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ABSTRACT

This document brings together eight papers presented at a rehabilitation technology conference, authored by individuals affiliated with the Trace R & D Center on Communication, Control and Computer Access for Handicapped Individuals. Titles and authors of the papers are as follows: "Current Initiatives in Accessible Computing" (Jane Berliss); "Development of a Serial Auxiliary Control Interface for Powered Wheelchairs" (Joseph Schauer and others); "Transparent Access Interface for Apple and IBM Computers: The T-TAM" (Joseph Schauer and others); "Development of a Public Domain, User Accessible, Inter-State Directory/Database for Assistive Technology Service Delivery Programs" (Gregg C. Vanderheiden); "Cognitive Skills Associated with the Operation of Various Computer Interfaces" (Cynthia J. Cress, JoAnn P. Tew); "Specialization in Technology Service Delivery: What Is an Interface Specialist?" (Roger O. Smith and others); "Systems 3--An Interface to Graphic Computers for Blind Users" (Gregg C. Vanderheiden and David C. Kunz); and "Pre-Service Technology Specialization Training (TechSpec): Year 2" (Roger O. Smith and others). (JDD)

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Trace R & D Center
on Communication, Control
and Computer Access
for Handicapped Individuals

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CURRENT INITIATIVES IN ACCESSIBLE COMPUTING ON CAMPUSES

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INTRODUCTION

Since computers have become a crucial factor in most aspects of postsecondary education, the ability of students, faculty, and staff with disabilities to access computer equipment has become imperative.[1] Thanks to legislation such as Section 504 and 508 of the Rehabilitation Act, as well as increased consumer awareness, the need for accessibility is being brought to the attention of both computer center and disabled student service personnel. Two groups – Project EASI and the AHSSPPE Computer SIG – have recently been formed. These groups share information on accessible equipment on campus among group participants and act as a resource to those beginning to explore accessibility issues. In addition, some established on-campus programs are willing to share information on their experiences developing and providing services.

PROJECT EASI *(Equal Access to Software for Instruction)*

Project EASI was founded in 1988 by Krista Kramer and Nils Peterson as a subgroup of the Interuniversity Communications Council, Inc.EDUCOM). EASI membership includes representatives from the Higher Education and Adult Training for people with Handicaps (HEATH) Resource Center,[2] the Trace Center, and the vendor community, as well as people involved in existing or developing initiatives on a variety of campuses. The group has developed two publications: "Computers and Students with Disabilities," intended to facilitate communication between disabled student service staff and computing center personnel, and "EASI Fixes," a set of guidelines for software developers. Group activities under development include workshops on adaptive technology at conferences where such information has not traditionally been available.[3]

AHSSPPE COMPUTER SPECIAL INTEREST GROUP

The Association of Handicapped Student Service Providers in Postsecondary Education (AHSSPPE) has had a computer special interest group since 1988. The group's focus encompasses both administrative and personal uses of available computer systems. Led by Christy Horn of the University of Nebraska, the AHSSPPE Computer SIG periodically publishes a newsletter and has sponsored meetings and presentations at the last two AHSSPPE conferences. Plans for future projects include compilation and publication of a list of SIG members and supporters with expertise in specific computer-related areas.[4]

EXISTING CAMPUS MODELS

A number of college campuses have already set up adaptive computing services. Profiles and contact addresses for several of these campuses are included in the "Computers and Students with Disabilities" brochure published by Project EASI. Many of these listed campuses provide their own information packets as well.

California has a unique inter-campus program: the High Tech Centers for the Disabled. Fifty-five institutions of postsecondary education and three high school Regional Occupational Programs house High Tech Centers. The centers provide adaptive technology and information, and serve as research centers. The central facility, located in Sacramento, trains professionals in assisting High Tech Center users and provides technical support to High Tech Center employees. The program has also established criteria for selection of adaptive equipment, and publishes support materials for use by other campuses.[5]

Computer user groups can also play an important role in providing access. These groups provide persons at non-administrative levels, such as students and community members, with an opportunity to influence policy involving accessible computer equipment. The Barrier-Free Computer User Group (BFCUG) was founded in 1986 at The University of Michigan, when only a minimal amount of equipment was available in an obscure location. Thanks in large part to the efforts of BFCUG members, a centrally located Low Vision Room has been established featuring state-of-the-art equipment. Other BFCUG accomplishments include establishment of a mechanism for informing the campus computing center of new adaptive equipment that should be supported.[6]

Finally, major centers dealing with adaptive equipment are providing assistance to the campuses on which they are located. For example, staff members at the Trace Research and Development Center at the University of Wisconsin-Madison are working with disabled student service personnel and library staff to facilitate acquisition of appropriate adaptive computer equipment. This interaction includes Trace participation in campus automation and disability committees, and development of a set of accessibility guidelines to provide other campuses with timeline and budget models for establishing an accessible computing environment.

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DEVELOPMENT OF A SERIAL AUXILIARY CONTROL INTERFACE FOR POWERED WHEELCHAIRS

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ABSTRACT

The Trace Center has been working with interested manufacturers of communication aids and wheelchairs, in an effort to develop a standard interface for the control of powered wheelchairs by devices such as communication aids and other microprocessor controlled user input devices. This paper describes past and future efforts toward adoption of this proposal as an ISO Standard and summarizes the current draft standard.

INTRODUCTION

As electronic communication aids and environmental control devices become more and more advanced, their ability to perform more sophisticated functions expands. In fact, many aids are based on portable computer systems with tremendous programmability and control capabilities.

As a result of this increased capability, there is a growing interest in interfacing suitable aids to wheelchairs so that the aid can assume the control functions typically performed by joysticks on powered wheelchairs. This would enable people who currently cannot operate standard wheelchair controls to operate a powered wheelchair. Also, the number of control interfaces a person would require could be reduced.

Today, most wheelchair controls are an integrated part of the total wheelchair system. Furthermore, each manufacturer uses different designs and connectors (if any) for their control interface. Because of this, costly custom adaptations are required to replace the existing control, and completely different modifications must be made for each family of wheelchairs.

To remove this barrier, several interested researchers and manufactures have begun development of a electronic interface standard that would allow communication aids and other intelligent control devices to drive future powered wheelchairs. Wheelchairs implementing this standard would provide an auxiliary serial interface port which would allow control of the chair by other devices having a serial output port.

It is felt that a standard interface would benefit consumers, clinicians, and manufacturers of wheelchairs and communication aids. The consumer would have an expanded selection of components from which to choose. Compatible components would reduce the amount of specialized knowledge required of the clinician and make the assembling of a custom system much easier. The manufacturers would enjoy an expanded market for their wheelchairs and aids, a reduction in the amount of customization that is often required, and lower costs for educating dealers and consumers.

BACKGROUND

Initial efforts to develop a control link began at the 1987 RESNA conference and resulted in a draft document of design specifications. Over the past two years continuing revisions have been made. Copies of the working document have been distributed to interested manufacturers and researches.

In November of 1989, the draft document was presented at a meeting of the ISO Wheelchair Standards Working Group. It was favorably received and continued efforts in this area were encouraged. It was recommended that the proposal be submitted to the USA member organization for consideration so that the document can be formally placed on the ISO Working Group agenda.

At this time, the proposal is being submitted to the ANSI/RESNA Technical Advisory Group for consideration.

TECHNICAL SUMMARY

This is a brief summary of the proposed specifications titled, "Serial Wheelchair Control Interface Standard". Both a Short Version and a Long Version of the proposed standard exist. At this time, only the Short Version is under consideration and review.

