Other Research

Disability Studies Quarterly
Spring 2002, Volume 22, No. 2
pages 159-174 <www.cds.hawaii.edu>


# Information Technology for Protected Individuals: A Survey of Current Status

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## Abstract

Information technology has greatly impacted the life of everyone in recent years. It is therefore important to be aware of current technology and know how it can improve functional participation in today's society that is better known as the "Information" Society. The purpose is to foster equality in using technology for everyone, able or disabled. Everyone should have equal access to technology and the presence of a disability should not preclude one from this benefit. The purpose of this article is to summarize important developments in computer technology for individuals experiencing disability and to provide a brief explanation of how they can be utilized to promote participation in society.

Children and adults with disabilities make up one of the largest minority populations in the United States, 49 million citizens who evidence a variety of disabilities. Those with disabilities have one of the highest unemployment rates in the nation (Galvin and Schere, 1996). The potential of technology to increase the independence and productivity of the disabled is well recognized. This recognition has been supported by legislation designed to provide necessary access to technology. The 1996 amendments to the Rehabilitation Act (P.L. 99-506), the 1990 Americans with Disabilities Act (P.L. 101-336), the 1990 Individuals with Disabilities Act (P.L. 101-476), and the 1998 Technology-Related Assistance for Individuals with Disabilities Act (P.L. 100-407) have all placed significant emphasis on the use of supporting technology. They have also mandated that technology become more consumer responsive. The Telecommunications Act also requires accessibility to the information provided on the World Wide Web. Accessing computers and their use are essential for many for the purpose of support and employment in a rapidly changing technological environment.

In order to achieve full access to standard computers and software either for primary access to the computer or access to the computer as a link in using supportive technology, the goal is transparency. That is, the individual must be able to interface with the computer so that the special access technology is transparent or invisible to the computer user.

There are four strategies for achieving transparent access to computers for those with disabilities. These strategies include: (1) building features into computer hardware, operating system, or application programs; (2) use of adaptive interfaces comprised of standard software or hardware products that provide modifications or alternate interfaces for accessibility; (3) establishing connectivity to personal supportive devices; and (4) developing custom adaptations. The hardware and software features that support these four strategies as applied to those with visual impairment, physical disabilities, and hearing impairments are discussed. Awareness of the means to computer access for the disabled is essential if barriers are to be eliminated thus positively influencing the contribution of those with disabilities to society.

## TECHNOLOGY FOR VISUALLY IMPAIRED PERSONS

Computer access is necessary for visually impaired users who can utilize computers as speech-enabled training programs, Braille training programs, Braille translators, Braille, voice, and large-print notetaking systems, speech output calculators, interfaces with other equipment, orientation and mobility aids, and dynamic Braille displays (Galvin and Scherer, 1996). The major barrier for computer use among the visually impaired is the screen display. The increased use of graphics on computers have resulted in a net loss of accessibility to the computers and to the information presented through them to people with visual impairments (Galvin and Scherer, 1996). The visually impaired need access not only to input text, but also to text attributes, help information, prompts, messages, menus, and requested information.

Compensation for the display can be in an auditory mode, tactile mode, or a combination. For persons with low vision, there is a need to enlarge the text and graphics to various degrees: 27% of individuals identified as legally blind use primarily visual means to access text while 10% use primarily auditory means. The remainder use a combination of techniques (Smith, 1998). Thus a variety of means needs to be available to create access to computers for the visually impaired.

Braille is one way in which the visually impaired can receive tactile input to replace or augment visual input. Fant (1982) developed a method to allow brailling on a standard line printer. The adjustment to the printer is a strip of specially prepared cellophane tape. Since it is not necessary to remove the ribbon or adjust the impact force, printer output can be obtained concurrently with Braille output. When a specially designed printer is attached to a microcomputer, standard text can be translated into Braille allowing a sighted person who does not know how to use Braille to produce Braille copies of handouts and other textual materials. Some printers produce Braille and print on the same page so that users may read along with the visually impaired user (Smith, 1998). The disadvantages of Braille printers are that they are slower and noisier than ink printers as they are driven by solenoids that emboss Braille dots on a page. Depending upon the cost, the printers can produce 10 or more characters per second (Galvin and Scherer, 1996).

