HUMAN
TECHNOLOGY

An Interdisciplinary Journal on Humans in ICT Environments ISSN: 1795-6889

www.humantechnology.jyu.fi Volume 2 (1), April 2006, 38–54

COMPUTER VISION INTERACTION FOR PEOPLE WITH SEVERE MOVEMENT RESTRICTIONS

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Abstract: *In this paper we present the starting point of research in applying human-computer interaction (HCI) techniques to help people with cerebral palsy to use computers via vision-based interaction. Our work includes the development and improvement of vision-based assistive technology, which was tested in experiments with cerebral palsy users. A brief review of current assistive technologies for severely physically impaired people and an explanation of the developed applications of such technologies are also presented. The final part of the paper describes the experimentation goals, process, and preliminary results. Future work directions are also indicated.*

Keywords: *accessibility, cerebral palsy, physically disabled users, computer vision interaction, human-computer interaction, design for all.*

INTRODUCTION

This paper explains a research project applying human-computer interaction (HCI) knowledge and techniques, such as accessibility and usability, to help people with cerebral palsy or other severe disabilities carry out specific tasks with a computer. As a first step, our main interest is focused on testing and developing new input devices based on computer vision, and testing different interaction methods. The fundamental goal is to enable users with special needs to access computers easily, or, at least, use the computer as an educational or training tool.

DOI: http://dx.doi.org/10.17011/ht/urn.2006158

We have chosen computer vision techniques because they allow for the building of noninvasive, versatile, and flexible systems at a very low cost due the software nature of these systems. The cost of a system, an important aspect of the design process, is too often forgotten. These systems open new paradigms in HCI and allow us to innovate ways of interaction that can benefit people with severe disabilities.

Three bodies are involved in this work: (a) the research community, represented by Grup de Recerca Interacció Persona Ordinador i Bases de Dades (the HCI research group from University of Lleida, Spain; GRIHO, n.d.); (b) the final users, surfaced through the nonprofit Asociación Provincial de Parálisis Cerebral (APPC; Provincial Cerebral Palsy Association, 2006); and (c) the computer vision industry, represented by CREA Sistemes Informàtics (CREA, 2005). The first body contributes through research, the second through actual testing, and the third with product development.

What is Cerebral Palsy (CP)?

According with the United Cerebral Palsy (UCP),

> Cerebral palsy describes a group of disorders of the development of movement and posture causing activity limitation that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception and/or behavior, and/or by a seizure disorder. (Bax, Goldstein, Rosenbaum, Leviton, & Paneth, 2005, p. 574)

Said more succinctly, CP is a nondegenerative disease that has an impact on a user's mobility and, usually, cognitive abilities. This produces a great range of disorders, from slight to severe, where mobility, the senses, language, reasoning, attention, and so forth, are greatly altered. Moreover, the normal development process of the individual is impacted due to motor impairments from a very early age. Therefore, early attention and a specialized education program are necessary to provide the best possible quality of life and autonomy for individuals with CP.

Human-Computer Interaction

HCI is "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (Hewett et al., 2004, Chapter 2.1, p. 5).

The discipline studies all the factors related to the communication process between the human and the interactive system with the objective of developing or improving the safety, utility, effectiveness, and usability of interactive computer-based products. By consequence, as Figure 1 summarizes, not only the computer has to be studied (as software engineering does) but also the human physical and mental characteristics (also known as human factors) and the context where the interaction is carried out.

