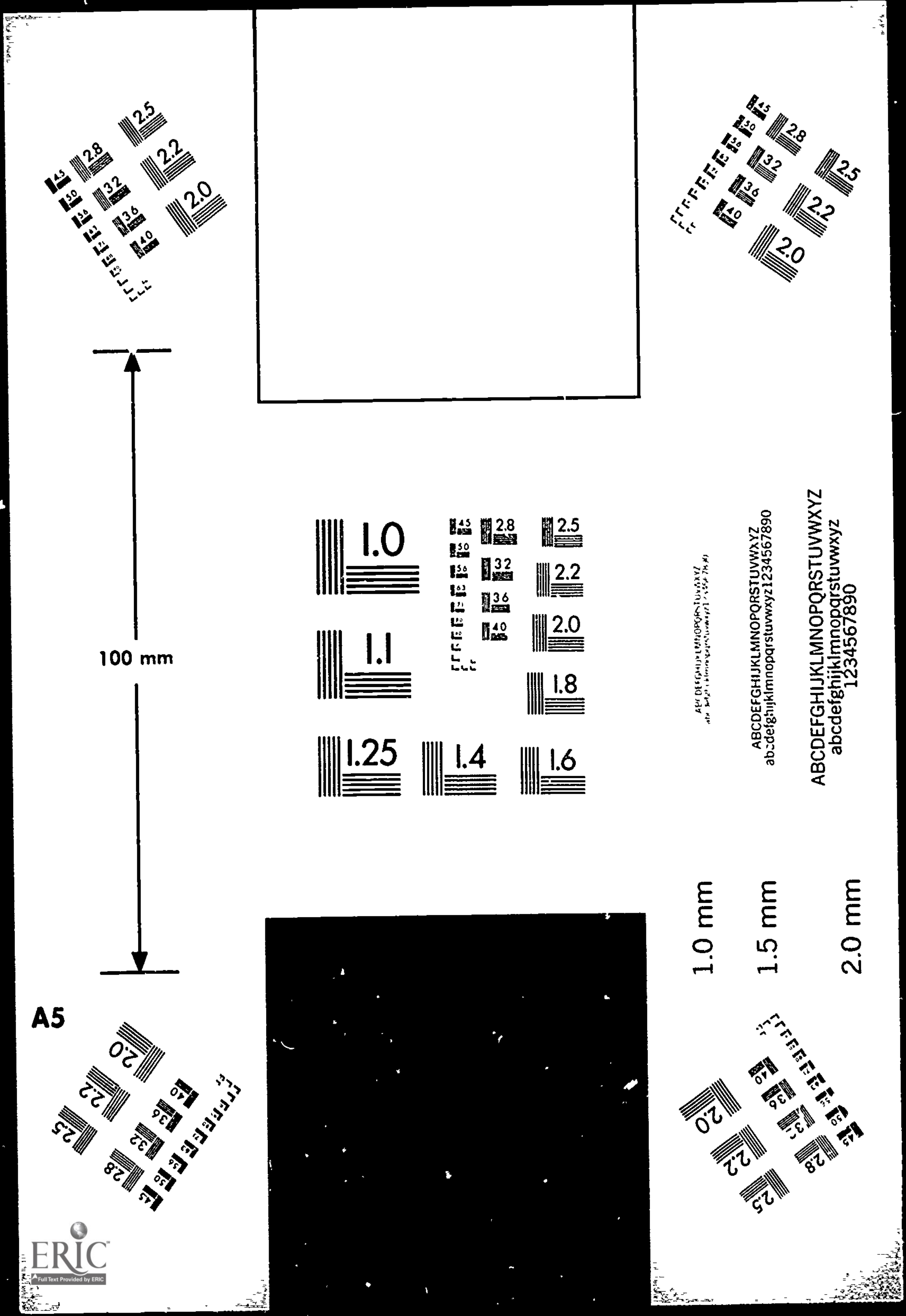

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ED 320 354 EC 231 163

AUTHOR	Burnette, Jane
TITLE	Assistive Technology Design in Special Education. Issue Brief 2.
INSTITUTION	Council for Exceptional Children, Reston, Va.; ERIC Clearinghouse on Handicapped and Gifted Children, Reston, Va.
SPONS AGENCY	Office of Special Education and Rehabilitative Services (ED), Washington, DC. Div. of Innovation and Development.
PUB DATE	Apr 90
CONTRACT	RI88062007
NOTE	34p.
AVAILABLE FROM	ERIC/OSEP Special Project on Interagency Information Dissemination, Council for Exceptional Children, 1920 Association Dr., Reston, VA 22091 ($5.00).
PUB TYPE	Information Analyses (070) -- Reports - Descriptive (141)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Assistive Devices (for Disabled); *Disabilities; Electromechanical Technology; Electronic Equipment; *Information Dissemination; *Information Utilization; Linking Agents; Research and Development; Research Utilization; *Technology; *Technology Transfer
IDENTIFIERS	*Office of Special Education Programs

ABSTRACT

The issue brief discusses technological principles, issues, and design features discovered or used by projects funded by the Office of Special Education Programs (OSEP). Information was obtained from interviews with project directors who were asked about their project experiences, the features and design principles essential to the success of their projects, the problems they encountered, and how these problems could be resolved. After a brief discussion of technology transfer, information is presented according to three major stages in assistive technology development: designing to fit user needs; prototype development, testing, and evaluation; and distribution. Key features of 10 projects contributing to the report are summarized in tabular form and include information on project director and organization, grant or contract period, prototype educational aid, function, functional limitations, and features. An appendix charts accessibility features in relation to user characteristics (such as physical impairments, visual impairments, hearing impairments, or seizure disorders) as well as features to facilitate third party manufacturers for all five disability areas. Name, address, and telephone number of five current OSEP projects promoting the use of assistive technology are also appended. Twenty-eight additional resources are suggested. (DB)

ISSUE BRIEF 2

April 1990

Assistive Technology Design in Special Education

by Jane Burnette

A Product of the ERIC/OSEP Special Project on Interagency Information Dissemination, the ERIC Clearinghouse on Handicapped and Gifted Children

Published by The Council for Exceptional Children

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▪ Issue Brief 2 ▪

▪ Assistive Technology Design in Special Education ▪

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Issue Brief 2
The ERIC/OSEP Special Project on
Interagency Information Dissemination

The ERIC/OSEP Special Project on Interagency Information Dissemination is designed to provide information about research in special education, in particular, research funded by the Division of Innovation and Development, Office of Special Education Programs, U.S. Department of Education. This product was developed by the ERIC Clearinghouse on Handicapped and Gifted Children under contract no. RI88062007 with the Office of Special Education Programs, U.S. Department of Education. The content, however, does not necessarily reflect the position of OSEP/ED, and no official endorsement by either OSEP or ERIC of these materials, the products discussed in this report, or the publications mentioned should be inferred.

Contents

Introduction

Technology traditionally has been a major source of improvements in the education of students with disabilities. Technology includes applications of science to the industrial arts and mechanics ("hard" technologies), as well as to abstract strategies and training techniques ("soft" technologies). With the advent of electronic technology and computer science, the potential for new improvements in the education of students with disabilities has escalated dramatically. Since they allow equipment and procedures to be modeled after human processes, applications of computer science and electronic technology seem especially appropriate to the solution of problems in physical, sensory, and cognitive functioning that impede learning and effective performance.

To learn, a student must first be able to receive information. This depends both on physical access to the source of information and on adequate functioning of the senses, as the first stage of information transmission to the brain. Next, the student must organize and assimilate that information, selecting what is important and relating it to past knowledge and experiences. This depends on the student's organizational abilities and the ability of the memory to retrieve stored information. Finally, the student must demonstrate the knowledge acquired, using physical tests or graphic or verbal communication to check the accuracy of the processed knowledge against the realities of the outside world. This final stage, like the first, requires overt physical action. The use of assistive technology can compensate for dysfunctions or disabilities in the performance of these processes.