Braille printers can be classified into three categories including personal, medium duty, and heavy duty. Personal printers are designed for use at home with a speed of approximately 20 characters per second. Medium duty printers are designed for small business use with a speed of 20-40 characters per second. Production houses or organizations that need to print a large quantity primarily use heavy-duty printers with a speed of hundreds of characters per second. Like standard printers, Braille printers interface with the computer through a serial or parallel port (Lazzaro, 1990, 1993). Braille output may also be produced on paperless Braille systems in which retractable pins are used to form Braille characters (Kaplan, 1996).

In addition to the use of Braille printers, refreshable Braille displays are separate devices that connect to a computer and display 20, 40, or 80 characters of text (Lazarro, 1993; Galvin and Scherer, 1996). Each Braille cell consists of six solenoids. The Braille letters are formed by sets of pins being raised and lowered electromechanically. As the input is typed in, the user can review it on the 1 line display. The displays are refreshable in that they allow the information displayed to change as the user moves the display window around the screen. Each refreshable cell displays one character and costs approximately seventy dollars to build. The high cost of Braille displays forces many to develop the skill using synthetic speech.

Portable Braille computers have also been developed. The keyboard consists of six standard keys that allow the user to produce a standard 6-dot Braille symbol. These computers can be used as input devices that interface with personal computers. Braille notetakers are small battery-powered devices that allow the user to enter the information on a Braille keyboard and then review the information through the use of synthetic speech or through a Braille display. The information stored in the memory can be saved to a computer disk or printed when the user returns to the home or office (Galvin and Scherer, 1996).

In the 1970s Raymond Kurzweil developed the first computer-based reading machine that consisted of a flatbed scanner, central processing unit, and a detachable keyboard. The cost was $30,000. For over a decade this was the only option for transforming printed text from a book, magazine, or newspaper into synthetic speech. In contrast to these stand-alone reading machines, there are PC-based reading machines that scan a page of print and convert the text to synthesized speech, Braille, or large print output. Since they are PC-based, they have the advantage of being usable with other typical computer software.

Telesensory Corporation has developed a system to send output to a Braille printer or the Optacon hand-held scanner that converts Braille to tactile letters using vibrating metal pins that are felt on the index finger. There is also an Optacon II that scans computer screens and can send output to a Braille display or a speech synthesis system. The hand-held scanners make it possible for visually impaired users to access many documents found on the internet (Galvin and Scherer, 1996). However, these reading machines use computer based optical character recognition systems and all have limitations on what types of fonts they can recognize. Using intelligent character recognition (ICR), some machines can now recognize thousands of typefaces and styles. The user must be able to use a keypad for adjusting volume, voice, and speech rate as well as placing the document correctly so the page can be scanned (Kaplan, 1996).

The development of the Kurzweil Reading Machine showed that speech synthesis was possible in the 1970s. In contrast to the Optacon, one of the advantages of synthesized speech is that it allows a rate of speech as fast as human speech. To enable a computer for synthesized speech output the system generally requires software, a speech synthesis board with audio amplification, an interface to the personal computer bus, and a speaker that is external to the computer. Products are available as internal circuit cards or external devices that connect via serial or parallel ports. Synthesizers with higher speech quality are often more easily understood and require less training time, but have slower response times and are more expensive than those characterized by a robotic, artificial quality.

The Microvox is an intelligent peripheral device designed for use in a wide number of applications. Its hardware is like a general-purpose computer with a speech synthesizer attached using a memory-mapped I/O port. By combining the text to speech algorithm with a dedicated processor, dependency on the operating system and application programs to support speech synthesis is no longer necessary. A computer with a sound card has a synthesizer capable of speech and on a Windows-based PC, a keyboard or series of keyboard commands can also perform any command that can be performed with a mouse command.

Since the majority of those who are legally blind and evidence low vision have residual vision, use of magnification devices is an important option for accessing computer displays. Beginning in 1980 traditional magnification techniques have included large pieces of equipment to be attached to the computer. Compu-Lenz consists of a plastic lens and mounting hardware. One method to add large print to a computer is to use a hardware-based large print system which includes a special video card, a larger monitor to increase font size, and a joystick or mouse to move the cursor (Lazzaro, 1993).

Portable Braille computers generally come with word processing and telecommunications software. Other possible features are a stopwatch, calculator, and appointment software. The devices are compatible with most commercial screen reader software (Lazzaro, 1990, 1993).