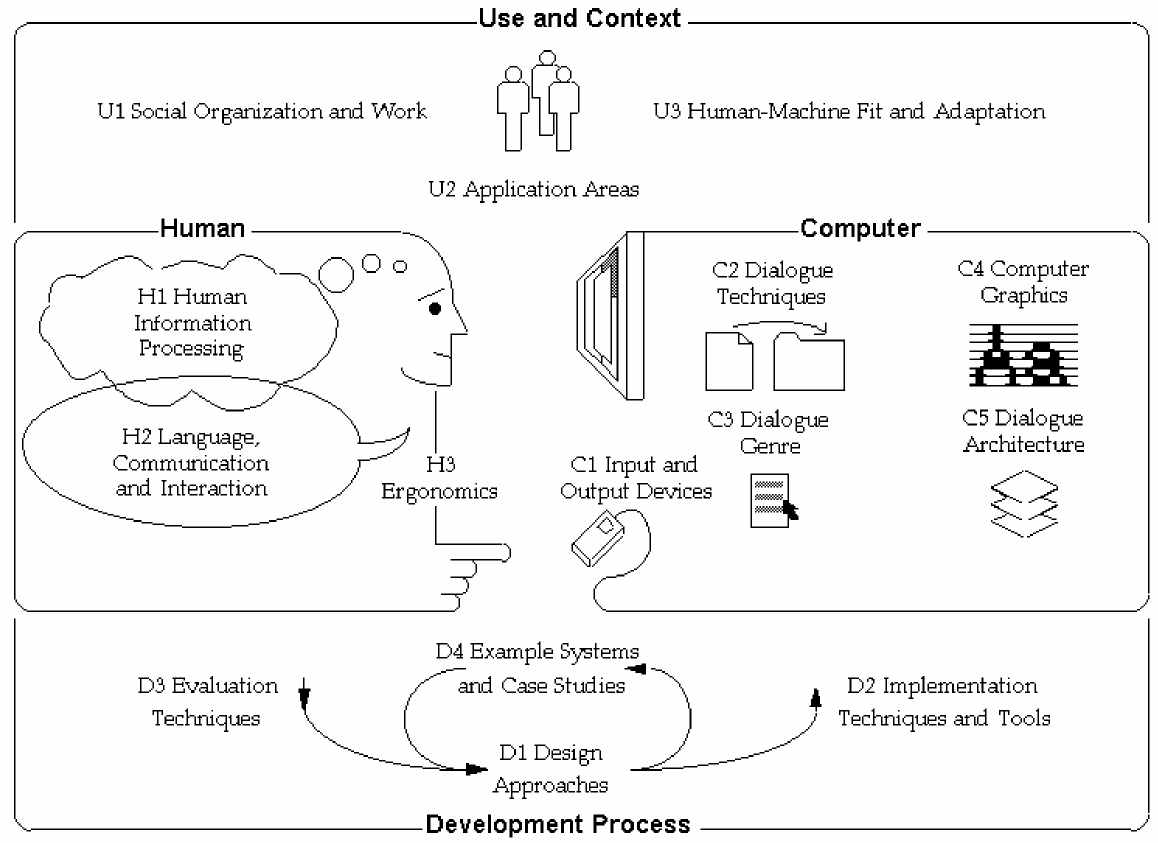

Figure 1. Human-Computer Interaction (Hewett et al., 2004) [1.]

Two of the most relevant HCI attributes are usability and accessibility. *Usability* refers to the extent to which a product can be used by specific users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specific context of use (Usability Net, 2006; see also International Organization for Standardization [ISO], 1998). It is considered within the first-level internal and external software quality attributes (International Organization for Standardization [ISO] & International Electrotechnical Commission [IEC], 2001).

Accessibility means that people with disabilities can perceive, understand, navigate, and interact with an interactive system. Accessibility also addresses the needs of a wider range of users, including people with changing abilities due to aging. Accessibility problems can also be caused by specific environment or social conditions.

Both above-mentioned attributes are largely treated and tested in this paper. First we will explain our work developing technology to overcome accessibility barriers using people with CP as target users. Later, once the interfaces are accessible, our experimentation looked to improve usability of these interfaces.

DESIGN FOR ALL AND ASSISTIVE TECHNOLOGIES

Design for all means that the products and environments should be designed so that they are usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. This will only come about as a result of designing mainstream products and services to be accessible by as broad a range of users as possible (van Dusseldorp, Paul, & Ballon, 1998). An architectural analogy would be the ramp or the elevator (as opposed to the stairs), which makes movement within the environment possible for most people.

Design for all involves the principles of accessibility and usability (see Figure 2). Since accessibility means removing barriers, an accessible system allows a blind person to "view" a Web site or a paralyzed person to move the screen cursor without a mouse. Since usability means minimizing the overload imposed by the use of computers in terms of motor and cognitive load, a usable system makes manipulation of the system easier.

Therefore, design for all also involves assistive technologies to overcome any impairments of a user. In the context of this paper, *assistive technology* refers to the (special) computer hardware and/or software used to increase, maintain, or improve the functional capabilities of individuals with disabilities (Blaise, 2003). Examples of computer assistive technology devices are Braille readers, screen magnification software, eye-tracking devices, and so forth. In spatial accessibly, a wheelchair is an assistive technology device.