Assistive technology can provide physical and cognitive access to education. For many students, it can provide the mobility and stamina needed to get to school and be integrated into regular classes for more of the school day. Assistive technology devices can bypass malfunctioning senses such as sight or hearing by providing information via another sense. For students who have problems selecting or organizing information, computers can help focus attention, for example, by outlining or highlighting relevant aspects of the information presented. For students who have trouble encoding information, computers can provide multisensory and dynamic presentations that assist in the realization of key concepts and skills. The computer's data storage and retrieval capacity can also supplement memory. In addition, assistive devices can provide the physical means by which students can express their thoughts and feelings and manipulate and control their environments.

Although assistive technology is not a panacea that can automatically educate students, it is a tool that they can use in order to learn, demonstrate their knowledge, and achieve their potential.

OSEP's Role in Supporting Assistive Technology Development

Under Part G of the Education of the Handicapped Act, the Office of Special Education Programs (OSEP) in the U.S. Department of Education is authorized to support the development and appropriate use of technology in special education. Part G specifically authorizes four areas in which OSEP actively supports projects: (1) determining how technology is currently used in educating students with handicaps and how it can be used more effectively; (2) designing and adapting new technology to improve the education of these students; (3) stimulating the public and private sectors in the development and marketing of new technologies; and (4) disseminating information on the availability and use of technologies. While Part G supports a broad range of projects covering many aspects of technology, the ones discussed in this brief are concerned specifically with assistive technology.

Goals

OSEP's main goals in sponsoring assistive technology projects are (a) to specify features and design processes that best serve the educational needs of students with disabilities and (b) to determine the match between student characteristics and appropriate devices. Thus, projects are directed to identify significant needs in the education of students with disabilities and design devices and support systems to meet those learning needs.

These projects focus on creative uses of technology to serve students with handicaps. Some of them result in commercially viable products; others experiment with applications of science to special education, building the knowledge base from which future practical applications will be derived. In this way, the projects forward both the state of the art and the state of practice in special education technology.

Prototype Development

The federal role in supporting research and development projects of this type is important in keeping up-to-date products in the marketplace. The high costs of research, coupled with limited market populations for some items, prevent many private-sector enterprises from engaging in prototype development. Many manufacturers are not geared to building and testing prototype products; they do not have adequate resources for the staff and the facilities required to conduct research and evaluation. By supporting the influx of new technologies into the market, government-sponsored research helps to keep the R&D process synchronized with current trends and research. Government-sponsored research also helps to avoid obsolescence of technological products for people with disabilities, thus performing a quality control function for this market.

To get the most from limited funds, OSEP's strategy has been to leverage funding so that projects fulfill several functions. Many projects adapt innovations from other sectors such as business and the military; they rely on technology transfer rather than basic research. In addition, the prototypes sponsored are often generalizable to other populations or hold the potential for additional applications—they are designed so that others can learn or get ideas from them. This approach results in OSEP's strong emphasis on identifying design principles, issues, and features that hold across a number of applications and target populations.

Issue Brief Overview

This Issue Brief discusses some of the principles, issues, and design features discovered or used by the OSEP projects funded to date and illustrates these principles with examples from the projects themselves. The information presented was taken from telephone interviews with the project directors, who were asked about their project experiences, the features and design principles essential to the success of their projects, the problems they encountered, and how these problems could be resolved. Additional information was drawn from project reports and related literature.

After a brief discussion of technology transfer, the information is presented according to three major stages in assistive technology development: designing to fit user needs; prototype development, testing, and evaluation; and distribution. Table 1 describes the projects that have contributed information to this brief. These include projects in various stages of completion: Some were completed several years ago, while others have just begun. Readers should note that the products described are not all commercially available.

Technology Transfer

The projects described in this Issue Brief rely on the transfer of technologies to special education applications. Technology transfer has been defined as the art of moving technology from its place of origin into various applications (Johnson, 1981). The art of transferring technology is not just a matter of moving the technology from one setting to another, but involves acknowledging and defining the need for the technology in the new setting and adapting the technology to meet the need. Technology transfer can become extremely complicated. The following four stages of technology transfer have been identified by Freda (1980):

1. Analysis of requirements.
2. Research, development, testing, and evaluation of solutions.
3. Dissemination of findings.
4. Institutionalization (the integration and assimilation of the technology into existing organizations).

Principles and Conditions

Studies of the effectiveness of technology transfer have yielded information about some of the principles that apply and conditions that must be met to achieve success. The first principle serves as a caution regarding other principles and conditions: Innovations are so diverse that it is extremely difficult to identify or generalize factors critical to success. This area of study has even been described as "beyond interpretation" because "variables found to be important for one innovation are not important at all, or even inversely important, for another" (Downs & Mohr, 1976, p. 700).

However, some principles have been found to apply across various technologies and settings. A meta-analysis (Tornatzky & Klein, 1982) found four characteristics of technology transfer to be related to the adoption of an innovation. These are *compatibility, relative advantage, complexity*, and *cost*. Innovations that are compatible with the existing values, past experiences, and needs of the users are more likely to be adopted. Relative advantage is "the degree to which one innovation is perceived as being better than the idea it supercedes" (Rogers & Shoemaker, 1971, p. 138). A higher relative advantage increases the likelihood that an innovation will be adopted. If people perceive an innovation to be complex, difficult to understand, and difficult to use, they are less likely to adopt it. Although cost is apparently related to the use of an innovation, some studies have found it negatively related, and some have found it positively related (Tornatzky & Klein, 1982).

A flexible implementation approach is also considered important to the adoption of transferred tech-

Table 1. A Sample of OSEP Assistive Technology Projects

Project Director & Organization	*Grant or Contract Period*	*Prototype Educational Aid*
Dr. Al Cavalier Dr. Carrie Brown Association for Retarded Citizens 2501 Avenue J Arlington, TX 76005	1987–1989	Eyegaze detector
Mr. Greg Carr Prentke Romich Corp. 1022 Heyl Road Wooster, OH 44961	1983–1985	"Lainey," a mobility and communications control center
Dr. William Gavin Logopedics Institute 2400 Jardine Drive Wichita, KS 67219	1983–1985	Multichannel vibrotactile vocoder & training program
Ms. Christy Horn Dr. David Beukelman University of Nebraska Handicapped Student Services 132 Administration Building Lincoln, NE 68588-0401	1988–1990	"InfoNet," a local computer network & database library
Dr. Richard Howell Ohio State University 1314 Kinnear Road Columbus, OH 43212	1987–1989	Robot & science activities using robotics
Dr. David Lunney Dr. Robert C. Morrison Science Institute for the Disabled East Carolina University Greenville, NC 27834	1983–1985	"ULTRA" (Universal Laboratory Training and Research Aid)
Dr. Peter Maggs Dr. Diana Visek 2011 Silver Court East Urbana, IL 61801	1983–1985	Software driver for high-speed voice output
Mr. Ronald Morford Automated Functions, Inc. 11800 Clover Hill Lane Olney, MD 20832	1988–1989	"PACE" (Print and Computer Enlargement System)
Dr. Alan VanBiervliet University of Arkansas 2081 South University Little Rock, AR 72204	1983–1985	"COMPACT," a multipurpose communication aid
Dr. Gregg Vanderheiden The Trace Research and Development Center Waisman Center 1500 Highland Avenue Madison, WI 53705-2280	1983–1985	The "Trine System," a communication and writing aid with software interface