Fant (1982) developed a software method using the Pascal language to allow brailling on a standard line printer. With the development of Braille printers came the need for Braille translation software. Translation consists of two steps. First, the print symbol in the source document is translated to a corresponding Braille symbol. Second, text is reformatted to fit on the smaller page. This translation can be accomplished on various computers as translation software is available for the IBM PC and Macintosh. For example, the Duxbury Braille Translator from Duxbury Systems works with most word processing packages including WordPerfect. In some packages, the software is placed on a ROM chip (Lazzaro, 1993).

Like Braille printers, a Braille display requires software to control it from the keyboard. Software allows reading the text line-by-line, word-by-word, or character-by-character (Lazzaro, 1993). One type of technology which recognizes graphic icons and uses synthesized speech or Braille, OCR (Optical Character Recognition) technology, requires software which handles document recognition. This document recognition may be accomplished using two methods, template-based and feature-based recognition. The template method involves scanning a collection of letters and finding the template which most closely resembles the ink mark. The feature method breaks an ink mark into a collection of features by identifying where strokes join and curve significantly (Wayner, 1993).

Verbal input may be used in lieu of the keyboard to access computer technology. While there are no speech-enabled operating systems, there are now a number of speech-enabled application programs. This may be accomplished by using speech synthesizers, which require software that is commonly referred to as a screen reader. According to Ciarcia (1982), there are three methods used in converting phrases to phonemes. In the first method, whole words can be translated to phonemes by looking the words up in a table. The second method breaks words into syntactically significant groups of letters and looks up the phonemes that correspond to each group of letters. The final method applies a set of rules, commonly known as algorithms, to letters and letter patterns in a word.

The visually impaired person can also receive computer information output through speech synthesizers with adaptive software. Software for the Microvox synthesizer allows punctuation symbols and abbreviations to be converted into words. Speech output may also be synchronized with other information such as text or graphics on the screen. A complete phrase can be input before translation from text to speech. This minimizes distractions which could arise if the software were to output each character or phoneme as it was input. The Microvox can output the information in four modes of translation. These modes are text-to-speech, text-to-spelled-speech, phoneme-to-code, and music.

There were disadvantages in the earlier speech synthesis packages such as the Texttalker software which was combined with the Echo II synthesizer for the Apple II. Words were occasionally mispronounced and it did not make all programs talk (Lazzaro, 1984). Prior to 1986 there were only two or three screen reader packages available for use by the visually impaired, but development of better systems increased by the end of the year. In 1989 Berkeley Systems developed OutSpoken for the Macintosh. This program was the first screen reader to work with graphics and it allowed icons, pull-down menus, and dialogue boxes to be verbalized (McNulty and Suvino, 1993; Lazzaro, 1990). Window Bridge by SynthaVoice is the first screen reader to work with the IBM compatible Windows system. Windows can be selected by menu key and rising tones represent upward mouse movement via the keyboard (Lazzaro, 1993).

Improved screen readers now allow visually impaired persons to access commercial software with an unlimited vocabulary. The user can choose from a variety of verbal output modes such as character-by-character, word-by-word, line-by-line, and screen-by-screen. Additionally, various settings can be controlled including volume level, pitch quality, punctuation marks pronunciation, pronunciation of numbers as digits or words, elimination of repeating or special characters, and indication of capital letters by changing the pitch or saying "capital" before the letter.

Users of speech output software encounter problems when they access the World Wide Web. These problems can be eliminated with foresight on the part of the webpage designer. The designer should use "ALT" tags with all images as users of speech output software or non-graphical browsers rely on these alternate text labels. The designer should also limit the use of image height and width tags to larger images. In browsers that maintain image size even when images are not displayed, an ALT tag may not have room to display within the borders of a small image and therefore will not be read properly. Finally, the designer should avoid using tables. Screen reader programs are often unable to interpret a logical order within tables and tend to read straight across a page, even when cells or columns contain wrapped lines (Illinois, 1997).

Magnification is necessary for low vision users as the icons on computer screens are often too small and detailed. For those visually impaired persons who have low vision, software is a more practical solution to magnification than hardware. Screen magnification software is often used to provide higher magnification and additional contrast and color enhancement which can increase the user's access to the World Wide Web. Screen appearance can affect the user's access to the World Wide Web if the webpage designer does not consider the user's needs. HTML, the language which webpage designers use, was not intended to control the appearance or layout of a page, but designers sometimes limit the user's choices in setting up the page design. Viewers should have complete control of how a page is displayed including whether it is with large fonts, high contrast colors, or in a format compatible with a special accessibility program.