Transmission Format

Control signals in an encoded packet are transmitted in RS-232C serial format from the controlling device to the powered wheelchair. Data characters are sent as 10 data bits (1 start bit, 8 data bits, no parity, 1 stop bit). This data is transmitted semi-continuously while a hardware handshaking line is active. Any data received by the wheelchair that contains a transmission error will be ignored along with any additional data until the wheelchair can re-synchronize itself with the beginning of the data packets.

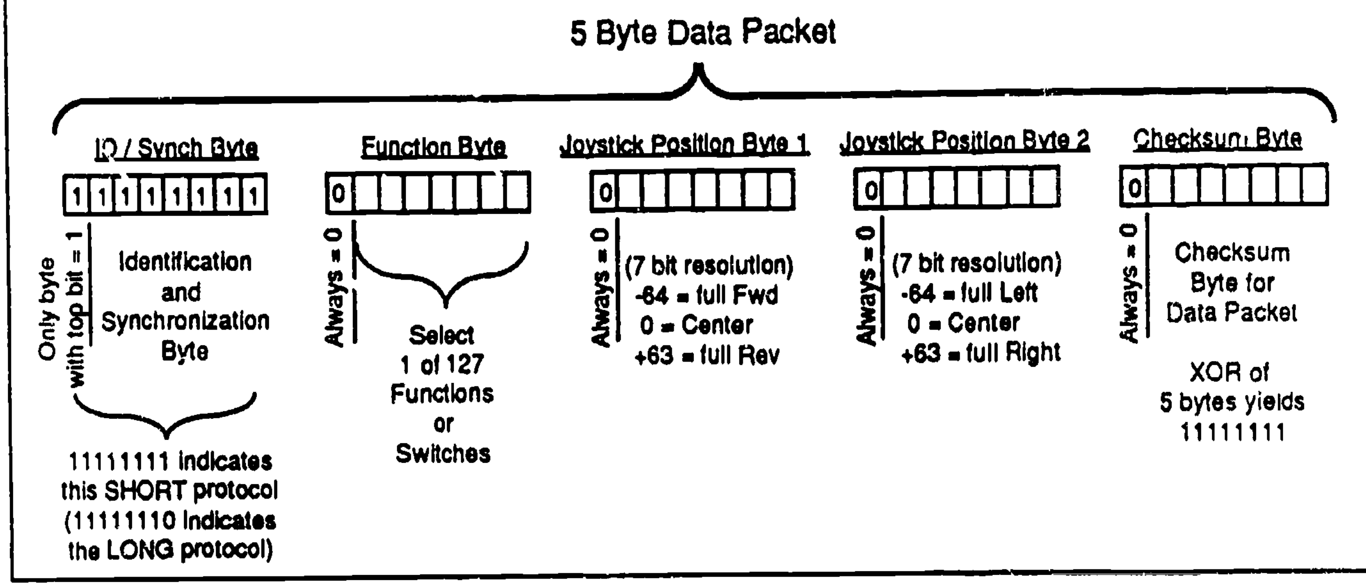
Data Format

Each packet of information consists of 5 bytes. (See Fig. 1.)

The first byte signals the beginning of the packet and contains an identification number, which can be used to distinguish among different packet formats as well as to allow for future expansion.

The second byte is the Function Byte. It specifies the activation of any one of 127 functions that will be defined in the standard. Examples of these functions are: headlights on, headlights off, recline backrest forward, recline backrest backward.

Figure 1



The third and fourth bytes of the packet are the Joystick Position Bytes. These may be used to control wheelchair functions normally controlled with analog transducers. They can be thought of as a digital representation of the analog signal.

The final byte of the packet is the Checksum Byte. It is used to help verify the integrity of the packet as a whole. Any packet received with a checksum error will be ignored.

Data Timing
To insure smooth operation of the wheelchair, the controlling device will be required to transmit data packets on a timely basis. This rate is under review and depends upon the baud rate selected, but some initial guidelines have been proposed. A complete packet should be transmitted to the wheelchair every 40-100ms. If packets are not received by the workshop within a set period of time (e.g., 100-200ms), the wheelchair will stop all activity. This latter requirement will provide automatic fault detection if the control is disabled or disconnected.

Safety Kill Switch
To provide additional safety in the use of this interface, a separately wired, normally closed switch will be required to enable the interface. When this circuit is opened, the wheelchair will immediately cease all movement activity.

Connectors
At this time the use of a 9-pin D connector for handling data transmissions has been proposed. It is widely available and allows for the possible expansion to two-way communication over the interface. The Safety Kill Switch will be connected by a separate line using a standard 3.5mm phone plug.

CONCLUSIONS

The current draft has been reviewed by several individuals and additional revisions are in progress. Initial responses have been favorable and at least three manufacturers have expressed their intention to develop designs based on the standard. A considerable amount of work still remains in developing solid and well designed specifications before the proposal can become an ANSI or ISO Standard. It is essential to its success that people with expertise in this area express their views and provide technical input while the standard is under development.

While this standard will be voluntary, standardization of such control links will help to insure compatibility and assist the user in selecting compatible components. Efforts will continue to insure that these specifications do not restrict creative or innovative design.

Individuals and organizations interested in participating in the development of this standard should contact the Trace Research and Development Center.

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Schauer, Joseph M., Vanderheiden, Gregg C., & Kelso, David P. (1988). *Serial wheelchair control interface standard*. Madison, WI: University of Wisconsin, Trace Research and Development Center.

This project has been funded in part by Grant H133E80021 from the National Institute on Disability and Rehabilitation Research.

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TRANSPARENT ACCESS INTERFACE FOR APPLE AND IBM COMPUTERS: THE T-TAM

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ABSTRACT

Many advances designed to simplify the use of the computer and to make it more user friendly for able-bodied users have created new barriers for people with physical disabilities (e.g., mouse input, new operating systems). These barriers often times cannot be overcome in a practical sense with software patches. In answer to the need for an effective interface, a new, low-cost hardware keyboard and mouse emulating interface for IBM and Apple computers has been developed. It also implements many keyboard enhancements which work with all operating systems and application programs running on these computers.

INTRODUCTION

The inability of many users to operate standard input devices such as the keyboard and mouse has spurred the development of several software programs that aid the disabled user in accessing popular computer systems. While programs that provide features such as "sticky key" operation and keyboard and mouse emulation are available for many computers, it is becoming more and more difficult to implement these features with third party software patches when new and more powerful operating systems and computers are developed. In addition, not all application programs work with these software patches.

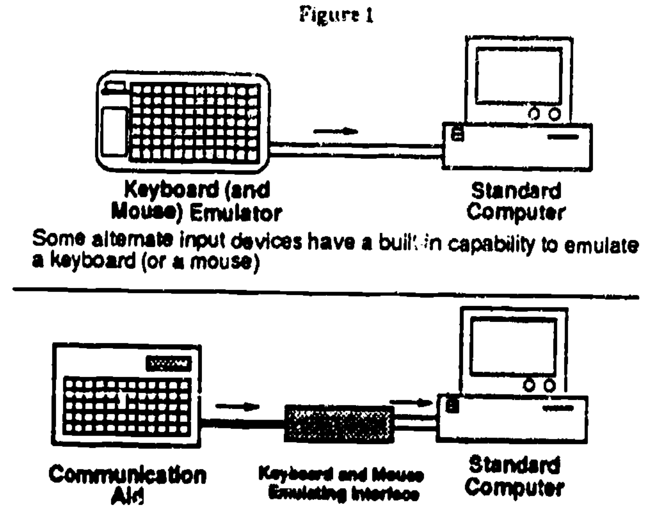
For this reason, many users require a different access avenue is 100% transparent to the operating system and computer. The common approach to providing this avenue is to develop hardware emulation devices which operate outside the computer and use special input methods. These devices typically connect to the computer keyboard and/or mouse ports and exactly mimic the electrical signals of these standard input devices. In this way, the computer, and programs running on the computer, cannot distinguish between the standard input devices and the alternate input devices.