Function	Functional Limitations Addressed	Features
Uses eyegaze as an access mode to computer; controls speech synthesizer and appliances; provides communication and environmental control	Limited motor coordination, vocal ability	Portable, may be placed on lap tray or table top; uses on-screen symbols as input; detects user selection from symbol menu via eyegaze
Provides mobility, artificial voice, motorized wireless communication with computers	Lack of mobility, gross motor coordination, vocal ability	Wireless communication, multiple input and output modes; based on motorized wheelchair
Translates sounds into tactile sensations	Deafness, hearing impairment	Instantaneous translations; wireless, compact; can be worn under clothing
Provides access to printed sources of information	"Print disabilities," visual impairment, learning disabilities, physical limitations	Alternative adaptive input and output modes
Provides access to instructional materials and learning experiences	Orthopedic & mobility disabilities, communication disorders	Microcomputer control; adaptive input devices
Provides audio output from laboratory instruments	Blindness, low vision	Uses tones, music, and speech to present data; serves as calculator or terminal; can be adapted for voice entry
Provides high-speed artificial voice computer output for study of complex subjects	Blindness, low vision, speech handicaps	Portable; continually modifiable; multiple input and output modes; compatible with other software and a variety of hardware
Provides access to printed text; also a writing aid	Low vision	Portable; uses hand-held optical scanner; large display screen; low cost
Translates graphic symbols into speech	Speech handicaps, difficulty with spelling	Portable; operator's manual on-screen; pressure-sensitive selection pad; other input modes; visual display with animated graphics and "memory bar"; automated recording and analysis
Provides access to standard educational computer programs; abbreviation/expansion system expands a few keyboard strokes to entire phrases	Lack of manual dexterity; inability to communicate vocally	Portable; low cost; requires minimal training; compatible with other hardware and software; multiple input and output modes; easily updated and modified

nologies, as is the degree to which the user can clearly formulate needs (Back & McCombs, 1984). With respect to assistive technology, these principles may be analogous: Flexibility is important to allow for student growth, compatibility with other devices, and the addition of improvements and new features to a device. The degree to which a user can clearly state needs can be important not only in design considerations but also in the decision as to whether or not to purchase or use a device.

Principles from instructional technology may also be applicable in assistive technology. For example, instructional designers recognize the importance of using an adequate mix of media that is matched to user needs (McCombs, Back, & West, 1984). As applied to assistive technology, this principle would recognize the need for multiple input/output modes and the desirability of different styles and means of communication with the user (e.g., graphic, written, or verbal communication or dynamic versus static displays), depending on user needs.

Caffarella, Cavert, Legum, Shtogren, and Wagner (1980) have urged that instructional designers consider instructional setting, instructional tasks, course management, instructor characteristics, parent characteristics, and student characteristics. These considerations all apply to assistive technology design as well. Hickey (1975) recommended including provisions for differing student abilities, aptitudes, personality types, information processing styles, and perceptual abilities in instructional designs. In assistive technology, these principles imply that the designer must consider a range of user characteristics and design for flexibility in the use of the assistive device. The following sections apply these principles as they were discussed by the directors of OSEP-funded assistive technology projects.

DESIGNING TO FIT USER NEEDS

Functional Analysis of Educational Needs and User Capabilities

Designing to fit user needs involves creating a match between the needs, desires, and capabilities of users and the functions and features of the product. In assistive technology for education, this requires an analysis of the educational function that the user wishes to perform—that is, what the user wishes to learn and what functions are required in order to learn it. While traditional categories of disability and their associated characteristics may provide a starting point for this type of analysis, they do not provide a framework for the design of assistive technology. This is because several categories may include disabilities with regard to the same educational function. In addition, not all individuals who fall within a category will necessarily have a disability with respect to that function.

For example, to read, a student must be able to get books from shelves, hold his or her head in the proper reading position, see and fixate on the printed words long enough to perceive them, mentally decipher and organize the meaning of the words, and remember what was just read. Individuals who may have difficulty performing these functions include those with visual impairments, learning handicaps, and physical disabilities. However, not all people with learning or physical disabilities have trouble reading. A functional analysis of educational tasks in relation to user capabilities provides a basic framework for the design of assistive technology.

The Trine Project

An example of design based on functional analysis is provided by the Trine project, which identified three needs in the education of learners who are disabled: writing, communication, and access to the computers used in school for regular activities. The project developed a computer-based aid to meet these needs. The project was directed by Gregg Vanderheiden of the Trace Center at the University of Wisconsin. Excerpts from the project's report describe the needs of the users with regard to writing:

> A large number of children with physical disabilities are unable to use a standard pencil and paper in order to take notes, do independent work in school and at home, carry out mathematical manipulations, organize thoughts, and complete assignments. An alternate pencil and paper—a means for personal writing—must be provided. It must be portable and unobtrusive so it can be kept with the child as he or she moves within the school, work, and home environments. It is also important that these alternate pencils be provided at the same time the ordinary child is provided with pencil and paper, and that it allow the child to write at a rate that approaches the writing rate of the ordinary child. A child who writes five to ten times slower than the ordinary students will not be able to keep up with regular work. Thus, it is very important that the alternate pencil and paper be as fast as possible.

In designing the system, the developers saw the need for portability as especially important, since many of the children who will be using the system are ambulatory and need to carry their writing aid from class to class. The development of powerful, portable, and inexpensive general-purpose computers made such a system practicable.

Another major goal was to integrate the three functions (writing, computer access, and communication) into a single aid. Since children need to interrupt writing and computer access work to answer questions, it was important to design the system so that all three functions were always available and to make it possible for them to switch easily from writing to talking and back to writing or computer access without losing time or their places (Gunderson, Rodgers, Fishman, Crocker, & Vanderheiden, 1986).

ARC Eyegaze Detector

Al Cavalier, principal investigator of a project conducted by the Association for Retarded Citizens (ARC) that developed an eyegaze detector, commented on the needs of students with profound handicaps:

> For students who are profoundly handicapped, whether it be because of mental retardation, cerebral palsy, quadriplegia, or combinations of these and other conditions, there is often a need for some alternate means by which they can act on their environments, control their surroundings, communicate their needs or desires, and begin to break out of a history of dependency and passivity. To be usable, this alternate means must often require the absolute minimum of effort. Eyegaze holds this potential. To design such a system for educational applications, we needed to evaluate the range of such user capabilities as how steadily the students

can maintain their head position, how much "eyelid droop" they typically display, and how iconic the display items must be to carry representational meaning. When dealing with advanced technologies, we found the students' most knowledgeable associates, e.g., parents, teachers, aides, were valuable sources of information to these issues up to a point. Their difficulty in conceptualizing the functioning of the proposed system often forced us to delay the final decision on many device/user match-ups until we could conduct device simulations.

Like the designers of the Trine system, the ARC designers considered portability important in order to "provide the students increased freedom of choice and freedom of expression" when using the system. They believe that the students should not be deprived of these freedoms just because they move to another classroom or outdoors.

■ Identifying the Range of Relevant Users and Decision Makers ■

In addition to the individual user, the range of people who are involved in the use of a device and the decision to buy the device may include parents, teachers, counselors, therapists, physicians, or social workers. Educational administrators, loan program administrators, and third-party payers such as insurance adjusters are also often involved in the buying decision. Figure 1 illustrates potential users and purchasers.

Project COMPACT

The importance of involving representatives of all user populations in design was stressed by Alan VanBiervliet, Director of Project COMPACT, which developed a multipurpose communication aid:

> It is important to design the whole product from the users' perspective. In projects like this one, designers need to consider how teachers or related services workers behave. Therapists, like teachers, have little time for fine-tuning and modifying communication aids. For example, a therapist working in a rural area may have only one client in 9 months who needs such a device. If customization of the assistive device requires complex, idiosyncratic procedures, the therapist would practically have to relearn the system each time it is used.

Project Description

Project COMPACT produced a communications system that uses graphic symbols as input and produces voice output. It is programmed by the therapist to include words and phrases most frequently used by the client. The system is designed for students with cognitive impairments, individuals with aphasia, and anyone for whom a spelling-based communication system would be inappropriate. Systems that use multimeaning symbols may be frustrating for some users and are also difficult for therapists to program and set up for the users. The Project COMPACT designers included an automatic recording and analysis system that records each response the user makes and analyzes the frequency with which each word or phrase is used.

This feature is unique to the COMPACT device. It provides the therapist with information on how to use the system and also incorporates artificial intelligence to make data-based suggestions to the therapist about how to modify the system. For each response, the item selected, time, and location in the system are recorded. This feedback helps the therapist tailor the system to the user's own speech patterns, vocabulary, and conversational situations. It also provides the therapist with information useful in therapy (e.g., how often the client uses the language forms being taught and whether speed or fluency has increased).

