we had watching our daughter exploring her environment and dreaming of what the possibilities were with this application in her life? The possibilities seemed endless now. Since then Jordan has become more sophisticated with this computer … it has given her

> the chance to actively participate in learning what her typical developing peers are learning, it has given her a way to communicate her thoughts, it gives the school that she is attending a way to adapt the curriculum so that Jordan can participate in a REGULAR preschool, it put Jordan in a situation where people can see her ABILITIES rather than her disabilities, and it allows a level playing field where Jordan can play from.
>
> In our situation we were very fortunate that the Camera Mouse System was available to us ... I feel strongly that this system needs ... support so that many individuals will be given the same opportunities to learn and express themselves. This type of independence is a rare gift for someone that has any type of disability where they are unable to explore their world. The best thing that the Camera Mouse System has given us, is watching both of our daughters sharing and playing at something that brings them so much joy and giggles. That is an experience that should not be missed by other families.
>
> Thank You,
>
> Cheryl, Mike, Alyssa, and Jordan

Since obtaining the Camera Mouse**,** Jordan has transitioned from an early intervention program to a pre-school regular education program. Despite her inability to vocalize and her very limited muscle control, she is functioning at grade level and above in most areas of cognitive and social development. Our goal now is to help Jordan access the regular schoolwork that is afforded her peers.

5. FUTURE WORK

Our major thrust is to improve the Camera Mouse system itself by improving the algorithm used for tracking, the interface with the program, and the cost of the camera and video capture hardware needed. We continue to work on developing new communication software. We are contemplating a better web browser to use with the Camera Mouse to mitigate the Midas Touch problem.

More ambitiously, we would like to expand our vision software to include recognition of gestures such as laughter and blinking and eye movements so that we can more fully allow people with limited physical abilities to access the computer.

We are planning a website that will serve as a "meeting place in cyberspace" for people who use the Camera Mouse and EagleEyes. The site will allow the people in England or Boston or Florida using these technologies (or, indeed, anyone) to engage in cooperative and competitive problem solving and educational development. It will allow them to chat with each other and see each other on live video. We hope it will begin to break down the isolation in these people's lives.

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