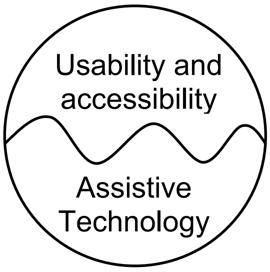

Figure 2. Design for all involves a synergy between usability and accessibility combined with the appropriate user dependant assistive technology.

User Interface Accessibility

From the user's viewpoint, interface means "the whole system." The barriers that disabled and elderly people find when accessing interactive systems are mainly related to the user interface. These barriers reflect the physical difficulties users might have to manage the devices and the cognitive barriers users may have in understanding the operating procedures for interacting with the interface. The studies made with users demonstrate the necessity of adaptable interfaces that allow the control of devices and services through integrated interoperable systems in intelligent surroundings (Abascal, 2003).

Physical Accessibility

Standard interfaces are based on the most common interaction devices: the keyboard and mouse for data input, and the screen (and sometimes speakers) for data output. The use of these devices requires a certain level of physical ability from the user. Input via these devices demands precision and motor coordination; visual-motor coordination is also needed to use the pointing device. Output requires visual and, sometimes, auditory abilities.

People present disabilities in diverse ways. A significant percentage of the general population does not possess the necessary minimum physical ability to use standard input/output devices. This occurs for various reasons, for example, aging, physical or cognitive disability, or the inability to execute multiple tasks simultaneously (browsing the address book of a mobile phone while driving, for example).

Cognitive Accessibility

Interfaces control the user-application dialog through a set of procedures, such as the available commands, browsing procedures, and so on. These elements are related to a model of the task that is explained like a metaphor of the same activity achieved without a computer (for example, dragging a file icon to the trash can). Users must understand the procedures, the metaphors of the browsing process, for instance, in order to successfully complete their task. All of this depends on the vision for operation that both the users and the application have.

The cognitive abilities and disabilities of users are diverse (Cañas & Waern, 2001). Besides aging and cognitive disabilities, the use of a foreign language or the reduction in attention when doing simultaneous tasks may influence the cognitive ability of the user. Therefore it is necessary to take into account this diversity when designing interaction methods. Despite the fact that the cognitive disabilities affect a large number of people, many of whom are not considered disabled, cognitive accessibility studies are less developed than those for physical accessibility.

Computer Assistive Technology Devices

Focusing on the severe physical motor disabilities and interaction at the sensory-motor level, most of the recent computer assistive technology devices are based on the extraction of a stimulus generated by the users, usually through voluntary movement of any part of their body. Here we have compiled a representative set of computer assistive technology devices commonly used with our disabled target users, individuals with CP. The information presented here comes from organizations and projects like the Centro Estatal de Autonomía Personal y Ayudas Técnicas (CEAPAT, n.d.; National Center for Personal Autonomy and Technical Aids of Spain), the European Assistive Technology Information Network (EASTIN, n.d.), and the on-line database of assistive technology maintained by the United Spinal Association (2004).

Switch

The switch is one of the most simple and widely used computer access systems and consists of an electrical device that the user activates with the part of his/her body that has movement (see Figure 3). Available in different sizes and sensibilities, the switch can be activated by the hand, foot, head, or by blowing, for example.

In general, switches allow for a simple interaction and are usually combined with (screen) scan software. The scan is done in one dimension (as a list of menu options, icons in a window, rows and columns of the screen, etc.). The user activates the switch when the desired option is highlighted to execute the selection.

Figure 3. Examples of various switches (activated by the hand, head, and chin).

However, this technology has a technologic problem: its low bandwidth. This feature affects a normal communication between the user and the system; the pair action-reaction is not instantaneous (with action meaning “what the user does” and reaction “the system feedback”) and can frustrate the user with a lot of dead time.

Joystick

The joystick is a well-known computer peripheral used mainly for gaming. In the ambit of disabilities it is used for controlling a mouse pointer (see Figure 4) or driving a wheelchair, for example. It usually acts as a substitute for a mouse when the user has difficulties using one. There are joysticks that can be used with the hand, foot, chin, or mouth.

Interaction is based on a succession of directional selections over time; this allows for a greater bandwidth than the switch. But the time constraint remains present when emulating the mouse functionality. Thus the user must wait while the pointer is moving.