Although the distinction is not always clear cut, most hardware devices which function as described above can be categorized into two groups: the emulating interface and the emulator. (See Fig. 1) The emulating interface is a device which simply provides the "curbcut" to the computer; that is, it connects the alternate input device to the computer system. The emulator, on the other hand, is a device which provides the alternate input device together with the emulating interface as an integrated package.

Many communication aids today are not keyboard and mouse emulators by design. It is therefore necessary for these aids to use an emulating interface device to provide the user with access to computers.

The need for emulating interfaces for newer computers, especially computers using mouse input devices, has resulted in the development of the Trace Transparent Access Module (T-TAM). This device provides transparent access to Apple and IBM computers for users of a wide variety of communication aids. In addition to its emulating interface function, features were implemented to provide increased accessibility to these computers by people who simply require keyboard enhancement features.

Figure 1



Some alternate input devices have a built in capability to emulate a keyboard (or a mouse)

A communication aid can be used to perform the actions of the computer's standard keyboard and mouse, through an emulating interface

DESCRIPTION

The T-TAM was developed to meet the following design goals:

- Supports Apple computers which use the Apple Desktop Bus to connect input devices. (Apple IIGS, Macintosh SE, and Macintosh II's)
- Supports IBM AT and PS/2 computers
- The standard keyboard and mouse should function normally with the device attached and running
- Requires no special software running on the computer
- Requires no special modifications to the computer
- Provides 100% transparency so it will work with all operating systems and application software
- Obtains all power from the computer (no batteries or power supply)

The T-TAM functions in different ways to meet many of the needs of a wide range of users. For individuals who cannot use the standard keyboard or mouse (even with modifications), the T-TAM has a General Input Device Emulating Interface (GIDEI) which allows people to use a wide variety of augmentative communication aids or other special aids in place of the computer keyboard and mouse. In addition, the T-TAM modifies the behavior of the standard keyboard so that people with mild or moderate disabilities may use the standard keyboard directly. For individuals who cannot use the mouse, the T-TAM provides a "mouse key" fea-

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ture which allows the user to control the mouse from the standard keyboard keypad.

The T-TAM is a box measuring 5 1/8" x 1 1/2" x 5 1/4" and weighing approximately 16 ounces. It is controlled by a Texas Instruments TMS370 microprocessor with 8K of external RAM and 48K of external EPROM. It contains circuitry for interfacing w·.h the Apple Desktop Bus and the IBM keyboard and mouse. In addition, it contains circuitry for an RS-232 serial port and a piezo electric speaker.

Input Device Emulation

The primary goal in the development of the T-TAM was to provide a new emulating interface that would support not only the keyboard, but also the mouse, touchpad and future input devices.

To accomplish this, the T-TAM has an RS-232 serial port for accepting input from alternate input devices. Serial RS-232 is used because this is the most commonly available port on current communication aids and has proved suitable in previous implementations of keyboard emulating interfaces.

This serial port accepts ASCII characters in the new General Input Device Emulating Interface (GIDEI) format and translates them into keystrokes and/or mouse activity on the target computer. Keys which have an ASCII representation (such as alphabetic characters) are "typed" by the T-TAM by simply sending to it the corresponding ASCII character. For keys which do not have an ASCII representation (e.g., Page Down, Left Arrow), and for mouse actions, a special sequence of characters is programmed into a selection on the aid and sent to the T-TAM.

Additional commands exist to enable the user to type multiple sequences of keys and key+mouse actions (e.g., shift-click), to change baud rates, and to select different keyboards.

Keyboard Enhancement

While the primary goal of the project was to develop a new emulating interface device, it became evident that with minor design changes, additional accessibility features could be implemented for people who wish to use the standard keyboard. This was accomplished by designing the T-TAM to be functionally in series with the keyboard and mouse. In this fashion, the T-TAM is able to intercept all input device activity. The signals can then be interpreted and modified before sending them on to the computer.

By allowing the T-TAM to intercept the keyboard and mouse signals before they ever reach the computer, it is possible to implement many of the same features that have previously been implemented as software patches to the operating system. These features are StickyKeys, SlowKeys, Auto-Repeat Rate Adjustment, and MouseKeys. The fact that they are implemented in hardware outside of the computer, however, allows these features to be used with all software and all operating systems for the computer.

The StickyKeys feature is a well known keyboard modification that enables the individual who requires one finger typing to type multiple-key sequences. The implementation of this feature in the T-TAM very closely follows the One-Finger software program for IBM computers available from the Trace Center and the StickyKeys feature available in the Easy Access program in the Apple Macintosh operating system.

SlowKeys is used by individuals who often accidentally press unintended keys while attempting to press a desired key. The SlowKeys feature requires the user to hold down a key for a user-adjustable period of time before the key will be sent to the computer. This setting may be saved in EEPROM memory in the microcomputer for later recall by the user after the device has been powered down.

Adjustment of the auto-repeat rate is a feature used by individuals who are unable to accurately control the release of a key. This adjustment allows the user to slow down the rate at which keys will repeat as well as to adjust the delay before a key starts to repeat. It also allows the user to totally deactivate the repeat action of the keyboard.

MouseKeys is a feature useful to individuals who cannot use the standard mouse to operate mouse-driven software, but can still use the standard keyboard either modified or unmodified. It enables the user to control mouse activity from the keypad portion of their keyboard. Cursor keys move the mouse in the corresponding direction. Pressing other keys causes the "locking down" of the mouse button(s) for dragging or highlighting objects.

For individuals with impaired vision, an audible tone is produced whenever the state of a toggle key (num lock, caps lock, scroll lock) has changed.

CONCLUSION

Several advantages exist both to the user and the manufacturer of communication aids with a system incorporating a stand-alone communication aid used with an emulating interface. For the user, this modular design allows a wider selection of communication aids to choose from, a wider selection of computers to access, potentially less costly repairs, and easier updating to support new features. Manufacturers will find that their aids will access a wider variety of computers, less space on the aid will be taken up by multiple connectors for the various computers, and more resources can be devoted to the development of better user interfaces.

The ideal situation for the implementation of the special keyboard enhancement features would be to build them directly into the keyboards. However, due to economic concerns, computer manufacturers are reluctant to do this. The use of the T-TAM to deliver these functions when software solutions do not work provides a bridge until such time arrives as these features are built into all operating systems and/or computer input devices.

At this time, cooperative efforts are underway with manufacturers to transfer the device for commercial production. It is anticipated that the T-TAM will be commercially available from one or more manufacturers by May 1990.

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DEVELOPMENT OF A PUBLIC DOMAIN, USER ACCESSIBLE, INTER-STATE DIRECTORY/DATABASE FOR ASSISTIVE TECHNOLOGY SERVICE DELIVERY PROGRAMS

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ABSTRACT

With the advent of the Assistive Technology Act and the grants to states, there has been a rapid increase in the interest in service delivery directories. One of the major problems faced by the states, however, is the need to have a database which is flexible enough to meet their particular needs and yet simple enough to operate that it can be readily accessed and used by the wide diversity of people throughout their state. In order to address this problem, a very user-friendly and flexible resource database shell was developed. This database takes advantage of graphics and hypertext strategies to provide a zero-instruction database format. The database looks and acts like a book, except that it is possible to quickly move between sections of the book and to have it automatically create new "chapters" containing just the entries the user is interested in. A first prototype of the system has been completed. After internal testing, it will be released to the pilot states for testing in 1990.