Design and Review Process

Project COMPACT researchers interviewed therapists and their clients to design a system that was easily adapted and used. They asked therapists about their needs with respect to system operation, caseload, and the time available to use such a system. They used other sources of information as well, including literature reviews and professional society meetings. They obtained feedback from other professionals through the International Society for Augmentative and Alternative Communications (ISAAC) and also gathered information from augmentative and communication literature.

The project had an advisory committee of national experts that reviewed the conceptual design of the device, provided feedback, reviewed the prototype model, and participated in an evaluation review meeting. This information not only yielded general design information, but formed the basis for specific features as well. For example, users may have difficulty remembering information from page to page on a computer screen. With this in mind, designers included an onscreen reminder—a "memory bar"—across the top of the screen. The memory bar presents the words the user has already selected, so that he or she can continue the train of thought.

The child and parents, teachers, or therapists are involved in the use of such devices. One concern with educational assistive devices is that they are purchased not by the ultimate user—the student—but by another party such as an educational administrator, agency rep-

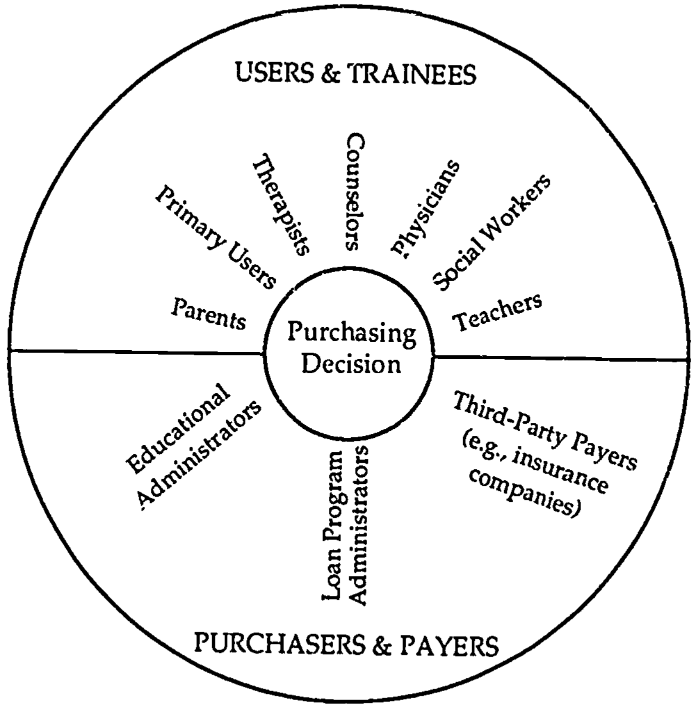

Figure 1. Potential Range of Relevant Users and Decision Makers

resentative, or teacher. Thus, the ultimate user may have little to say in the selection of the technology. This, in effect, bypasses an important source of market feedback for assistive tec! ology. The careful consideration of the needs o: studen. s well as other users in product design thus becomes mure critical.

Enhancing Ease of Use and Accessibility

Certain features can make new technological innovations easier to use. Ease-of-use features can make the difference between accessibility and nonaccessibility for some people. For example, in using the Project COMPACT device, the user can easily locate desired buttons because they are clearly labeled. The user does not have to memorize extensive phrases or combinations of keys because all commands are controlled by simple words and keystrokes. Also, a variety of "alerts" and feedback statements are provided to ensure that an accidental mouse movement or keystroke does not erase or destroy the therapist's work.

A chart relating accessibility features to specific user characteristics is presented in Appendix A. The chart is an excerpt from *Considerations in the Design of Computers and Operating Systems to Increase their Accessibility to Persons with Disabilities*, a report of the Industry/Government Cooperative Initiative on Computer Accessibility (May, 1988).

Similarly, the Trine system uses menus and dedicated keys for most functions. The four keys that usually must be held down simultaneously with other keys (SHIFT, ALT, CONTROL, and FUNCTION) can instead be pressed sequentially (e.g., SHIFT, then t types T), which makes one-finger or headstick typing possible. The system features an abbreviation expansion system, QuicKey, in which users can easily enter their own abbreviations that can later be typed into the keyboard to summon a frequently used word or phrase. A built-in cassette drive can store the user's abbreviations as well as up to 18 workspaces of writing.

Flexibility for Growth and Compatibility with Other Assistive Aids

Many assistive devices are used in conjunction with other devices to make a customized system that meets the needs of an individual user. This applies in a class.oom setting as well as to aids that travel with the user, and it holds several implications for design. First, multiple input mode capability for such equipment as a mouse, a touchscreen, a single-switch-operated scanner, or an infrared headset may be important for user accessibility. Multiple adaptive output modes (e.g., voice, tones, print, or braille) are equally important.

In addition, designing devices in a way that allows new features or input and output modes to be added easily and other, separate devices to be connected easily increases flexibility. Multiple functions can also broaden the market for an assistive aid. In Project COMPACT, the graphic communication aid, several additional features were added including phone dialing, environmental control, ties to educational software, and laboratory equipment operation. Another example of a multifunction device is ULTRA, a portable talking laboratory computer that serves as an instructional laboratory aid, a talking computer terminal, a talking calculator, and a personal computer. Using ULTRA, a student can hear laboratory instrument readings; they are presented as acoustical tones. ULTRA was developed by a group at East Carolina University to adapt college chemistry laboratories for students who are blind or have low vision. It can be interfaced easily to most standard laboratory instruments.

Al Cavalier, developer of the eyegaze system, recommends that designers consider using an RS232 serial port (a standard computer port). This offers a fairly standard means of linking an assistive device to other devices that may at some time have a need to communicate with the assistive device. The eyegaze system can not only upload its collected data onto a microcomputer system, but also download specific parameters that a teacher selects from the microcomputer for instructional purposes.

■ Limiting Training Requirements ■

It is important to provide all the information a user will need to operate the new equipment. As the Trine project report states, "Technical aid systems . . . [can] be underutilized because users are unable to learn from the documentation provided and are unable to get the expert help they need locally. Many users can't get expert help locally because they live in less populated areas and the manufacturer has no local expert" (Gunderson et al., 1986, p. 6).

However, many of the project directors cited minimal training as an important feature of their products. Training concerns were considered early in the design process, so that the product is not complex from the user's perspective. The full range of relevant users was considered in training design. William Gavin, director of a project that developed a vibrotactile vocoder, which translates sounds into skin vibrations for students who are deaf or hard of hearing, pointed out that training is required on two levels: end-user training plus training the trainer.

Alan VanBiervliet considered an important design feature of Project COMPACT to be that the product does not require a manual. All of the information that would be contained in a manual is contained within the on-screen help section. The help system is easily accessed and provides all of the information needed to program and set up the device for the client. The product uses dynamic running displays that involve speech output and animated graphics to show people how to operate the system.

Manuals were used for Project Trine, and the principles of instructional design guided manual development. The manual, *A Journeyer's Guide to the Trine System*, was designed to be as physically accessible as possible, and it allows a user with normal intelligence, a sixth grade reading level, and no experience with computer or multifunction aids to learn the system without help.

The manual incorporates different cognitive learning styles so that it can be more effective for different people. The information is presented in five ways: (1) a summary, (2) straight text, (3) a follow-along example, (4) a realistic illustration of the device in use including a facsimile of the computer screen, and (5) a tabular instruction list. Information is always presented positively; negations are eliminated (e.g., instead of saying, "The power switch doesn't have to be turned off," it says, "You can leave the power switch on").

Interviews with users and their families, teachers, and clinicians revealed that each of the five information types was the primary information source for different people. The 15 people interviewed were almost evenly split among the five information types as their primary source. Testing revealed that the guidebook allowed the users to learn the system without expert support (Gunderson et al., 1986).

One drawback of using this approach, however, is that designers must be very careful that the manual does not become excessive in length. It is easy for manuals developed under this approach to become cumbersome and difficult to use.