Figure 4. Examples of joysticks (hand, chin, and mouth).

Trackball

The trackball is a pointing device consisting of a ball housed in a socket that contains sensors to detect the rotation of the ball around two axes. The user rolls the ball with a thumb, the palm of a hand, or another part of his/her body to move the screen pointer. Trackballs are useful for people with reduced mobility in their upper limbs and where the lack of precise motion invalidates the use of the standard mouse. Interaction is done across two dimensions and equivalent to a mouse.

Keyguard

The keyguard is a rigid plate, usually made of methacrylate, with holes in it that coincide with key positions in the keyboard below. Keyguards are available for standard computer keyboards and for a range of specialist keyboards. They are useful for people with erratic movements and help decrease undesired keystrokes.

Virtual keyboard

The virtual keyboard is an on-screen representation of a (standard) keyboard (see Figure 5). As long as the person can control a mouse, trackball, or other pointing device, he/she can mimic keystrokes for virtually any application.

Figure 5. Screenshot of the virtual keyboard included in the Windows operating system.

Speech Recognition Software

Speech or voluntary sound emission also can be used by people to interact with computers. Core uses include sending simple verbal orders (opening an application, clicking the mouse, etc.) or continuous speech recognition to write text.

Head Pointer

The head pointer is a pointing device controlled with the user's head and is useful for people with good cephalic control. There are different kinds of head pointers.

- Head sticks are head-worn pointers (see Figure 6). These can be used in a number of ways: for signaling pictures, words, communication board icons; as a keyboard aid; or as a pencil holder, for turning pages or drawing, for example. The only requirement is the user ability to move their head with certain precision. The user of these devices heavily depends on third party assistance in order to place the device on user's head.
- Light (laser) head pointers. These have evolved from the early head pointers. A laser emitter is mounted on a head-worn device and can be used for signaling functions. The main difference from the preceding technology is that while the older pointers interact with physical touch, the new ones interact with a laser light.

Figure 6. Examples of head stick pointers.

- Electronic head pointers. Based on infrared (HeadMouse Extreme[2], IRdata 2000[3], SmartNav 3 Hands Free Mouse[4], Tracker One[5]) or ultrasonic technology (HeadMaster Plus[6]), these devices usually require a mounted headset or reflective dot on the user's head to make the system functional. The pointer is used mainly to control an onscreen pointer.
- Webcam-based devices. These devices usually track facial features to gather the user's motion and do not need any headset or dots mounted on the user's head. As a result, third party assistance is minimal. Moreover, Webcam-based head pointers are usually software-only solutions based on standard hardware, thus they are cheaper than electronic ones. (See Betke, Gips & Fleming, 2002; HandiEye[7], Hologram[8], Mauri, 2004; QualiEye[9]).

All head pointing devices usually emulate a standard mouse, meaning they have a two-dimensional interaction space equivalent to a standard mouse. The click generation is usually done through the mouse-over method (also called a dwell click; Bohan & Chaparro, 1998) that consists of stopping the pointer over the desired location for a moment.

Eye Tracking

An eye tracking system consists of one or more cameras that focus on one or both eyes and record the movement as the user looks at an area. Eye tracking setups vary greatly: some are head-mounted, some require the head to be stable, and some automatically track the head.

Eye tracking in HCI is used frequently for usability analysis purposes or as a method of input in gaze-based interfaces. The latter is what interests us because such systems allow the use of a computer by people with eye-only motion. (For an overview of eye tracking applications, see Duchowski, 2002.)

Neural Interfaces

Neural interfaces allow computers to pick up the user's intention through sensors connected to nerve terminations on different parts of the body or directly to the brain. Because interaction is done solely through the voluntary control of user's own mental activity[10] this technology implies that no mobility is necessary for use.

COMPUTER VISION-BASED INTERACTION SYSTEMS

Computer vision-based interaction systems process the images coming from one or more cameras to extract features that are interpreted for implementation by way of specialized software. These systems are extremely flexible because any modification detected in the video is susceptible to be interpreted by the computer and used to unleash some action.