INTRODUCTION

There is a need today for a good mechanism for generating, maintaining and distributing a directory of the various scattered service delivery agencies and programs that handle or specialize in assistive technologies. Although computer-based service delivery and resource databases exist, they typically require a trained operator in order to be used effectively. The operator must not only be an effective clinician with knowledge of the consumers and their problems, but also familiar with computers, the specific computer database system, and, often, Boolean logic search strategies.

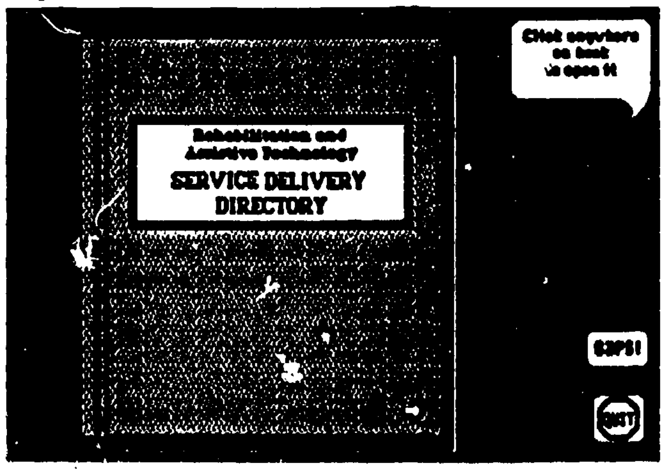
FEATURES OF THE PROPOSED DIRECTORY

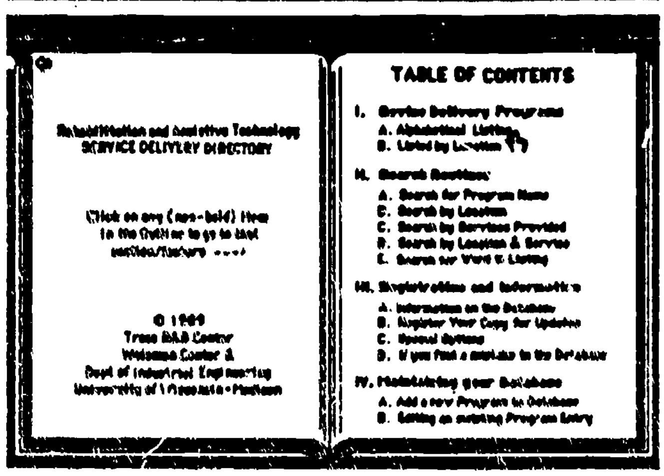
The service delivery directory/database shell utilizes many of the same concepts pioneered in Hyper-ABLEDATA. After discussions with states, information brokers, and information consumers, the following criteria were identified as being critical to the development of an effective Service Delivery Directory. The Directory must be:

1) Easy to use;
2) Accessible;
3) Low cost and easy to distribute
4) User customizable; and
5) Easily updated.

1) Easy to Use

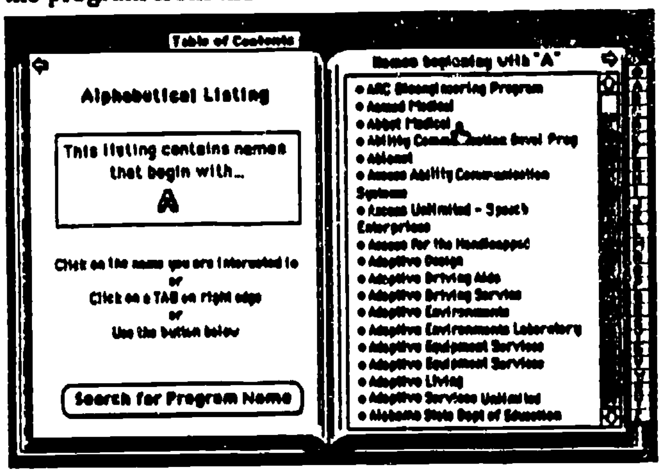
The database was designed to build upon the natural experiences of the user. In order to do this, a "book" motif was used. Other familiar metaphors, such as bookmarks and lettered tabs down the edge of the book (for the alphabetical listing) were also incorporated. In addition, each "page" contains the directions necessary for its use. As a result, no special manuals or training is required for use of the database.

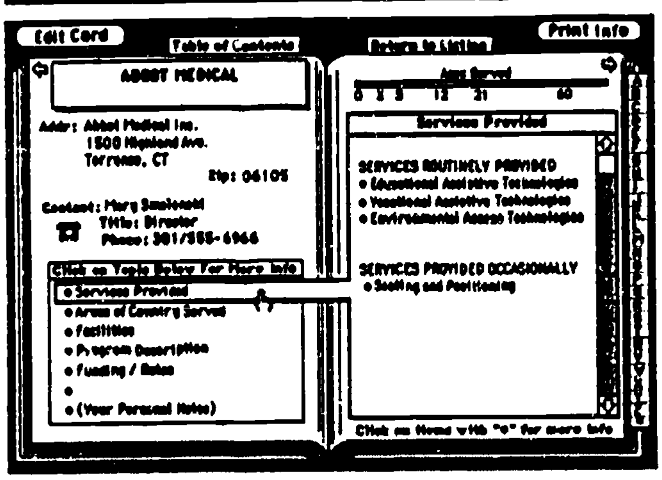




Operation of the directory relies primarily on a "point-and-click" mechanism. That is, the user would point to an item on the computer screen using a mouse or touchscreen. When the user is satisfied that the appropriate item has been pointed to, a click of the mouse button (or removing their finger from the touchscreen) will select that item. (See "Accessibility" for access by users with disabilities.)

In addition to being able to look up listings of service delivery programs arranged alphabetically or by region of the country, it is also possible to do custom searches. Starting with the Table of Contents, the individual would simply click on the type of search they are interested in doing. The database will then show them a map, and ask them to point to the state(s) they are interested in having searched. It then provides a listing of the various types of services or resources covered by the database. The individual would point to or click on the various services in which they are interested. If they wished to limit the search to programs serving a particular age, they could also indicate this. The database will automatically generate a new "chapter" to the book which contains only those entries from the area specified which meet the particular specifications. Initially, these names will be arranged in alphabetical order. The individual has the option, however, of clicking on a button labeled "Ordered by Distance from User." When the individual clicks on this button, the database will ask for the client's ZIP code. It will then order all of the programs in the list (and the "pages" in the "chapter") so that they are ordered by the distance of the program from the client's door.





Other features of the database allow the users to add their own notes to the standard entries, and to add their own entries to the book. Again, everything is done in a paced fashion, with integral instructions, so that special tutorials or manuals should not be needed for any of these standard functions.

2) Accessibility
A key feature in any effective database in assistive technologies is its accessibility to users with disabilities. Unfortunately, many of the same techniques which make a database very user friendly make it very unfriendly to persons with visual or physical disabilities. To address these needs, alternate modes of operating the database are being developed. These include mechanisms for enlarging the text, for allowing complete control through the keyboard (for individuals with movement impairments), the ability to control the program from an external communication aid (for individuals with severe motor impairments), and the ability to operate the database entirely auditorially (for individuals who are blind).

3) Low Cost and Easy to Distribute
In order for the Directory to have widespread use, it must be affordable. Even the $30-40 cost for some books puts them beyond the reach of the average user or advocacy worker, both of whom would find the information very helpful. This problem is amplified by the fact that such resource databases must be continually re-issued every six months or so in order to stay up-to-date. The Service Delivery Directory shell is being made available to the states on a no-cost basis. Individual states can then take the shell and build it into a resource base using information from their individual programs. No dissemination limitations will be placed on the database, so that states are may make as many copies as they wish, and disseminate them within their states (and in other states) freely.