In considering screen magnification software, Glinert and Ladner (1984) developed a prototype for a Unix system that runs on a VAX-11/780 which is a large multi-user network server system. Using this prototype, the user may select among four font sizes. The character sizes in column by row are 14 x 12, 10 x 8, 5 x 7, and 5 x 5. The user may also choose between normal dot matrix and graphics modes. In graphics mode, graphics characters are used to create a continuous display rather than one of the dot-matrix types. The user can also choose between line break and stream modes. In stream mode, the program ignores line breaks whereas in the line break mode the computer stops reading at the end of the line. It was the prototype authors' intent to transfer the interface to a smaller personal computer that could be used as a dedicated front-end large font display generator.

The current generation of magnification software is generally TSR (Terminate Stay Resident), a program that is loaded and then disappears but stays active in the computer. Commercial software can then be loaded on top of it and the TSR program automatically magnifies the output from the commercial software. Average magnification ranges from 1.4x to 16x, and it is advantageous that no additional hardware is needed with this software (Lazzaro, 1990, 1993). Screen magnification is also a standard feature of Windows 95. This system allows magnification of up to 16x (Galvin and Scherer, 1996).

## TECHNOLOGY FOR THE PHYSICALLY IMPAIRED

Technology has changed the lives of people with disabilities by allowing them to perform daily activities they would not be able to do without help. Computers may be used for augmentative communication, writing and printing, and creating smartrooms where the thermostat, lights, music, and doors are all controlled by a computer panel (Smith, 1998). However, the physically impaired user's computer access is often hindered by the typical keyboard design which necessitates the ability to execute multiple keystrokes with reasonable typing speed by those who are able to use the keyboard to some degree. The accessibility needs of the physically disabled users vary greatly due to range of movement capabilities. Therefore, hardware and software must also show great adaptability in meeting their needs. The ABLEDATA and Tracebase databases list 20,000 assistive technology devices of all types including communication, control, and computer access aids containing a wide range of adaptations. These adaptations include arm supports, copyholders, keyboard trays, paper loaders, and wheelchair interfaces. There are also a wide variety of software adaptations and switches listed (Galvin and Scherer, 1996).

For those physically impaired users with severe disabilities, single-switch input systems can be used. Single-switch input systems may be placed so as to utilize those body parts that the user is able to move or apply pressure with. The user then activates the switch when the desired choice is presented. Other special input switches include brow movement switches, sip and puff switches, and lip, tongue, jaw, head, knee, touch, flex, squeeze, blink, or tip switches (Vanderheiden, 1987). Those with good control of neck and head muscles may use Mouthsticks. Disadvantages in using these methods of input include their tendency to be slow and not allow keys to be pressed simultaneously (Brody, 1989).

Those who have head control also may use screen-based optical headpointing schemes. The user may wear a small headband hat or headset and as the user moves the head a sensor points to a function menu and activates the desired command. Head movements may also control the cursor on the screen (Kaplan, 1996). The H-Com hardware was designed for those with severe mobility limitations (Ciarcia, 1983). The H-Com was developed as a peripheral to do the same job as a keyboard. It allows use of one key as a single user-input point referred to as a switch. A more recent development is the use of a camera which can be attached to the head. The user then searches an emulated keyboard and selects a letter. If the gaze is held for a second, that letter is input as if it came from the keyboard. In the same manner, lightweight reflectors on the head or any part of the body can send an infrared signal to the position of the cursor, which then activates a switch.

For those users with less severe physical impairment, expanded keyboards may be utilized. For those who are able to print, but have a limited range of motion, small arrays of numbers can be used to specify letters and words by encoding (Vanderheiden, 1982). Miniature keyboards are an option for those with good control, but a small range of motion. Those with limited upper limb control can use light pointers strapped to the wrist or attached to a headpiece. These pointers are used to direct a light beam toward a sensor panel or a screen drawing of the keyboard to indicate the chosen keys. Adaptive firmware cards provide control of the computer using a single switch. Firmware is programmable hardware. The keyboard may be adjusted with a keyguard which prevents accidental keystrokes due to extraneous motion by recessing the keys. A key must be pushed by putting the finger or stick through a hole in the keyguard. The size of keyboards can vary enabling individuals with large arm movements who lack finger control to use an oversized keyboard (Brody, 1989).