There are many advantages to computer vision-based interaction systems. First, a user can interact at a distance, without physical contact with the device. Additionally, virtually any part of the body with mobility can be used to perform the interaction, which is especially important for people with severe physical disabilities. It is also possible to combine classic interaction peripherals, like keyboard or mouse, to improve interaction in a multimodal way. In addition, Webcam-based technologies, for instance, are particularly affordable compared to professional (industrial) computer vision devices.

The idea of using computer vision-based interaction systems for people with severe movement restrictions is not new. As stated above, several systems exist in the market. However, these systems are mainly oriented toward face tracking. Furthermore, these systems are usually not useful for people with seizure disorders like spastic movements (Gips, Betke, & Fleming, 2000).

In this paper we present two new types of computer vision-based systems: one based on face tracking and the other on color tracking. These systems overcome the limitations of the former systems for people with spastic movements and seizure disorders. This paper includes information on the research and development of these two systems: the Facial Mouse and the WebColor Detector (García & Mauri, 2004, 2005).

Facial Mouse

The Facial Mouse[11] is a mouse emulator system based on the facial movement of the user. A Webcam is placed in front of the user, focusing on the user's face. A motion extraction algorithm, which is user independent, is used to extract the facial motion from the video. This motion is used to move the mouse pointer that is controlled in a fashion relatively similar to standard mouse devices. This system can be used with great accuracy even when the user has exiguous cephalic motion control.

The click can be generated through several mechanisms:

- Built-in mechanisms.
  - Dwell click. This click is automatically generated after stopping the pointer for a certain amount of time.
  - Sound click. The click is generated when the user emits a sound whose input level is greater than a configured threshold.
- External mechanisms. An external device can be used to send click commands to the computer, like a keyboard, a standard mouse or a mechanical switch for example.

The Facial Mouse's working environment is composed of a camera, a computer, and the software (see Figure 7). Three elements are presented on the computer screen for the user:

- Application's main window. This shows the live video and offers all menu options.

- Click bar. This is the main complement for click selection and execution. It consists of a toolbar docked at the top of the screen (click bar) that allows for choosing the appropriate mouse action (right/left click, drag & drop, and double click).
- Task bar icon. This utility is used to maximize or minimize the application's main window.

Figure 7. The Facial Mouse's working environment. The Webcam captures the user's movements that a software program translates in order to position the cursor on the screen.

The WebColor Detector

This software, which uses a camera to gather data, is able to detect in real-time the presence or absence of a distinctive color and to track its position. WebColor also includes a built-in human skin color model.

Currently, WebColor emulates the functions of a switch, a joystick (to control the mouse pointer), and a mouse. Color markers are usually fluorescent-colored pieces of paper (see Figure 8) that can be attached to any surface or to the user's body.

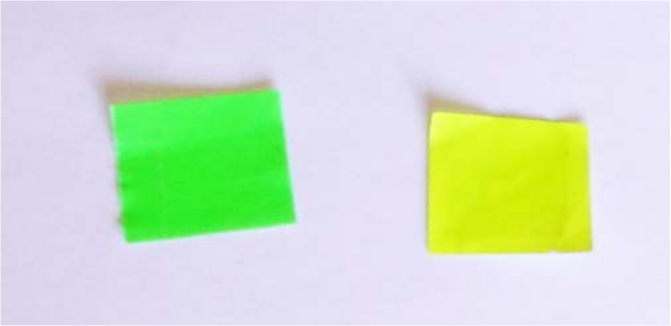

Figure 8. Fluorescent color marker samples.

Working Environment and Basic Operation

Figure 9 shows a sequence of the internal WebColor operation. The first step must train the software for the desired color, which is then saved and reused in subsequent executions. The training is performed by making a single click over the desired color.