For some aids, such as those based on sensory substitution, extensive training is required because the student must learn to obtain information using a different sense and to interpret that information. Both the structure and duration of training are critical to success. For example, in the case of the vibrotactile vocoder, developers recognized that use of the device called for students to learn to interpret the tactile sensations produced by the device and the sounds that these sensations represent. Experience in using the device is essential. In addition to an instructional curriculum based on its use, the project took this need into consideration in physical design. The vocoder is portable, lightweight, wearable, and self-contained. Small children can wear it under their clothing. To maximize their experience with the device, the children wear their vocoders throughout the entire school day and are allowed to take them home as long as their parents are willing to take care of the units and continue the training associated with their use.

Another product that requires training via physical experience is a robotic arm that students control by computer to manipulate objects in their environment. Richard Howell, the director of this project, stressed that the focus of training should be on educational applications of the device, with the "tool" features assuming a subordinate function in the overall learning process.

Al Cavalier pointed out that

> With the Eyegaze System, effective training strategies are essential in order to impart adequate understanding of the operation of the device to users, particularly those who are severely cognitively impaired with little receptive language. In fact, we believe that the development of effective training strategies for students who are low functioning is equally as important as the device itself in this project. The topic of effective training strategies for optimal device use is too often overlooked in research and development of assistive technology in special education, and we believe it often has a significant impact on a device's survival in the marketplace.

These projects make it clear that the amount of training required varies with the purpose and design of the device, but that training should be held to the minimum amount required to use the product easily. Training should be based on effective, efficient, and tested strategies in consideration of the device and all of its users. This applies across the continuum of device types.

PROTOTYPE DEVELOPMENT, TESTING, AND EVALUATION

Involving Manufacturers at the Outset

It is important for designers to work with manufacturers very early in the design process. Gregg Vanderheiden, director of Project Trine, recommends that if designers cannot find an interested manufacturer early in the process, they should seriously reconsider either the need for the product or the approach to its design.

> If the purpose of the project is product design, as opposed to research or demonstration, then the result must be commercially available if it is to benefit very many people. Product development is not just an academic activity—there are practical constraints in manufacturing and selling that must be taken into account. If a manufacturer tells you something is not practical, believe him—accept that that will be his basis for decisions. Even if the researcher thinks that the manufacturer *could* or *should* do something, he should listen carefully to the manufacturers, since it is they who will make the final decision.

Further, Vanderheiden stresses the importance of using the manufacturer's expertise to design a product that manufacturers want and to avoid overdesign—taking the design too far beyond what is needed. A product that is overdesigned later may need to be redesigned to meet manufacturing capabilities. Al Cavalier notes that

> Just as in applications research, researchers in R&D often fall prey to the temptation to focus on designs that are too ambitious—that is, they include the "bells and whistles" that, while offering some increase in functionality, are not essential to the design's basic purpose. They may also threaten the completion of the project.

It is also useful to search for existing devices that may fill similar functions. Christy Horn, director of Project InfoNet, recommends that designers call centers such as the Trace Center, InfoNet, and Heath or hotlines such as the IBM hotline to identify whether or not devices similar to the one planned already exist. In addition, she points out the need for networking among postsecondary institutions in order to ensure that new devices are designed to fill the most pressing needs and to avoid "reinventing the wheel." This type of search can also help designers avoid copyright problems among systems that offer similar features.

Involving manufacturers early can help solve problems such as the need for liability insurance before design money is spent. Manufacturers and vendors are having serious problems with liability insurance. High insurance costs have forced several manufacturers of good-quality products to go out of business (RESNA, 1988). Greg Carr, of Prentke Romich Corp., whose project designed a wheelchair that included a communication and software interface system, also stresses that "liability is a major issue in manufacturing products of this type. Even manufacturers that have confidence in their quality control must carry liability insurance, the cost of which is very high. This cost increases the cost of the final product."

In addition, manufacturers often can help to find ways of broadening the market for a product. Products and features that have broad application can increase revenue. This is another reason why multifunction products are popular. Features that can be marketed separately should not be overlooked. In Project Trine, the QuicKey abbreviation/expansion system was marketed separately for the general market and is a very popular added benefit of the project.

Al Cavalier cautions, however, that if a product is designed with added features in order to expand the potential consumer base, and if the target populations for the added features are larger than the population for which the device was originally targeted, the manufacturer may find it more profitable and attractive from a business standpoint to drop the design features that serve the smaller population. This concern can usually be guarded against by the developers at the time they negotiate an exclusive license with the manufacturer.

William Gavin points out that manufacturers are the means of distribution. Because the range of relevant users or purchasers for many products includes several people per sale, two or three parties must be considered as the consumers and each must be convinced of the benefits of the device before the unit actually can be sold. Different marketing strategies are needed for the different consumers; they all contribute to the decision to buy.

Building in Flexibility: Component Technologies and Modular Software

Component Technologies

Testing and acquiring components was mentioned by several project directors as a problem area. Although "off-the-shelf" components are used whenever possible to save the time and expense of designing and building all of the components of a product, a separate set of problems is associated with combining these ready-made components. William Gavin, director of the project that developed the vibrotactile vocoder, described problems of coordination and timing when parts are not available when needed:

> Designing devices using "off-the-shelf" technology requires time—integrating components and getting them to work is very time-consuming. It is a process of securing supplies, wiring, testing, changing supplies, and testing again; for 1 year of design there are 6 months of beta testing. We had to work on a fixed design to meet the deadlines; there was no time for trying alternatives. It is easy to get hung up if parts are not available.

For this reason, project directors recommend that alternative components be planned in advance whenever possible. This is also true for separate but compatible devices. For example, the Trine system software program is designed to work with three different speech synthesizers. Unfortunately, it is not always possible to select alternative components when products come from only one or a few manufacturers. For example, there are only three original equipment manufacturers of VCR's, and only three of compact disk players.

Another problem is original equipment manufacturers' estimates of availability of new components, which can be unreliable. There is often a long delay between announcements of new hardware products and their actual availability. In the case of Project COMPACT, a CD/ROM memory storage part was not available when needed and the project had to use an alternative. The new product would have allowed even greater miniaturization of the assistive device.

Alan VanBiervliet stresses the importance of using the latest technology: "It is important for projects such as this to be at the forefront, using the latest hardware, since it often takes at least 2 years from prototype development to market. Otherwise the products offered are not the best available and are quickly obsolete after they hit the market."

He also points out the problems of small universities in convincing manufacturers to give them access to prototypes to be used in development of devices. Manufacturers are interested in how many of the final devices will be sold, and they may require a commitment to a certain number of sales before they will provide early models. In developing a prototype, it is often difficult to predict this number with any accuracy. For larger universities, the number of students exposed to the device and the name and reputation of the university will often convince manufacturers to provide early products for testing and development purposes.

Larry Scadden, of the Electronic Industries Foundation, points out that small companies in the assistive technology field are usually extremely dedicated to producing products that can change the lives of people with disabilities. At the same time, they are required to turn a profit. Although many people appear to believe that these companies should be more altruistic in their dealings with their markets, the companies are altruistic by definition, or they would have entered a more profitable area of business.

A cautionary note was added by Charles Blashke, President of Education Turnkey Systems: Although it is important to design using the latest technology, designers who do so run the risk that the projected base of users may not materialize. For example, if a product planned for release 2 years in the future requires that users own a specific PC system or other compatible product, the designer must rely on projections of the number of owners of that system or product 2 years in the future. Such projections may or may not be accurate.

Modular Software

A number of project directors identified modular software written in a high-level language as an important key to flexibility in their products, especially given the limited time span within which devices must be developed. Gregg Vanderheiden recommends doing "as much in software and as little in hardware as is possible." David Lunney, developer of science equipment with acoustical read-outs for students who are blind or have low vision, notes that "standardized, modular hardware and modular software written in standard languages can lower costs, shorten design times, and facilitate updating."