A large number of physically disabled individuals can also utilize voice recognition systems. Voice recognition systems using both peripherals and circuit cards existed or were in development in the early 1980s. The Cognivox VIO-1003 for the Apple II personal computer was designed as a peripheral. This system plugged into the game-paddle I/O port of the Apple II. Although the Cognivox contained an internal amplifier and speaker, it also had an audio output jack for use with a high-quality amplifier system (Murray, 1982). Threshold Technology is developing a 16-bit microprocessor-based system with custom circuits that free the main chip for speech processing and Kwip has developed a prototype using Scott Instruments voice boards.

Most products use a microphone which is worn on the user's head. However, the high signal-to-noise ratio can affect the computer's ability to recognize voice input. A lapel microphone was considered by IBM; however, problems were found to exist. Other voice recognition systems use a standard microphone and an A/D (analog to digital) converter. The Kurzweil Voice Report system can be plugged into most PC compatibles (Lazzaro, 1990). Macintosh computers have built-in microphones. However, on other computers an external microphone is attached through a jack without regard to whether a circuit card is used. External voice recognition systems are generally the size of an external modem and are attached to the serial or parallel port. On the Macintosh, a voice recognition system can be interfaced to the SCSI port (Lazzaro, 1993). The minimal hardware for a voice recognition system is a microphone and an ADC (A/D converter) chip although a digital signal processor (DSP) can be used to increase the processing power. The purpose of the hardware is to convert analog speech into digital form which is then processed by a DSP, a microprocessor, or both. A few computers are now available with some built-in hardware. Sun Microsystems' workstations include a microphone port and A/D converter. Compaq PCs may come with built-in speech hardware and include speech recognition software (Meisel, 1993).

IBM has redesigned its computer case to give physically impaired users easier access. IBM has improved the floppy disk drive ejection mechanism so that disks protrude farther when ejected so that they are easier to grasp. IBM has also repositioned the on/off switch to the front of the case, and it has changed concave buttons for the disk drives and power button to facilitate use with headsticks and mouthsticks (Galvin and

Scherer, 1996).

Macro programs allow modification of keyboards to combine common commands in a single keystroke (Brody, 1989). This can assist the user in performing activities related to word processing, database management, spreadsheets, bookkeeping, telecommunications, and programming. Macro programs also allow the redefinition of the keyboard by rearranging the keys into a more convenient pattern. This modification may be utilized when a key is in a position that is difficult for the individual to use. Built-in macro programs exist in some commercial software such as WordPerfect and Lotus 1-2-3. However, the macro program can only be utilized when the application is running (Lazzaro, 1993).

In addition to allowing the keyboard to be simplified or rearranged, StickyKey software and keyboard modification programs provide benefits for the physically disabled. StickyKey software is an option for individuals with spastic movements. This software makes it possible to enable keys that must be pressed simultaneously to be pressed in sequence. The capacity is also available to toggle keys such as Alternate (ALT) and Control (CTRL). SlowKeys adjust the length of time that a key needs to be held down before the character is accepted. MouseKeys is a keyboard modification has the ability to emulate the mouse movement through use of the number keypad. RepeatKeys slows down the effects of accidentally struck keys that repeat. BounceKeys direct the computer to ignore keys that are bounced or struck twice by users with tremors. SerialKeys allows a person to connect their personal assistive devices to a computer and use them instead of the keyboard or mouse (Galvin and Scherer, 1996). These software packages are compatible with most computer systems and are TSR (Lazzaro, 1990, 1993).

Word-prediction software further increases the speed of inputting data through the use of a keyboard. The software monitors the keyboard for characters typed in sequence. Based on those few characters, a list of possible words is supplied. The user may select a word or continue typing to narrow down the choice of words. Words utilized most frequently by the user are placed at the top of the list (Lazzaro, 1990).