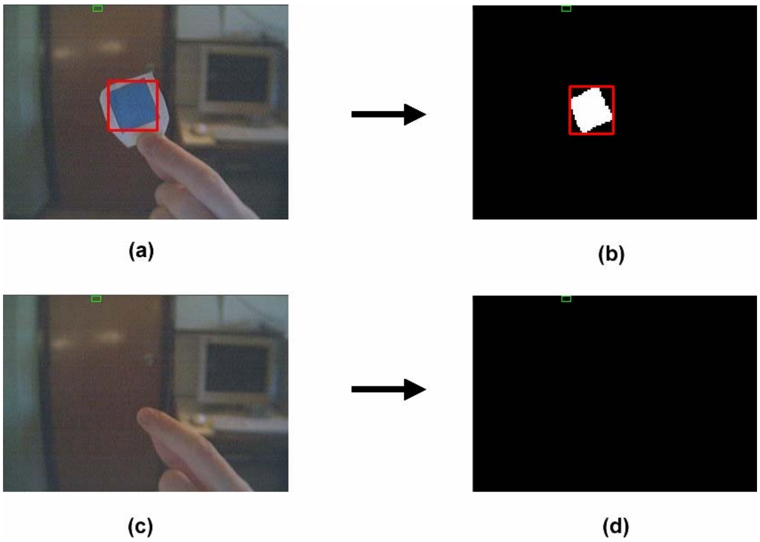

Figure 9. (a) After the color training process, WebColor detects a blue color, and then a red box encircles the marker. (b) The program “sees” only the white stain that corresponds to the marker, a red box encircles the marker; (c) When the mark is removed, (d) the result is a black image because nothing is detected.

Afterward, the application automatically finds and tracks that specific color marker as a means of operating the system. The working environment of the program, then, allows for the related applications of the switch, the joystick, and the mouse to be activated. These modes of operation are explained more fully below.

Switch Emulation

The switch functionality is the most simple. The marker can be attached over a surface, like a table or wall (static marker), or over the user (dynamic marker). When using the static marker the user must cover or uncover the marker by moving the part of the body that has mobility. When using the dynamic marker, the user must move the part of his/her body that has the marker attached (and has mobility, of course) until it appears or disappears in the video. When the marker appears or disappears (this behavior is configurable), an action is triggered. The action can be configured as a mouse click or keyboard keystroke. Usually this system is used in conjunction with third-party interactive switch-oriented software.

Mouse Emulation

In this working mode the position of the marker in the video is coordinated with the screen pointer. So moving the marker in the web camera scene moves the pointer on the screen (for dynamic marker users only). The click is emulated with the dwell click technique or the user can select the appropriate action from the click bar at the top of the screen.

Joystick Emulation

This mode also allows control of the mouse pointer, but in this case the user interacts in a joystick mode fashion. In the video window, a 3 x 3 matrix is shown in red (see Figure 10).

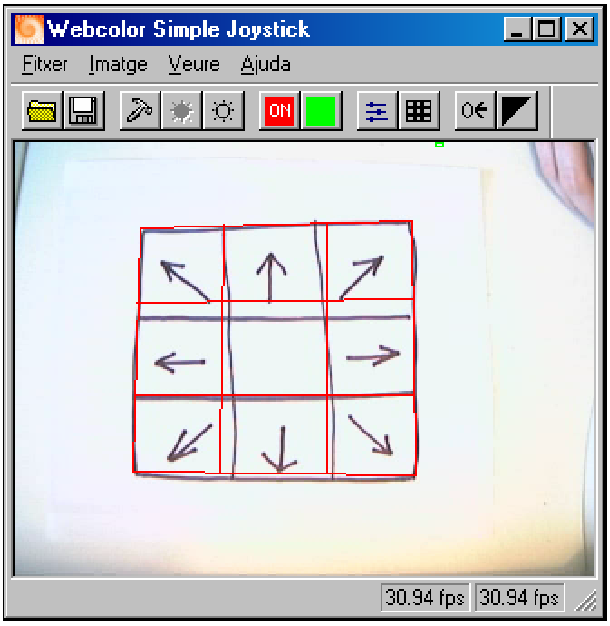

Figure 10. WebColor screenshot running the joystick emulation mode.

Each cell corresponds to one of the eight possible directions and the central cell is used to click. When the marker is in one of the external cells, the pointer begins moving in the appropriate direction, first at low speed then faster as time advances. The click is generated by putting the mark in the central cell and waiting for a specific amount of time (dwell click). The joystick emulator also has a click bar.

Moreover, the joystick matrix is not fixed; it can be adjusted to fit a matrix that the camera sees, for example, the matrix painted on a paper. One useful process we have found for improving the usability for all users has been mounting the camera perpendicular to the table and putting a drawing of a matrix with the eight directions to provide a reference.

A typical session with the WebColor includes the setup of the user, establishing marker location, and positioning the camera, depending on the kind of interaction planned. With the switch, the marker can be attached anywhere; all that matters is that the user is able to show or hide it as stated above. With the mouse and the joystick applications, the marker should be attached to the user where he/she has mobility, usually on the forehead, hand, or finger.