As Alan VanBiervliet explains,

> Traditional programming languages do not offer the flexibility of object-oriented or modular languages such as Smalltalk, Hypercard, Linkway, or Modula. Traditional languages integrate the entire system so that a change in one part of the program requires corresponding changes in other parts. Modular languages encapsulate program components so that they can be easily changed or new components added without affecting other parts of

the program system. This allows system developers to test and change each component as the system is being developed, rather than waiting until the entire project is completed before testing can begin. It is also easier for different people to work on the system and change components, so that the original programmer does not have to make all later changes. For this reason, many programmers are hesitant to work with traditional languages. Modular languages are also easier to learn, and other people can later add new features to the system by putting in new modules that can easily be linked to other parts of the system. The modular languages offer the power of traditional languages and the simplicity of authoring systems. They provide an inexpensive and easy way to expand and customize devices, and they are software driven, not hardware driven.

Peter Maggs, director of a project that developed a software driver for high-speed voice output, cautions that it is dangerous to use a computer language that is tied closely to particular hardware because of the rapid changes that take place in hardware. There is much to be said for using a portable language such as "C," even though such languages put a major burden on the system designers to ensure good documentation and modularity.

"Document now, code later!" is a principle that Al Cavalier considers essential to the smooth and steady operation of R&D projects. He reports that documentation is the bane of programmers' and engineers' existence, particularly if it is done in sufficient detail to permit another person to come in and pick up where they left off or to transfer development to a commercial publisher or manufacturer. They have a strong tendency to put off documentation until the very end of the project, when there is typically too little time or money remaining to ensure that documentation is adequate. If project directors see the removal of threats to the timely completion of their projects as one of their major responsibilities, then few other items should be weighed as heavily as systematic checks on the ongoing documentation of their system's development.

■ Beta Testing and Clinical Trials ■

William Gavin points out the distinction between beta testing and clinical trials: Beta tests are designed to determine whether a device works as expected, while clinical trials assess whether, in actual use, the device solves the functional problem it was intended to address. He advocates repeated testing of prototypes:

> Even if the concept for design of a new device works, one prototype is not enough. Revisions of several successive prototypes are often required to refine the ergonomics of the device and to improve the device's durability against wear and tear. It is the results of the clinical trials that often require more than one cycle of design and beta testing.

With respect to clinical trials, he says,

> Clinical applications trials test the utility and feasibility of devices, to make sure they work as you said they would. Even the best-justified design proposals don't address how well the device fulfills the needs it was designed for. This is as important as how well the concept works.

Peter Maggs adds,

> Software maintenance is also important. Even with beta testing and clinical trials, the first release of software almost always contains bugs. In addition, the first time a large group of users tries the software, there will be users with good ideas for improvements or additional features. It is important to think in advance of mechanisms for feedback, to inform the software maker of the problems and possible improvements and for updating software in the field.

In the Trine system testing, an initial version of the system software and the guidebook were field tested with 13 typical users and 6 consultants. Information on how people were using it was collected over a 2-month period. The users learned the system on their own, with no direct support from the developers. After 2 weeks, the users were evaluated on their basic use of the system, and they were interviewed on how they had used the guidebook and what they liked and did not like about the system and the guidebook. The test report concluded that the system meets basic communication and writing needs in educational, vocational, and daily living situations, and that the guidebook allows the users to learn the system without expert support.

■ Standards* ■

Standards are measures of the quality of equipment stated in terms of device safety and performance. Product

*RESNA, an interdisciplinary association for the advancement of rehabilitation and assistive technology, provided a discussion of design and performance standards as applied to assistive devices in a statement to the Subcommittee on the Handicapped of the Senate Labor and Human Resources Committee on May 19, 1988. Much of the discussion presented here is based on that statement.

standards are model specifications prescribing requirements for a product, material, or procedure. They often include test procedures for determining whether or not specified requirements are satisfied.

It is important to distinguish between design requirements and performance requirements in product standards. Design requirements are expressed in terms of simple physical attributes such as dimensions, shapes, and specific material. They are used to ensure interchangeability or compatibility between system components. Design requirements may also include specifications that ensure accessibility by handicapped individuals, for example, the kind and position of connectors or user controls.

Performance requirements, on the other hand, are expressed in terms of functional attributes such as product durability and energy efficiency. For example, design standards of a light bulb may include such information as filament diameter, length, and material, while performance information would include brightness, energy consumption, and average life. Performance attributes are more difficult to measure than design attributes and are often more difficult to convey in understandable terms to consumers (RESNA, 1988). Both types of standards are crucial for assistive technology.

Design Requirements

The need for design standards affected Prentke Romich's interest in further development of their prototype, a wheelchair fitted with computers that provided a child who is severely handicapped the opportunity to communicate, use computers, and control the chair's movement from a single control mechanism. The control mechanism was a central aspect of the design. However, because there are currently no standards for a wheelchair drive interface, the product could not be manufactured easily. The controller would have to be customized for each model of chair, making the manufacturing costs too high for the market to bear.

Prentke Romich has stopped development of the design and has no plans to continue until a standard interface is available. The company is working with the Trace Center to get wheelchair manufacturers to support a standard serial interface for all electronically controlled wheelchairs. This would allow the controller system to be a single standard device, in turn allowing a smaller price tag. Greg Carr, of Prentke Romich, reports that, currently, Invacare Corporation, of Elyria, Ohio, is actively contributing to the work on this new standard. According to Carr, when this standard becomes a reality, the control of powered wheelchairs through augmentative communication devices can also become a reality.

Although several wheelchair manufacturers use a common interface that allows for environmental control (e.g., turning lights on or off) or communications, the development of a formal standard that will allow the use of controller systems such as that developed by Prentke Romich will greatly contribute to the versatility of powered wheelchairs.

However, Peter Maggs points out that it is difficult to get a standard adopted just for the needs of individuals with handicaps. When possible, he advises, a standard should be borrowed from another industry. For instance, instead of designing a new cable connection standard, one of the industry cable connection standards could be picked.

Performance Standards

Performance standards are the basis for comparative product performance information for consumers. They are obtained in accordance with standard tests and presented in a standardized format. Standard tests are essential for comparing the same features across products; they measure performance attributes such as durability, maneuverability, and energy consumption. Presenting this information in a standard format allows consumers to compare alternative products more easily. Performance information is much more useful than design information for product comparisons by consumers (RESNA, 1988.)

Peter Maggs observes that it is important to tie the performance standard closely to the needs of a particular handicapped population. A standard for a speech synthesizer for a computer user who is blind should measure the speed and comprehension of the user accustomed to the particular device. In contrast, a standard for a speech synthesizer for use by a person who has a speech disability should measure the comprehension of individuals who are *not* accustomed to the particular device.

When comparative product performance information is available, impressive benefits for both consumers and manufacturers accrue. Consumers, wheelchair users, third-party payers, and prescribers are able to make more informed procurement decisions, making it more likely that technology will be used appropriately and that devices serve the needs of consumers. This information also helps to justify a legitimate need for a device that has better than minimum product performance to insurance adjustors and other third-party payers.

Two major issues in the development of performance standards are (1) who will conduct performance evaluations and (2) who will pay for them. While many manufacturers provide such data on their products, it is up to other organizations, such as societies and trade associations, to collect information in a format that allows direct comparison across products and make it available to the public. For example, the Society of Automotive Engineers has developed adaptive device standards for cars. Since safety is one of the important features addressed, manufacturers and vendors who comply with the standards may reduce their liability risks.

RESNA, formerly called the Rehabilitation Engineering Society of North America, is currently working with the American National Standards Institute to develop performance standards for wheelchairs. The RESNA/ANSI standards for manual and powered wheelchairs will be the first information disclosure standards for assistive devices. To implement them, manufacturers or vendors must test their products in accordance with the standards' test procedures, the data must be collected and formatted, and the information must be disseminated. Financial, administrative, and technical support are being given by industry, wheelchair and modified van users, researchers, and state and federal agencies (RESNA, 1988).

Generally, such information disclosure standards do not contain pass/fail criteria; they are appropriate when there are no sharp divisions between acceptable and unacceptable levels of performance. For example, some wheelchair users may be willing to sacrifice durability to get more maneuverability. Appropriate trade-offs depend on an individual's needs and preferences (RESNA, 1988).