For those users who are unable to use the keyboard or other physical input devices, voice recognition systems may be used which also require software. Early voice recognition systems were limited in the number of words that could be recognized. For example, the Cognivox VIO-1003 for the Apple II computer could be trained to recognize a set of only 32 words or short phrases. However, sets of vocabularies could be stored on disk which expanded the system's capabilities somewhat. The software needed to be trained to recognize words or phrases. A training session involved repeating each entry three times and typing it once. After training, the recognition rate was 98-100% (Murray, 1982). Today's speech recognition software rarely involves a training session. According to White (1984), speech recognition systems that involved pattern-matching techniques were elementary for they were limited to recognizing short phrases. Prior to 1987, there were systems that would recognize a large vocabulary, recognize continuous speech, or provide speaker independence. However, no system could provide more than one of these capabilities (Kurzweil, 1989).

Voice recognition software can be classified by speaker dependency or by how words are recognized. The speaker-independent system recognizes voice with no training; however, it is restricted to a small vocabulary. A speaker-dependent system must be trained. This training time is approximately 1 hour on most systems. One of the most sophisticated systems uses a speech recognition board and software capable of understanding 25,000 common words with room for adding 5,000 special-need words. Multiple users can utilize this system if it is trained to recognize each voice. When words are entered during the training process a template is built for later use when the system performs then cross-matches the input. The input is converted to standard computer code which is then compared against the template to do pattern matching. Words can be recognized as separate units or as blocks of words. Discrete-utterance systems require a slight pause between each word while continuous-utterance systems understand uninterrupted bursts of speech. IBM began working on a discrete recognition project in the early 1980s. Most systems are now speaker dependent and discrete-utterance (Lazzaro, 1993).

Eyegaze is another computer software product which can be used by physically impaired users who cannot use single switches or voice systems. The computer is installed with a camera that follows the person's eyes and types the letters that he looks at on the screen. When the user is finished with the sentence he looks at the enter button. This program is useful for regular word-processing and e-mail software; however, the cost is high at about $25,000 (Smith, 1998).

## TECHNOLOGY FOR THE HEARING IMPAIRED

Until recently, the hearing impaired user has not had much trouble using computers as the computer interface has been largely visual; however, the current shift toward multimedia and sound is producing drastic changes. Sound effects and speech are being used to convey important information that is not heard by the hearing impaired user (Galvin and Scherer, 1996). It is important that hearing impaired users continue to gain access to computers as computers perform many uses for hearing impaired persons such as capturing and translating spoken speech into text for visual display, providing real-time captioning for speakers at public and private events, teaching finger spelling and sign language, controlling home signaling and security systems, carrying on communication via e-mail and on-line chat sessions, and providing multifunctioning telecommunications access (Galvin and Scherer, 1996).

Telecommunication is important in the life of the hearing impaired person as it is a bridge between the hearing impaired and hearing world when communication is vital. Computer systems allow hearing impaired persons to communicate via TDD (telephone device for the deaf) or TTY, ASCII, speech recognition, speech synthesis, and Touchstone keypad to text translation. Hearing impaired users can benefit form the KEYPlus keyboard from Ultratec which is designed for use on IBM-compatible computers. KEYPlus contains a freestanding TDD and TDD call detector. The TDD contains a 48 character two line tilted display and a 24 character thermal printer. It can communicate with ASCII or Baudot modems and it also allows a user to answer a TDD call without interrupting the operation of the computer (Galvin and Scherer, 1996).

It is difficult for hearing impaired persons to watch an interpreter and take notes at the same time. A system called C-print is useful in note-taking situations. This system uses a computer laptop, 2 commercial software packages, a standard word-processing program, and a computer shorthand system. To provide real-time translations, C-print uses a trained operator who listens to the lecture and types special codes that represent words into the computer. The translation is instantly shown on a special screen that sits on top of an overhead projector. Once the lecture is completed, the hearing impaired person can get a printout. Studies have shown that students have a higher rate of understanding lecture materials when using C-print than they do when using sign language interpreters (Smith, 1998).

Present computers contain four types of built-in accommodations which allow further adaptations through software. Computers contain features such as controllable volume level, headphone/speaker jacks (which allow for amplification modification), SoundSentry features, and ShowSound features which include captions.

Special software can be used to convert audio output into a video format. Many programs can use captioning to display audio information in a visual format. Microsystems Software's SeeBeep allows the whole screen to flash or to have the word "beep" flash at the location of the cursor. Other software may display a small musical note in the upper left corner, change the screen color, or display the word "beep" at the cursor position (Lazzaro, 1990, 1993). The SoundSentry software adaptation, which is a standard feature on Windows 95, provides a visual on-screen indication whenever the computer emits a sound. Although good for detecting simple warnings or beeps, it does not tell what type of signal it is. It is not useful if the signal is speech. The ShowSounds system level software, which is also a standard feature on Windows 95, is a flag or switch contained in the computer's control panel. It allows the user to have any important sounds that are created by the computer shown in some visual way on the screen.