EXPERIMENTS

The two core purposes of the experiments were to validate the usefulness of the systems and to improve the interaction of the devices in actual use conditions. An interdisciplinary team was formed, consisting of a computer science engineer, who served as the research process coordinator and development supervisor, and a special education teacher who was responsible for the user experimentations at the APPC center. In addition, this team had the support and advice from researchers in the areas of speech therapy and physiotherapy.

Technical Setup

All the work was done in the APPC center (located in Tarragona, Spain), where we have a research laboratory equipped with a computer, several Webcams, and the necessary software, including the two systems explained above, and assorted special education software. These resources were provided by the APPC and CREA.

User Selection

For the trials we selected users from the three APPC centers, the La Muntanyeta school, the Gresol occupational workshop, and the Trèvol residence. The selection resulted in 11 persons, 5 women and 6 men, aged from 4 to 35 years.

This selection was done taking into account two parameters: the physical and cognitive conditions of the participants. We chose users with mobility in at least one part of their body and with sufficient cognitive ability to understand and execute simple orders.

Moreover, we developed a database where we compiled information about the selected users, such as name, birth date, medical record, physical and motor challenges, previous computer usage and manner of access, and a preliminary work plan. The database was also used to compile notes taken during experimentation sessions.

Testing Procedure

The experimental methodology was a qualitative evaluation. This evaluation took into account the accessibility and utility improvements introduced by the two new assistive devices (Facial Mouse and WebColor Detector) as compared to the computer experience of the user with previous systems. A simple scale was used to assess the change of in the quality of the interaction (see Table 1). Although a number of different tests were carried out with each of the participants, all of the obtained results were based on the perceived change as evaluated by the special education teacher. Thus, the data reflecting the degree of change were derived from a subjective measure.

Each user participated in several experimentation sessions, ranging from two to eight sessions. The duration of each session was variable, depending on the user's fatigue and attention levels, but the sessions lasted from 15 to 45 minutes. This time included the positioning of the user, cameras, and computer, which normally took about 5 minutes.

The goal of the first session was to familiarize the user with the working environment (screen, camera, color marker, and interaction pattern to execute) and to decide which system, the Facial Mouse or the WebColor, was better suited for each user. Depending on the cognitive level of the user, greater or lesser assistance from the teacher was needed in this step.

Table 1. Accessibility and Utility Improvements.

Qualitative evaluation	Description
No improvement	No improvements were shown.
Slight improvement	Minimal human computer interaction achieved.
Great improvement	Useful human computer interaction achieved.

In the following sessions, we studied the two computer vision applications. According to the cognitive level of each user, two core objectives were pursued: basic computer interaction, based on educational software or utilities developed at the APPC (simple Macromedia Flash applets or PowerPoint presentations), and higher level interaction, based on common computer desktop applications (drawing, writing, Internet browsing, e-mail, etc.). These sessions were useful in evaluating the functionality and compatibility of the selected computer vision application with each user and to compare it with that user's previous computer interaction experiences.

Results and Discussion

During the experiments the Facial Mouse system was shown to be less useful than the WebColor Detector system for the users of the study. Only 2 of the 11 experiment participants were able to use the Facial Mouse properly to control the mouse pointer; other participants used it merely as stimulation tool (erratic head motions were used to move a picture across the screen to attract the user's attention). The Facial Mouse seems to be especially suited for people with difficulties using a standard mouse but who have good cephalic control, which is not common for individuals with CP. The WebColor Detector, on the other hand, showed great flexibility in use by the individuals with CP, especially with the switch emulation.

The ease of use and preparation of the switch emulator in the WebColor Detector were the most noticeable features, compared to the use of mechanical switches that must be mounted in specialized supports. The joystick emulation was very useful for the participants who had enough motor capabilities to move one arm over the table but not to use a standard mouse. However, as a mouse emulator, the WebColor's performance was poor when compared to the Facial Mouse, which is more precise and smooth. Table 2 summarizes the evaluation for each participant.

Table 2. Resulting Evaluation for Each User.