From the manufacturers' and vendors' perspective, those who offer the products that perform best at reasonable prices will be more likely to be rewarded in a market having consumer product performance information available. Comparative information will assist manufacturers and vendors who want to supply quality products to compete against inferior products, since trade-offs between quality and costs will be clearer. Dissemination of such information by well-known independent organizations will be a valuable supplement to regular advertising by participating vendors and manufacturers.

DISTRIBUTION

In recent years, a greater interest in assistive technology has been generated by the potential of technological innovations to increase the independence and productivity of individuals with disabilities. The innovations themselves appeal to a wider market and generate even more new ideas. With this increased interest has come a host of new issues and questions, particularly about how to get these powerful new devices to the people who can best use them.

Several OSEP technology projects address this need. One project is creating an expert system to help professionals identify appropriate technology devices for children with severe physical and sensory handicaps. It is being conducted by Michael Behrmann at George Mason University in Fairfax, Virginia.

The project is developing a microcomputer-based artificial intelligence system that will act as a consultant to related services and education professionals. It will prompt them with questions about the broad goals of the student including goals related to vocation, daily living, reading, speaking, writing, and environmental control, as well as the student's specific capabilities with regard to head control; hand control; range of motion; and physical, cognitive, and sensory abilities. It will then compare this information to an existing database of assistive technology (ABLEDATA), identify the needs best filled by technology and those best filled by humans, and suggest the combinations that will meet the needs of this individual. The computer will identify the categories and features of devices needed and provide a list of specific models available within each category. The system can be placed in school districts, agencies, and centers so that it will be available to large groups of professionals.

In designing the system, the project researchers investigated assessment protocols used in determining technology needs and collected a literature library including these protocols. The researchers also evaluated different authoring programs and examined the human interface with artificial intelligence systems, for example, where graphics and help menus should be provided.

As well as supporting the design and development of innovations in assistive technology, OSEP supports projects that provide information to various audiences including teachers, parents, and related services professionals. On the national level, the Center for Special Education Technology at The Council for Exceptional Children provides resources and information to professionals. It sponsors conferences on current issues and topics, houses a technology library, and provides information services.

At sites across the United States, five projects conduct a range of activities for promoting the use of assistive technology. These activities include training and on-site technical assistance to related services personnel, teachers, and parents; coordinating activities among agencies, training programs, facilities, private companies, and other resources; and developing information networks and loan banks. Project activities differ across sites, which are located in Oregon, Pennsylvania, Maryland, Connecticut, and Nebraska. (Addresses are provided in Appendix B.)

The distribution of assistive devices and information about them was also supported by an OSEP-sponsored video teleconference on communication aids and assistive devices for consumers and professionals. The April, 1989, teleconference was broadcast by public television stations across the country to provide information about assistive devices, presentations on various types of assistive devices, a panel discussion of devices and support and referral services, and a long-distance question-and-answer session in which viewers called to discuss questions and problems with experts. After the teleconference, a series of orientation and training videos were broadcast and were made available for taping by schools and other agencies that serve special education students. The teleconference was received by over 400 sites across the United States and was seen by over 50,000 viewers.

A second teleconference is being arranged by the same contractor, Education Turnkey Systems, of Falls Church, Virginia. It will focus on communication aids and devices to assist people with cognitive impairments. Education Turnkey is also planning a third teleconference sponsored by another agency.

Federal support for the distribution of assistive technology is now provided through the Technology-Related Assistance for Individuals with Disabilities Act of 1988. This new law is intended to help states develop and implement statewide programs to help individuals with disabilities obtain devices, services, and information about assistive technologies. The law provides for grants to states to catalyze public and private assistive technology services.

This law reflects increased interest in assistive technology, recognition of its potential, and an understanding that reaping the benefits of assistive devices is not just a matter of developing ideas and technological applications—equally important are the social factors involved in getting devices to the people who need them. Such interest in the distribution of technology-related assistance is a logical extension of work by OSEP and other agencies to develop assistive technology and systems for sharing information about it. As progress on these various fronts continues, students with disabilities can look forward to unprecedented increases in independence and productivity through greater access to education.

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APPENDIX A

Accessibility Features in Relation to User Characteristics

Excerpted from *Considerations in the Design of Computers and Operating Systems to Increase Their Accessibility to Persons with Disabilities*, a report of the Industry/Government Cooperative on Computer Accessibility (May 8, 1988). The report is available from the Trace Center, S-151 Waisman Center, 1500 Highland Avenue, Madison, WI 53705. Reprinted with permission.

QUICK SUMMARY OF DESIGN CONSIDERATIONS

(See Part II of full document for details and design notes)

PHYSICAL IMPAIRMENTS

Persons with moderate PHYSICAL IMPAIRMENTS have difficulty using some input devices and controls

Problem Areas	Examples	Needed Features or Capabilities	Priority (* = GSA)	Example Strategies
P1 - Cannot do simultaneous actions such as SHIFT, CONTROL, ALT, etc. (eg can only use 1 hand or mouthstick)	Individuals with one arm, or those who use a mouthstick, cannot use shift/control keys on standard keyboards... or use a 2-button mouse.	• Alternate sequential method for achieving all functions which normally require simultaneous actions	1*	1) StickyKeys (1-Finger option) 2) Keyboard Alternate for 2-Button Mouse
P2 - Cannot respond quickly (key repeat and other timed responses)	Individuals with a slower reaction time can have trouble if the key repeat rate is too fast.	• Ability to slow down or turn off timed response	1*	1) Key Repeat Adjustable (start/rate/on-off) 2) Software design rules for 3rd party mfgrs.
P3 - Cannot use standard mouse or other pointing devices which use fine movement	Individuals with motor problems or paralysis cannot accurately use a mouse or touchpad.	• Alternate way to move/control mouse or pointing device cursor without fine movement	1*	1) Mousekeys (keyboard control of mouse) 2) Keyboard simulation of touchscreen
P4 - Difficulty in handling storage media delicately. Difficulty in reaching drives (Disks, CD ROM's, etc.)	Individuals with cerebral palsy have difficulty handling fragile media and reaching into drives to remove the floppy disks, CDs, etc.. Also have trouble reaching built-in drives, especially on floor-mounted computers.	• Removable media should be easy to insert and remove. It should also not require delicate handling. Drive would preferably have an external mounting option.	2	1) Electric push button operation 2) Concave buttons (if manual eject) 3) Ejects 1/2" to 3/4" or more 4) External mount drives available 5) Rigid, self-protecting media
P5 - Trouble operating controls that require manual dexterity or reach	Individuals with limited dexterity (arthritis, cerebral palsy, etc.) are unable to use controls which they cannot reach or which require a twist motion.	• Controls and latches NEEDED FOR OPERATION in easy reach & require minimum dexterity (eg stick in mouth, or arthritic hands)	3	1) Front mount (controls and drives) 2) No twist motions 3) Push button controls and latches 4) Edge operated (wheel) controls 5) Functions operable from keyboard
P6 - Bump wrong keys when typing	Individuals with cerebral palsy, tremor or weakness have trouble hitting keys accurately without touching adjacent keys.	• Delay key acceptance and/or provide for keyguard	i	1) Keyguard or keyguard mounting 2) Slowkeys utility (with a start-up warning sign!!)

Some people with SEVERE PHYSICAL IMPAIRMENTS cannot use standard input devices

Problem Areas	Examples	Needed Features or Capabilities	Priority (* = GSA)	Example Strategies
SP1 - Need to connect special input devices or interfaces (sip-puff, eyegaze, etc.)	Individuals who require an eyegaze or sip&puff controlled input cannot use the standard input devices on the computer and need a way to connect their device in place of the normal input devices (keyboard, mouse, touchscreen) on the various computers they encounter at work/school/etc.	• Way to connect alternate input systems (internally and externally). (For access to user owned/controlled computers, internal system hooks or access points can be used. For shared and public use computers, access must be external.)	1*	1) Point in operating system where simulated input can be injected (before first application or system use of input) 2) A callable system utility which, when invoked takes data from serial port and creates fake (simulated) keystrokes and other input activity

QUICK SUMMARY OF DESIGN CONSIDERATIONS

(See Part II of full document for details and design notes)

VISUAL IMPAIRMENTS

Some people with VISUAL IMPAIRMENTS cannot see lettering and symbols on keyboard, equipment or screen because it is too small or low contrast.

