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ABSTRACT

This report is the product of a symposium which examined the current knowledge base of technology use in special education and identified aspects ready to be transferred into the practical setting. Presentations revolve around students with low-incidence disabilities: severe physical and severe cognitive impairments, and those impairments in combination with severe sensory impairments. Six areas of research are addressed: choice making through environmental control, means of accessing instruction, alternative and augmentative means of communicating, information feedback in instructional design, graphics in instructional design, and speech technology. The research focuses on hardware design, software design, pedagogy embodied in those designs, teaching procedures to effect optimal use, and the outcomes that the designs serve. The report concludes with a discussion of the barriers that seem to limit the transfer of the research into practice and potential solutions to those barriers. Includes almost 150 references. (JDD)

Technology with Low Incidence Populations: Promoting Access to Education and Learning

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Preface

Annually, the Center for Special Education Technology sponsors an invitational technology symposium for active researchers to exchange information about the progress of research in technology use in special education. The focus of the 1989 meeting was *Advancing the Use of Technology: The Research/Practice Connection*. The goal was to examine the current knowledge base and identify aspects that are ready to be transferred into the practical setting.

The strand of presentations included in this paper revolve around students with low incidence disabilities: severe physical and severe cognitive impairments, and those in combination with severe sensory impairments. Seven presenters reviewed the research literature in six topic areas: environmental control, access to education, augmentative communication, information feedback, graphics, and speech technology. This paper is based on those seven presentations, which were edited to bring together one cohesive, comprehensive document on technology applications with low incidence disabilities. Liberties were taken in rewriting and rearranging sections of the paper so no one section is the work of a single author but the content, as a whole, is the contribution of seven researchers, recognized leaders in the field. ■

New Trends with Low Incidence Disabilities

Technology appears to hold unique attributes for teaching and advancing the life choices of persons with severe handicaps. People who are unfamiliar with persons with these handicaps typically underestimate their abilities and think of them in terms of what they cannot do. All too often people with these handicaps are observed sitting passively in a corner, or sitting in a wheelchair in some rigid position making unintelligible sounds, or lying on mats with atrophied bodies. Their handicaps have typically thwarted, up until recent years, our best efforts to engage them in active treatment. Because they have not communicated their desires and have not been able to act on their environments in meaningful ways, caregivers typically develop beliefs that these individuals do not have any desires or preferences, and that they absolutely cannot act on their environments. Based on such beliefs, it is common for caregivers to reduce their socializing with these clients, to make all their choices for them, and to perform all of their self-care functions for them (Houghton, Bronicki, & Guess, 1987; Mineo, 1985; Weisz, 1982). In effect, persons with severe handicaps become dehumanized.

The Association for Persons with Severe Handicaps (TASH) defines persons with severe handicaps as individuals who require "extensive on-going support in one or more life activities like communication, activities of daily living, mobility, and education to participate in integrated community settings." Although there are many low incidence disabilities, this paper is primarily limited to students who have severe physical involvement, severe or profound mental retardation, or one of the sensory impairments in addition to a physical or mental impairment. Problems of individuals with severe emotional disorders or any of the single sensory impairments will not be addressed.

Current Research

Through innovative educational practices and creative research with powerful tools in recent years, a growing body of evidence suggests that these individuals are more capable than ever before imagined. They *have* strong preferences, they *can* make definitive choices, they *can* act meaningfully on their environment, they *have* a sophisticated social system, and with some supports, they *can* work meaningfully in competitive employment (Brinker & Filler, 1985; Horner, Meyer, & Fredericks, 1986).

What persons with severe handicaps typically do not have are easily discernible, highly differentiated, unambiguous behaviors with which practitioners can work. What they typically offer are very subtle behaviors that are not differentiated. In other words, the signal-to-noise ratio in their behavioral repertoire is quite low. In a broad sense, the research presented in this paper has the effect of

A growing body of evidence suggests that [persons with severe handicaps]* have *strong preferences, they* can *make definitive choices, [and] they* can *act meaningfully on their environment.

filtering the subtle signals from that noise, amplifying them, and then elaborating them.