User	Age	Diagnosis	Qualitative evaluation
GRS	34	Spastic tetraparesia	Great improvement with Facial Mouse
CGA	34	Spastic tetraparesia	Great improvement with Facial Mouse
JBG	15	Spastic tetraparesia & low-vision	Slight improvement with Facial Mouse
RCL	17	Spastic-distonic-athetoid tetraparesia	No improvement. Uses a joystick to access the computer.
HR	16	Spastic-distonic-athetoid tetraparesia	No improvement. Uses a joystick to access the computer.
JI	4	Spastic-distonic tetraparesia	Slight improvement with WebColor Switch.
ENG	30	Spastic tetraparesia	Slight improvement with Facial Mouse and WebColor Switch
ADS	35	Mixed tetraparesia	Slight improvement with Facial Mouse
ICG	26	Spastic cerebal palsy	Slight improvement with WebColor Switch
MEM	8	Spastic cerebal palsy	Great improvement with WebColor Mouse.
IAMF	12	Spastic tetraparesia	Slight improvement with WebColor Switch

CONCLUSIONS

Computer vision-based interaction is an emerging technology that is becoming more useful, effective, and affordable. However, it raises new questions from the HCI viewpoint, for example, which environments are most suitable for interaction by users with disabilities. In our case we put emphasis on the accessibility and usability aspects of such interaction devices to meet the special needs of people with disabilities, and specifically people with CP.

Despite the fact that our work has just started, preliminary results show that, in general, computer vision interaction systems are very useful; in some cases, these systems are the only ways by which some people can interact with a computer. Computer vision-based interaction systems also give advantages—such as flexibility and lower cost—over other traditional assistive technologies.

The switch and joystick emulators of the WebColor Detector system have been very effective for users with CP. Overall, the WebColor Detector proved more applicable to the CP field. On the other hand, the program's mouse emulator showed a poorer performance than the Facial Mouse system. In those cases where the Facial Mouse could be used by persons with CP, it provided richer interaction with the software than did the WebColor system.

The results obtained with the participants with CP may be easily exportable to other people impaired by phenotypically similar disorders. For example, the Facial Mouse is being used by spinal cord injured quadriplegic people (Hospital Nacional de Parapléjicos [National Hospital of Paraplegics], 2004).

Future work may include the development of multimodal interfaces that combine various computer vision devices with other input devices (Ovita, 2001); improvements in the existing systems to accommodate more the special needs of individuals; the use and development of qualitative metrics with the aim of comparing the effectiveness of various devices and to study users' progress across time (Jacob, 1990; Noirhomme-Fraiture, Charriere, Vanderdonckt, & Bernard, 1993); the application of computer vision input for stimulation and telehealth (Lewis-Brooks & Petersson, 2005); and the development of alternative strategies to emulate mouse clicks besides the dwell clicks (Jacob, 1990). Finally, we plan to design new experimental environments in order to be able to analyze the whole behavior of the users that are involved in the project.

ENDNOTES

1. © 1992 Association for Computing Machinery, Figure 1 (Hewett et al., 2004). Reprinted by permission.
2. HeadMouse Extreme. http://www.orin.com/access/headmouse
3. IRdata. http://www.irdata.com/irdata2000_en.htm
4. SmartNav 3 Hands Free Mouse. http://www.novitatech.org.au/product.asp?p=247&id=1741
5. Tracker One. http://www.madentec.com/products/comaccess/trackone/about-t1.html
6. HeadMaster Plus. http://store.prentrom.com/cgi-bin/store/HM-3P.html
7. HandiEye. http://www.mousevision.com/assistech/html/products/handieye_pro.htm
8. Hologram. http://www.motionparallax.com
9. QualiEye. http://www.qualilife.com/products/index.cfm?id=183&prodType=0&prodTarget=0
10. In relation to physical and cognitive accessibility, we want to cite the research that Spanish scientist José del Rocío Millán is leading at the Insitute Dalle Molle d'Intelligence Artificielle Perceptive. Dr. Millán's research, called the Adaptive Brain Interfaces (ABI; Millán, 2003), has the main goal of users being able to send orders to a computer through their cerebral waves. Although these technologies are a long time from being a

quotidian reality, undoubtedly people with severe physical impairments would be the first and and perhaps most immense beneficiaries. Applications range from improving communication (virtual keyboards for typewriting or Internet browsing) to environmental control (lights, doors, etc.) to wheelchair motion control.

11. A free demo version of Facial Mouse is available for downloading at http://www.facialmouse.com

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