4) User-Customizable
A major problem with traditional databases is the inability of users to add to or customize the database to meet their own needs. Three levels of customizability are planned for the Directory. First, the users are able to add their own notes to any of the entries in the Directory. This is done by simply clicking on the "Your Personal Notes" category and then typing in the desired notes.

Secondly, the users are able to add new service delivery program entries to the Directory. This is particularly useful in rural communities, where the more "established" facilities may be far distant and more unusual local facilities need to be identified. For example, an individual who runs a saw-sharpening and welding service may also do emergency wheelchair repairs. While they would not be listed in the Directory put out by the state, they might be invaluable in a town where the nearest official wheelchair repair facility was hundreds of miles away.

The third mechanism for user customization is the ability to edit existing entries. The database allows the user to edit individual entries, revise incorrect information, or add missing information. In the future, a button in the database will be provided which will automatically make a report of these changes, which can, at the user's option, be mailed back to the State or other central resource directory source.

5) Easily Updated
In order to facilitate the updating process, three mechanisms are built into the database. First, as noted above, it will be easy to generate a report of the edits to the database. Secondly, there is a letter-writing facility built into the database which allows users to quickly and easily type a note back to the source of their Directory. The database automatically creates a self-addressed mailer which includes the note, so that the user need only type a few sentences and apply a stamp in order send information or corrections back to the central source. Third, the database is set up so that it has an auto-update feature. When the user receives an updated copy of the database from the central source, it will be possible for the user to easily transfer all of their individual notes to the new version of the database (rather than losing all of their notes when they started using the new version of the database).

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COGNITIVE SKILLS ASSOCIATED WITH THE OPERATION OF VARIOUS COMPUTER INTERFACES

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ABSTRACT

Interface selection is influenced by both individual and task considerations. Thus, it is necessary to understand the cognitive skills underlying interface use, as well as how they are manifested in performance. This paper provides an analysis of some of these cognitive skills involved in the use of six different interfaces. Identification of these skills is the first step toward measurement of the portion of cognitive load in computer use attributable to the interfaces.

INTRODUCTION

Cognitive load has been perceived in a number of ways. It is commonly defined in terms of measurable task performance characteristics, such as relative efficiency and correctness in accomplishing a task. Another approach to cognitive load is resource allocation which focuses on the cognitive skills, such as memory or attention, which underlie the user's performance on a task. Potential sources of cognitive load in computer systems include the input mechanism, presentation/output format, task structure (including prompting and other responses), and symbol system (see Cress & Goltz, 1989 for more information). If the relative contribution of these different elements of the computer system to cognitive load can be isolated, it may be possible to compare the expected cognitive difficulty of unique computer-user-task combinations. The focus of this paper is the contribution of the input mechanism to the cognitive load of the computer system.

Most task analyses in the human factors literature are based on a performance estimate of cognition. For instance, the GOMS task analysis (Card, Moran, & Newell, 1983) is used to predict subject performance based on task characteristics of goals, operators, methods, and selection rules. The GOMS does not account for the cognitive processes underlying subject performance, other than recognizing short- and long-term memory as a simple input/output mechanism. This analysis allows estimates of task difficulty for a given task across individuals. However, task-based analysis schemes are limited when selecting an interface for client use across tasks and programs.

The present analysis generalizes necessary subject skills from interface characteristics, to allow estimates of cognitive difficulty across tasks using those interfaces. This analysis, in taking a resource allocation approach, presents some of the cognitive resources implicit in the use of each interface to accomplish a goal. For this paper, the goal is reduced to moving a visual object (such as a cursor) on the computer screen to a predetermined location.

Porter, Lahm, Behrmann and Collins (1986) outlined the cognitive requirements for general computer use, including: 1) intentional communication, 2) awareness of options and the ability to make conscious decisions about them, 3) ability to define goals and plan action sequences to attain them, and 4) a concept of past events and an ability to anticipate future events. According to Piagetian hierarchies, Porter et al. report that all of these should be present in a normally developing child by approximately 18 months of age. In addition to these requirements, some understanding of means/end relationships (understanding that the person's actions have an effect on subsequent events or responses) must be present before functional computer use is possible.

Research suggests that some interfaces such as the touchscreen are consistently easier to use (Chapman, Dollaghan, Kenworthy & Miller, 1983), and the following list identifies some of the differences in required skills for interface use which may contribute to cognitive load across tasks. Some of the cognitive skills specific to six different interfaces (the touchscreen, mouse, joystick, trackball, touchpad/keyboard with repeating function, and touchpad/keyboard without repeating function are reported below.

COGNITIVE SKILLS ASSOCIATED WITH SPECIFIC INTERFACES

Touchscreen

Moving a visual object with a touchscreen involves a 2-step process: touch the screen on the cursor, and drag the cursor to the intended location. Dragging involves maintaining contact with the touchscreen throughout the movement. While the computer program interprets the release of pressure from the screen to signal completion, the act of removing the finger from the screen is an intrinsic, unlearned stopping of an action rather than the execution of an intentional, independent movement. Therefore, this is not seen as an additional step in touchscreen operation. Necessary cognitive skills include:

- ability to differentiate between effective and ineffective means of touchscreen operation (e.g. touching the screen with one finger versus a whole hand, and limiting activity to the visual screen area).
- ability to anticipate the continued movement of the object along a planned trajectory in the presence of a delay between user action and screen response.

Mouse

Standard use of a mouse in moving a displayed object entails a 3-step process: clicking to pick up the cursor, dragging it to the intended location, and releasing the button to signal completion. The nature of the completion signal for the mouse, namely the release of pressure from the button, is motorically similar and electronically identical to the touchscreen. However, since the use of a mouse is a learned behavior, specific to computer operation, this movement is seen as a distinct step in correct mouse operation. Necessary cognitive skills include:

- comprehension of mouse motion in one plane producing cursor movement in another plane.
- ability to divide attention between operation of device and effective monitoring of cursor movement.
- ability to determine the amount of mouse movement needed for the desired amount of cursor movement.
- ability to plan and simultaneously execute two actions (e.g. maintaining button click and dragging the mouse).

Switch Joystick
Use of a switch joystick in moving a displayed object entails a 2-step process. The user must move the joystick in the desired direction, and return it to the neutral position when the cursor reaches the endpoint. Necessary cognitive skills include:

- comprehension of stationary joystick positioning in one plane producing continuous cursor movement in another plane.
- ability to divide attention between operating device and effective monitoring of cursor movement.
- comprehension of the relationship between amount of cursor movement and duration of joystick deflection.
- ability to plan timing of joystick release to correspond with the anticipated time of target acquisition.

Trackball
Use of a trackball in moving a displayed object involves an undetermined number of small steps. The user must move his hand over the trackball repeatedly to move the cursor the desired distance and in the desired direction. Upon reaching the endpoint, the user must signal completion by pressing a button. Necessary cognitive skills include:

- comprehension of the relationship between distance moved on the trackball and distance moved by the cursor.
- comprehension of the necessity for repeated movements for continued cursor movement.
- ability to continually re-evaluate the discrepancy between the current cursor position and the desired location, and to revise movement patterns accordingly.
- ability to divide attention between operation of the device and effective monitoring of cursor movement.