For those users who may only have a partial hearing loss, the volume control in the control panel of the Macintosh can be set to any level. If the volume is set to 0, the menu bar will flash in place of a beep (Lazzaro, 1990).

## FUTURE CHALLENGES

One of the biggest challenges for the future is to make graphic icons more accessible to the visually impaired through tactile, magnified, or audible displays. The present systems use small icons which are difficult to see and visually impaired users must use keystrokes to access the computer as opposed to using the mouse. Graphical User Interface (GUI) systems use a pixel-based display (such as that which is used in Windows systems) rather than a physical or character-based display (such as that which is used in DOS systems). Screen readers also need to be enhanced so that they will accept low-level graphics commands and build a text database that models the display. A prototype, Screen Reader/PM from IBM, allows the user to maneuver the mouse or the keypad while a voice synthesizer describes the icon displayed on the GUI or the graphical text shown on the screen.

In an effort to improve GUI accessibility, OutSpoken for the Macintosh uses a database called an offscreen model (OSM). This is a database reconstruction of what is visible and invisible on the screen. An OSM must manage text, off-screen bitmaps, icons, and cursors. Mouse movements must be tracked, positions must be matched with OSM icons and the associated icon names must be vocalized by a screen reader. The OSM needs to provide the cursor information so the screen reader can vocalize the position. It also must know the dimensions, associated text string, and string character position. The cursor's window identification must also be tracked. When a window becomes active, screen readers must determine if it has a cursor and vocalize it (Schwerdtfeger, 1991).

In the quest to improve GUI accessibility, Boyd, Boyd, and Vanderheiden (1990) describe three stages in the development of GUI access for the visually impaired. The first Customizing Stage involves utilizing applications whose purpose is to enable the visually impaired to read text produced on graphical computers through speech or Braille. This is essentially a coping strategy. The second Single Sensory Mouseless Stage involves an interception strategy in which ASCII information is captured before it gets to the screen. OutSpoken is the first commercial application to utilize an interception approach. This strategy also seeks to enhance the ability to recognize icons and simple graphics. The final stage is the Multi-Sensory Approach using a mouse. It involves extending capability across applications and operating systems and extending access to complex graphics. Currently, development is in Stage 2, Single Sensory Mouseless Strategy. The GUI should eventually provide the same benefits to the visually impaired person as it does for other users.

Voice recognition systems may not be a realistic input method for physically disabled individuals who also have a speech impediment or limited lung capacity. The Smith-Kettlewell Eye Research Institute has developed a brain wave interface which monitors electrical activity in the brain to determine where the user is staring on the screen. A theory exists that people's brains respond to words and ideas in similar ways; therefore, researchers intend to standardize computer input to the patterns of electrical activity. Electrodes will be used to determine the pattern of electrical activity that represents a word and the word being thought of will then appear on the screen (Brody, 1989).

Efforts must also be made to see that users with disabilities have transparent access to computers. The person must be able to interface with the computer in such a way that the computer can not tell that the user is not using a standard technique. In other words, the special access technology must be transparent or invisible to the computer. When an interface technique is truly transparent, the individual with the disability is able to access and use all of the standard software that is written for a computer that any individual without a disability could use.

## CONCLUSION

In addition to a lack of knowledge about adaptive technology, one of the barriers to making computers accessible to people with disabilities is the cost. This is especially true on university campuses. It is economically impractical to expect a university to have every computer equipped with every type of special technology.

In addressing the issue of financially feasible accessibility, California State University at Northridge has developed the Universal Access System. This system involves a host computer that contains software and an access device that is custom designed to meet the needs of a disabled individual. Rather than using wires to connect the host computer and the access device, invisible beams of infrared light are utilized. An engineer estimated the cost at under $200 to enable a disabled person to use a computer through an access device (Wilson, 1992). This system makes it feasible to provide computer access to persons with disabilities as the same computer can be used by disabled students without regard to the type of disability. Students without disabilities may even utilize these computers. As a result, this can eliminate the barrier of cost in the future.

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