Problem Areas	Examples	Needed Features or Capabilities	Priority (* = GSA)	Example Strategies
V1 - Screen display is too small to see	Individuals with low vision have difficulties reading the screen because the characters and images on the screen are too small.	• Ways to make screen image larger (up to 16 times)	1*	1) Video connectors for external displays 2) Zoom enlarge feature or utility
V2 - Color blind persons cannot see information presented through some colors	Color blind individuals cannot see text or highlights with some text/background color combinations.	• Allow user to select the colors or make color information redundant	1*	1) Colors selectable by user 2) Color redundancy whenever possible 3) Color redundancy design rule for 3rd party mfg
V3 - Trouble seeing/reading keys and legends on equipment	Individuals with low vision have difficulty seeing keys and reading legends on monitors, printers, etc.	• Larger, high contrast characters on keys and controls	2	1) Avoid low contrast colors 2) Larger letters on keys and controls 3) Stickers w/ large letters (and/or colors) 4) Replaceable keycaps with removable clear plastic lids

Some people are BLIND and cannot use standard visually based ouput & input devices and indicators

Problem Areas	Examples	Needed Features or Capabilities	Priority (* = GSA)	Example Strategies
B1 - Need electronic access to information displayed on the screen in order to use special non-vision display substitutes	Blind individuals can use a portable voice output access device in place of the computer's standard screen display, except where these devices cannot get access to the contents (information) displayed on the computer's screen.	• Provide display contents in an electronically accessible, interpretable form (For access to user owned/controlled computers, internal system hooks can be used. For shared and public use computers, access must be external.)	1*	1) Document access to screen memory 2) Export screen image memory 3) Screen description call/utility (internal) 4) Export description of screen contents
B2 - Do not have eye-hand coordination required for mouse tasks, touchscreens, etc.	Blind individuals cannot use a mouse because they cannot monitor the mouse cursor's continually changing position as they move.	• Provide alternate ways to achieve same function without eye-hand coordination whenever possible (eg as keyboard commands)	1	1) Keyboard access to menus 2) Keyboard access to window functions 3) Keyboard simulation of touchscreen
B3 - Cannot tell state of toggle keys/buttons whose state is only indicated visually	Blind individuals have trouble with toggle keys, printer status buttons, etc., which use LEDs to indicate state.	• Non-visual status cues or means to determine status non-visually	3*	1) Tone feedback for toggle keys 2) Auditory query of status (tones)
B4 - Trouble finding/identifying keys and controls	Blind individuals have difficulty using perfectly flat membrane keyboards, since they cannot find the keys even if they have memorized their position and function. They also have difficulty in locating keys on large keyboards without tactile landmarks.	• Tactile border to keys (eg no flat membrane keyboards without ridges or key dividers) • Non-visual key/control labeling	3*	1) No perfectly flat membrane keypads 2) Nibs on Home Keys 3) Tactile map with braille labels 4) Braille stickers on or above keys 5) Tactile labels on or next to keys 6) Voice cuing

QUICK SUMMARY OF DESIGN CONSIDERATIONS

(See Part II of full document for details and design notes)

HEARING IMPAIRMENTS

Some people with HEARING IMPAIRMENTS cannot hear auditory output at normal volume levels or at all.

Problem Areas	Examples	Needed Features or Capabilities	Priority (* = GSA)	Example Strategies
H1 - Cannot hear auditory warnings or other indications or output (including speech)	Individuals who are deaf cannot hear beeps that indicate errors when typing or issuing commands. They also cannot hear any spoken or other auditory output from the computer or programs. Natural noises (disk drives) used by hearing persons are also not available.	• Present all auditory information visually as well	1*	1) Flash with system beep 2) "Hearing Impaired User" or "Feedback Preference" flag in OS 3) Auditory redundancy design rule 4) "Active" lights for disk drives 5) Captioning(open or closed) of any spoken output
H2 - Cannot hear sounds at normal volume	Individuals who are hard of hearing have difficulty receiving auditory output at normal volume levels.	• Adjustable volume and facilitate external amplification (useful but not critical if all auditory information is also visual)	1*	1) Speaker near edge for easy pickup 2) Adjustable volume (with sufficient range) 3) Audio output jack

SEIZURE DISORDERS

Some people with SEIZURE DISORDERS are sensitive to certain flicker frequencies which can cause them to go into seizure.

S1 - Screen flicker at certain frequency can cause seizures (even if the person is only near the computer)	People with photosensitive epilepsy may have a seizure if exposed to strong stimuli in the 10-50 Hertz range.	• Avoid those frequencies	1*	1) Avoid refresh or flicker rates in the 10-50 Hz range (especially 15-30 Hz)

**FEATURES TO FACILITATE
3RD PARTY MANUFACTURERS
(FOR ALL DISABILITY AREAS)**

Some design features or changes would greatly reduce the cost or difficulty by 3RD PARTY MANUFACTURERS/AGENCIES in developing special access devices and materials

Problem Areas	Examples	Needed Features or Capabilities	Priority (* = GSA)	Example Strategies
M1 - Agencies have difficulty preparing manuals in alternate form (disk, Braille, speech)	Agencies who support persons with disabilities could provide special manuals in Braille, voice or electronic fo[illegible] if they could get the source text for the manuals in electronic form.	• Provide manuals in electronic form	3*	1) Text from manuals avail in electr. form 2) Information in all figures and graphics presented also (redundantly) in text 3) Special electronic manuals
M2 - Need to have speech output from computer for special need programs/utilities	Programs for blind access and for nonspeaking persons need to have access to a built-in or external speech synthesizer.	• Provide speech capability built in or ability to attach a synthesizer.	4*	1) Serial port 2) Speech capable sound system
M3 - Some alternate input routines require a window which always remains on top	Some special access programs need to use a window that is never hidden from the user, yet is not the "active" window.	• Provide a window which can always appear and remain on top.	4	1) Build necessary hooks into operating system
M4 - Some alternate input routines require connection of special switches or interfaces	Morse code, scanning, and other special input routines require the ability to connect special sip-puff, eyeblink, etc., switches.	• Provide a means for connecting special switches and transducers	4	1) Assign pins on existing connectors 2) General switch / transducer interface
M5 - Software sometimes ignores keystrokes sent faster than it can process them (assuming user got ahead of themselves) and thus defeating special macros	Word processing programs often throw away excess type-ahead backspace characters. This prevents some abbreviation expansion programs from working.	• Provide way in OS for distinguishing between typed, auto-repeat, and macro characters	4	
M6 - Trouble mounting keyguards to keyboards	Disabled individuals who share a computer with others have difficulty attaching and removing their keyguards.	• Provision in keyboard design to facilitate keyguard mounting	5*	1) Groove or holes in edge of keyboard 2) Keyguard from manufacturer

APPENDIX B

Current OSEP Projects That Promote the Use of Assistive Technology

InfoNet
University of Nebraska, Handicapped Student Services
132 Administration Building
Lincoln, NB 68588-0401

(402) 472-3787

Oregon Technology Access Project
1871 NE Stephens
Roseburg, OR 97470

(503) 440-4791

Statewide Model to Coordinate Technology Services for Students with Disabilities
Center for Technology in Human Disabilities
2301 Argonne Drive
Baltimore, MD 21218

(301) 554-3046

Technological Support and Empowerment Network for Service and Education (TECHSENSE)
University of Connecticut, U-64
249 Glenbrook Road
Storrs, CT 06269-2064

(203) 486-0701 or 0702

Transitional Technology between the Pennsylvania Assistive Device Center and the Office of Vocational Rehabilitation
Pennsylvania Assistive Device Center
150 South Progress Avenue
Harrisburg, PA 17109

(800) 222-7372
(717) 657-5840

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ERIC/OSEP Special Project
ERIC Clearinghouse on Handicapped and Gifted Children
The Council for Exceptional Children
1920 Association Drive
Reston, Virginia 22091-1589