Touchpad or Keyboard:
standard repeating function on
Use of the cursor keys on a keyboard with the repeating function on to move a displayed object involves an undetermined number of steps. The user must move the cursor on two axes toward the target, and may need any number of trials to refine final cursor placement. In many programs, upon reaching the endpoint, the user must also press a key to signal that the task is complete. Necessary cognitive skills include:

- comprehension of movement in one plane producing cursor movement in another plane.
- ability to differentiate the function of each cursor key.
- comprehension of stationary key operation producing continued cursor movement.
- comprehension of relationship between the duration of key depression and amount of cursor movement.
- ability to divide attention between operation of the device and effective monitoring of cursor movement.
- ability to continually re-evaluate the discrepancy between the current cursor position and the desired location, and to revise key selection and activation appropriately.

Touchpad or Keyboard:
standard repeating function off
Use of the cursor keys on a keyboard with the repeating function off requires an undetermined number of steps to move a displayed object. Since each tap of a key corresponds to cursor movement only one space in the designated direction, the user must tap the key repeatedly in order to reach the target. As with the other keyboard method, the user must move on two axes toward the target, and may then need to press a key to indicate completion. Necessary cognitive skills include:

- comprehension of movement in one plane producing cursor movement in another plane.
- ability to differentiate the function of each cursor key.
- comprehension of necessity to make repeated movements to achieve continued cursor movement.
- ability to continually re-evaluate the discrepancy between the current cursor position and to revise key selection and activation appropriately.
- ability to divide attention between operation of the device and effective monitoring of cursor movement.

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SPECIALIZATION IN TECHNOLOGY SERVICE DELIVERY: WHAT IS AN INTERFACE SPECIALIST?

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ABSTRACT

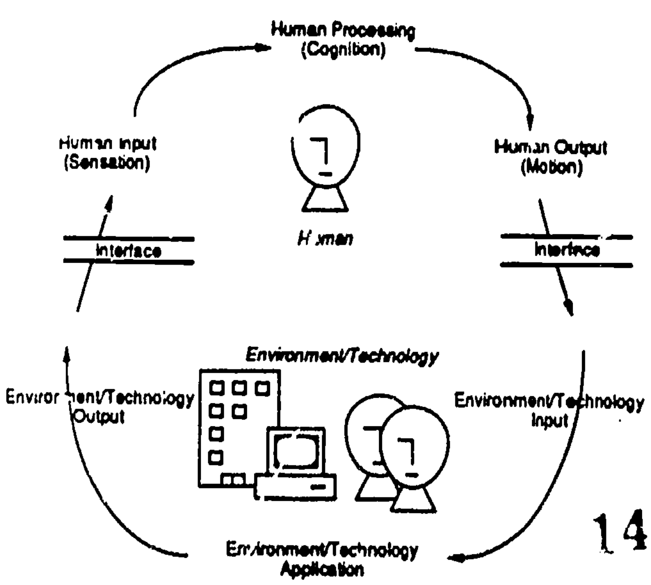
As service delivery in assistive and rehabilitation technology has matured, better role definitions and clarification of team member responsibilities has become necessary. While there continue to be no absolute definitive team member delineations, over the past decade the Trace Center and the Communication Aids and Systems Clinic (CASC) at the University of Wisconsin-Madison have begun to obtain a better grasp of the necessary team components for service delivery in the augmentative communication and computer access areas. One role which has gained a much better definition is the *interface specialist*: the team member who focuses specifically on optimizing the user's ability to operate a system.

This raises questions with serious policy implications. Adding another specialist on a technology service delivery team has obvious fiscal implications for society as a whole. Policy makers might inquire whether an additional team member is in fact required. While quantitative research is needed to quantitatively answer this question, this paper provides some initial data and discussion. Three questions are posed.

WHAT IS AN INTERFACE SPECIALIST?

In order for a person with a disability to use a communication device or a computer, they need to be able to control the system (input) and to understand the information that the system displays (output). Figure 1, based on Meister (1971) and Chapanis (1976) (from Smith, in press) displays this fundamental relationship between the human and the technological system. The role of the interface specialist is to understand the particular input and output needs of both the human and the technological device. In the context of persons with disabilities, this means that the role of the interface specialist is two-fold. First, the input and/or output of the device may need to be modified or adapted to match the capabilities and limitations of the human being. Second, the human being may need to adapt to the technology environment through either training or orthotic types of supplemental technologies. Usually, for optimal communication and computer system interface, adaptations or modifications are required for both the human and the technology ends of function.

Figure 1
Human-Environment/Technology Interface Model



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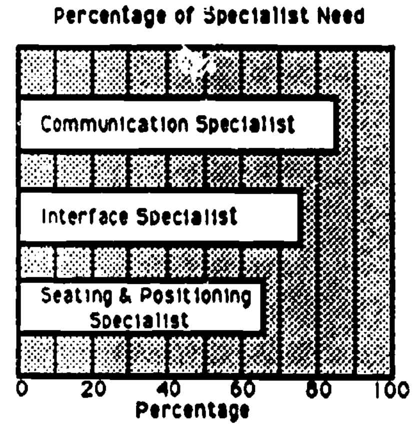
DO WE NEED AN INTERFACE SPECIALIST?

To begin to answer this question, this study performed a client needs analysis and a team function analysis. The client data analysis entailed both a staff survey and a case record review.

For the staff survey, CASC team members listed positions that they deemed important for augmentative communication and computer access evaluation and intervention. 100% of the responses listed a team position whose chief responsibilities focused on control, display, and overall component design. The survey also elicited the percent time that an interface specialist was thought to be needed for CASC evaluations. This mean average percentage, as estimated by CASC personnel, was 76.5%. This compared to 84.5% for a communication specialist, and 65% for a seating and positioning specialist. (See Figure 2.) These were the three positions listed by all team members as being necessary. Other positions listed included computer hardware/software specialist, social worker, engineer, and special educator.

FIGURE 2
Percentage of Specialist Need



Note that the data show that none of the three primary positions are required 100% of the time. Clinically, this has been shown to be true. For example, an interface specialist is not required when selecting vocabulary for a communication aid. A communication specialist would not be needed when a client (such as someone with spinal cord injury) has intact speech and language, but needs an adaptive writing system. A seating and positioning specialist would usually not be necessary for an ambulatory client.

SYSTEMS 3 - AN INTERFACE TO GRAPHIC COMPUTERS FOR BLIND USERS

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ABSTRACT

A nonvisual computer interface is proposed to allow access to standard, graphics-based computers and software (e.g., Macintosh) by persons who are blind. The system uses a five-layer access approach which seeks to optimize access to cooperating software, and provide access to non-cooperative software as well. The system is based upon the premise that it is more efficient and effective to present information to blind persons using nonvisual metaphors than to have them try to interpret information presented in a visual, graphic format. The proposed system operates using verbal and spatial/ tactile presentation of information, and only relies on interpretation of the actual graphic image when absolutely necessary (or desired by the blind user). The system incorporates speech output, speech input (optional), a full-page virtual tactile display with single-pixel resolution, and an optional braille display. These displays are used to present and manipulate information in verbal, tactile, or haptic form (or combinations thereof) in order to take advantage of the strengths of these different sensory channels for different types of information.

OVERVIEW OF THE PROPOSED SYSTEM

There are four basic components to the overall system:

- a full-page virtual tactile tablet;
- a voice synthesizer;
- a speech recognition system (optional); and
- a dynamic braille display (optional - especially useful for deaf-blind users).

The Virtual Tactile Tablet

The virtual tactile tablet consists of a standard graphics tablet with a special tactile mouse. This mouse has a small array of stimulators (5 columns of 20 pins) on 0.2 x 0.1" centers. This tactile array is mounted directly above the "virtual ball" of the mouse. As the individual moves the mouse around on the tablet, they would feel on their fingertip a raised, vibrating representation of the image on the screen at that point. The result would be similar to having a full-page raised tactile image of the screen, which the individual could feel with a single fingertip. The mouse chosen for this system also provides information as to the angle of the mouse, so that the blind individual can easily move about the tablet without having to hold the mouse perfectly vertical (Figure 1).

The tactile tablet is used in a number of ways within the system, usually in combination with the speech synthesizer. The tactile tablet is used for:

General orientation and layout of the document;

To direct the screen reading (via speech synthesizer feature) to the particular lines or words that the individual is interested in for spot reading;

To feel the particular shape of images on the screen (e.g., follow a line on a graph, feel a bar chart, etc.); and

To interpret simple graphic images with captions or words on them by feeling the image and having any words read aloud.

(Practiced Optacon users may be able to directly read the letters off of the screen using the tactile array, although it would be slower than using the 300+ words/minute speech synthesizer).

When the user is orienting himself to the layout of a large page of text and numbers, a tonal feature is also available which emits a different tone for letters, numbers, or graphics information, as the individual moves their hand about screen. Using a combination of the tones and the tactile image of the screen, the individual can quickly get a sense for the overall layout of the page, as well as the location of columns, words, numbers, and graphic elements on the page. The individual can then leave ToneTouch mode and proceed to explore the individual elements on the page in more detail.

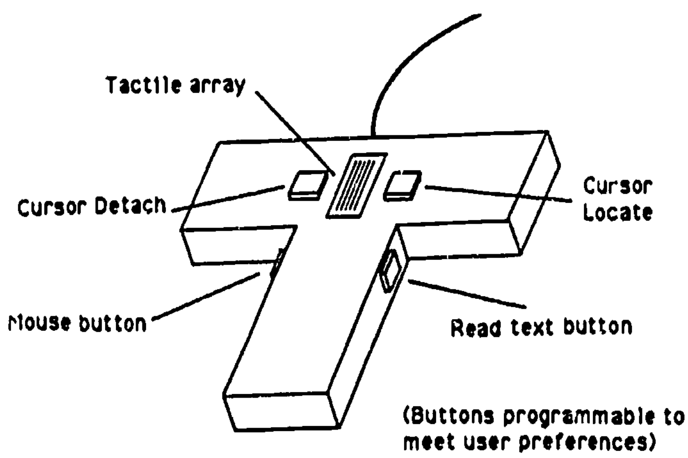

Figure 1:
The Visual Tactile Tablet -
Close-up of the tactile mouse
(the "wings" house the tactile actuators)

Voice Synthesizer Functions

The voice synthesizer provides two primary functions. First, it provides information to the user regarding the commands available or status of the computer. Second, it reads text, icons, and other information from the screen to the user. In both cases, the information read to the user is in direct response to an action or request from the user. Except for telling the user that an "alert box" has suddenly appeared on the screen, the synthesizer does little spontaneous talking that has not been directed by the user.

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Examples of control and status feedback supplied through the synthesizer would include: telling the user (on request) what document they are in, what programs are currently running, what documents are opened under each program, where they are in a document, etc.

Examples of synthesizer use in reading information from the screen would include reading: the word currently under the mouse, everything that they touch with the mouse, everything from the current point on down the page until they stop it, the whole line, the whole paragraph, the whole page, etc. The system will also have the ability to recognize commonly used icons and automatically read to the user a word or phrase that the user associates with that icon. A tone accompanies the icon's name so that the blind user can distinguish between icon names and regular text on the screen.

Speech Recognition or Tactile Tablet Commands

Commands can be given to the blind user's interface and to the computer itself in two ways. First, they can be given as vocal commands which are picked up by the speech recognition system and fed to the interface or computer. The command "Windows" for example would give the user a list of the windows currently open. The voice commands would also allow the individual complete access to the document manipulations, such as "Screen Up," "Screen Down," "Position (in document)," etc. Most of these are commands that are traditionally carried out using the mouse to click on or drag various visual symbols, scroll bars, etc., on the screen. With this system, the same functions would be achieved using a verbal rather than a visual metaphor. For deaf-blind users, a dynamic braille display can be substituted for the speech synthesizer. For selected applications, it may also be preferred to the voice output by blind users.

In some cases, vocal control of the computer is not desirable or effective. This may include environments where constant talking is not allowed, or situations where the speech recognition unit is not able to accurately recognize an individual's speech patterns or accent, or where the individual is not able to speak, such as an individual who is deaf-blind. In addition, once a system is mastered, quick manipulations of the hand can often be faster than vocal manipulations. The system therefore has the ability to be completely controlled from a virtual keypad on the tactile tablet. The virtual control keypads are located at the bottom, left and top of the touch tablet (see Figure 2). These buttons can be felt by the individual using the tactile mouse. Whenever they enter a button, its name is automatically spoken (quickly) up to them. If they enter another button while the computer is still reading the last button, it immediately stops and switches to reading the new button. Because the buttons exist in software, their size, shape, and number can be changed to meet the specific needs of the user. Their functions can also be dynamically changed to meet the needs of different applications. Because the button titles are read whenever they are entered, it is easy for a blind person to determine where they are and whether they are over the desired button before they click the mouse.

Basic principle in the design of the interface include:

Direct presentation of information in nonvisual form

Allow as much direct control as possible by the user

Utilize natural spatial perception systems and experiences of users

Use the best aspects of several presentation systems simultaneously to create synergistic benefits

Provide a simple cued mode of operation to allow the system to be used quickly and with minimal training

Provide faster, direct control shortcuts for more experienced user and make these intuitive as well

Make provisions for cooperative programs

Wherever possible, use identification and verbal presentation of common icons and graphic images, rather than forcing exploratory interpretation

Minimize the need for slow graphic interpretation by maximizing verbalization of command structures

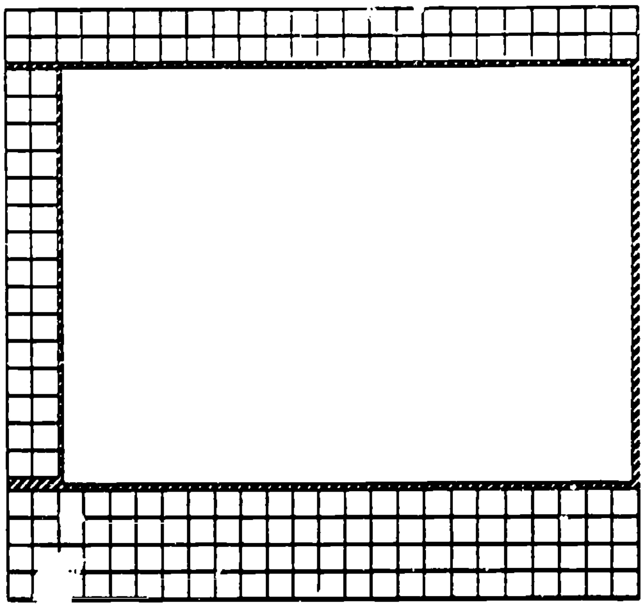

Figure 2

SUMMARY

This paper describes a nonvisual computer interface which is compatible with the visual metaphor operating systems now proliferating. The system is based upon two basic principles. The first principle is that of bypassing the visual metaphor wherever possible and presenting the information to the blind individual in the most effective form (tactile, audio, haptic), while providing tools to facilitate the direct interpretation of the visual image where that is optimum or desired. Secondly, the system is designed to be as intuitive and self-explanatory as possible while at the same time including more powerful shortcuts for more intense or experienced users. The overall objective is to create a system which not only provides access to the computers and programs, but to do so in such a way that the user who is bind can operate the computer and the programs at a rate which is more comparable to use by their sighted peers (except for graphic-intensive applications).

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PRE-SERVICE TECHNOLOGY SPECIALIZATION TRAINING (TECHSPEC): YEAR 2

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ABSTRACT

The University of Wisconsin-Madison began a preservice technology training program in 1988, which by June 1990 will be completing its second academic year. The overall model has been presented previously (Smith et al., 1989; Smith & Christiaansen; 1989). This paper specifically reports on the experiences and knowledge gained from the first and second years of this curriculum. In particular, two types of data have been collected from students to ascertain the extent to which they are benefitting from the program. In addition, the annual meeting of the TechSpec Advisory Panel has provided comments to improve the TechSpec model and its curriculum. Both of these sets of information should be of benefit to technology training programs which are just developing or to existing technology programs which are updating or revising their content or format.

OVERVIEW OF TECHSPEC

TechSpec is an interdisciplinary instructional model focused on occupational therapy students during their basic professional training. The program functions as a specialization certificate curriculum, similar to four others already available to occupational therapy students at the University of Wisconsin-Madison (Gerontology, Music Therapy, Dance, and School Certification). The program has a two-level design: some students receive foundation level training while others train to a specialization level. Both are elective tracks. However, students who elect to take the specialization direction commit themselves to 26 semester credits, of which 12 are already required for occupational therapy students and 14-18 are technology core and elective courses which must be completed before the Technology Specialization Certificate is awarded. The curriculum includes several introductory courses in assistive and rehabilitation technology, as well as a field work requirement. A set of competencies to be acquired is specified. In general, however, it is expected that graduates of this program will have the elemental understanding of assistive and rehabilitation technology applications and the basic skills to move into a specialized assistive and rehabilitation technology setting. There, they would be expected to gain substantial on-the-job training. It is not expected that a technology specialist graduating TechSpec will be ready to "hit the ground running" in any specialized area within assistive and rehabilitation technology. For example, a graduate will not be immediately capable of serving as a specialist in interfacing, seating and positioning, mobility, robotics, etc. They will, however, have received an educational background that makes it much easier to absorb increasingly specialized information about technology. This background will enable them to become more proficient through subsequent specialized fieldwork and on-the-job training.

In addition, this program is producing a set of teaching workbooks/guides for other curricula. These resources are being made available at cost to other faculty, curriculum planners, and projects through the Trace Center's Reprint Service.

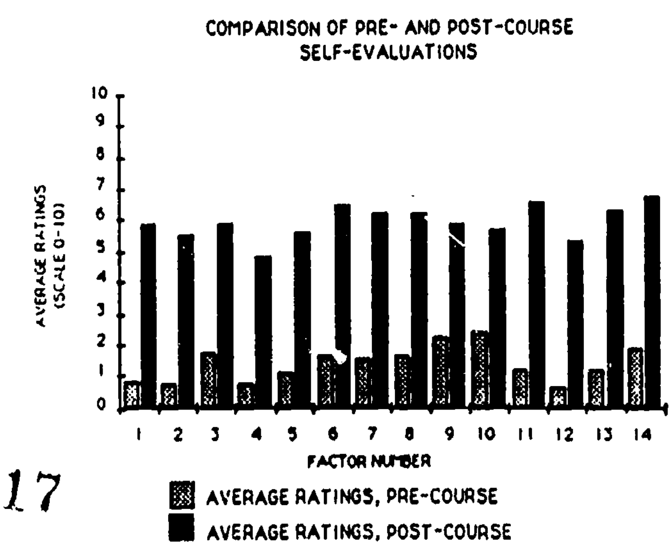
FINDINGS AND PRODUCTS TO DATE

Courses Taught

Six courses are taught specifically out of the TechSpec program on annual academic cycles. During the initial year, 48 students enrolled in the "Introduction to Assistive and Rehabilitation Technology," 28 in the "Design of Technology for Persons with Disabilities," 42 in "Adaptation and Construction of Equipment for Persons with Disabilities," 14 in "Microcomputer Software Applications in Occupational Therapy," 12 in independent study products, and 7 in fieldwork practica. Similar enrollment data are expected in subsequent years, although the hope is that class size will moderate after the initial influx.

Program Evaluation Results

A set of specific evaluation components are integral to this project. One is the assessment of the perceived knowledge and comfort of students. This subjective rating scale covers 14 different areas of technology. Students are asked to rate, on a scale of 0-10, their level of comfort in applying these areas of technology. This self-assessment rating scale is given to all students in the occupational therapy program as they enter their junior year, and readministered at the end of each semester, and at the completion of the TechSpec program for specializing students. The impact of the course "Introduction to Assistive and Rehabilitation Technology" is highlighted in Figure 1. As can be seen, the students' self-assessment is significantly increased



between the beginning of the course and the end of the course. The TechSpec project staff were also happy to see that even at the end of the introductory course, students were demonstrating that there remained substantial room for further skill building and knowledge acquisition. The self-perception rating scale data also highlight the impact of the progression of TechSpec courses on students' perception of their abilities. The data displayed stepwise increases of perceived abilities with each technology course taken.

A third comparison was made, of the TechSpec students' self-perception scores with the non-TechSpec students' self-perception scores. It revealed substantially higher ratings from the TechSpec students.

The occupational therapy students involved in the TechSpec program, as well as those who were not, also completed a 25 question multiple-choice test, focusing on their knowledge base in assistive and rehabilitation technologies and their application. In all cases, scores from the subjective test showed trends and differences similar to those described with the subjective data.

TechSpec Advisory Panel
Advisory Panel members expressed belief that the TechSpec program was benefitting the students, and that the program had moved into an up-and-running condition very quickly during the initial two years. The Advisory Panel also produced a list of suggested improvements, which provide some generic advice to not only this TechSpec program, but technology curricula in general.

Two major themes seem to run through the suggestions for improvement. The first was that training individuals to become competent technologists is extremely difficult and requires a long-term process. The second is that a program should focus on teaching not only technology and application outcomes but more on the detail of the process of evaluating, selecting, and applying assistive and rehabilitation technologies. Some of the specific ideas identified by the Panel are listed in Table 1.

Course Guides
Four course guides and publications have emerged from the TechSpec program, for use by other curricula. These include a course guide for the Introduction to Assistive and Rehabilitation Technology, a guide for the practicum courses, an overview of the TechSpec program, and a chapter introducing technology and its applications, appearing in a textbook aimed at advanced occupational therapists. (This chapter is used as one of the introductory readings.)

SUMMARY

In summary, the TechSpec program has moved very quickly in its initial two years. The program staff believe that the program has been successful in meeting its goals. However, the program has also encountered some frustrations and barriers in assistive and rehabilitation technology education. It continues to be the hope of the program staff that the program will not only provide direct training to students at the University of Wisconsin, but will provide resources and experiential comments which will be valuable to other curricula.

Table 1

- Consider optimal sequence of courses.
- Add the basic computer introductory course to the requirements.
- Encourage additional fieldwork experiences.
- Improve coverage in the areas of technology which are weakest in the current curriculum.
- Emphasize distinction between technology and technology applications (equipment versus technique).
- Limit enrollment in program, or secure funding for additional resources.
- Involve students more heavily in course design.
- Submit courses for formal University listing.
- Encourage University support, and move off grant funding.
- Add course content on documentation and reporting of assistive and rehabilitation technology interventions (assessment and documentation of efficacy of intervention).
- Increase time spent on ethical issues surrounding technology applications.
- Implement technology terminology earlier in the curriculum.
- Increase emphasis on technology user.

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