Six areas of research regarding technology and low incidence disabilities are addressed in this paper:

- Choice making through environmental control
- Means of accessing instruction
- Alternative and augmentative means of communicating
- Instructional design—Information feedback
- Instructional design—Graphics
- Speech Technology

Research has begun to look at how to reduce the physical and mental load that the technology or the environment places on them [people with severe handicaps].

The questions on which the research focuses address hardware design, software design, pedagogy embodied in those designs, teaching procedures to effect optimal use, and the end effects or outcomes that the designs serve. Significantly, this research has begun to look at how to increase the saliency of the information that can be provided to this population to reduce the physical and mental load that the technology or the environment places on them.

New Developments

Exciting developments in the special education technology field for persons with severe handicaps are currently taking place. Students who have learned to be helpless their whole lives are now learning to take active control over decisions about what they would like to have, what they would like to say, and what they would like to do in their environment. Prototypes of robotic aids have been developed that offer promise of facilitating their progression through cognitive milestones that blocked them before (Howell, Damarin, & Post, 1987; Nof, Karlan, & Widmer, 1988). Prototypes of ultrasonic bladder sensors are being refined to assist them over obstacles in becoming independent in toileting (Mineo & Cavalier, 1987). Environmental control systems exist that provide them the freedom to exert personal preferences that the rest of us have come to take for granted (Brown, Cavalier, & Tipton, 1986). Methods that reduce the cognitive load and require minimal effort to access information on computer screens have been developed, and for some, no greater effort than touching the computer screen or directing one's line of sight is required to interact with a computer (Brown, Cavalier, Mineo, & Friedman, 1987).

Techniques and procedures are being developed for infants who are handicapped to counteract their lack of success in controlling surroundings and to impart an early sense of control (Brinker & Lewis, 1982). Likewise, improved understanding of the dynamics of communicative interactions with school-aged members of this population is being acquired and exemplary augmentative communication strategies are being identified (Blackstone, 1989). While the research knowledge available to developers and practitioners with respect to computer-generated graphic representations and speech output is meager at this time, the evidence that exists suggests these areas of research hold exciting promise for powerful instructional and augmentative applications of technology with this population.

The remainder of this paper will present a broad array of these recent and exciting developments in the six areas just mentioned: choice making through environmental control, access to instruction, augmentative communication, information feedback, graphics, and speech synthesis. The paper will conclude with a discussion of the barriers that seem to limit the transfer of this research into practice and potential solutions to those barriers. ■

Preferences and Choice Making Through Environmental Control

The use of assistive technology as a tool for environmental control for the low incidence population of people with severe mental retardation, as well as severe physical disabilities, is a recent research area. Consequently, little has been published which addresses this research area. The research which has been reported reflects the exciting prospect of improving the quality of life through assistive technology for these unique individuals who have spent much of their lives in a passive state because they cannot care for themselves, communicate effectively, work productively, or interact socially. Of equal importance is the discovery that these individuals have tremendous human potential which technology can unlock. They can begin to demonstrate their choices, likes, and dislikes.

In reviewing the literature, some general tendencies are worth noting. Consistently, the researchers express concerns that individuals with severe handicaps learn to be passive rather than active agents in their world. This phenomenon has been labeled the "learned helplessness" syndrome (DeVellis, 1977; Floor & Rosen, 1975; Weisz, 1982). Because of the person's cognitive and physical limitations, exploration of his or her environment is severely limited; consequently, interest in his or her world fades and learning ceases. Oftentimes parents, teachers, and caregivers contribute to this problem because they limit their expectations of what a child with severe handicaps can achieve. A parent or caregiver of an infant with severe handicaps often assumes that interaction with the infant should be stifled or altered due to the child's handicaps, or stimulation is thwarted because the parent/caregiver is not taught creative ways to help the infant experience the world. Without the stimulations, interactions, and experiences that the normally developing child encounters, the child with severe handicaps soon learns to be passive and to be a none[illegible]r—to expect little from his or her world.

"Learned helplessness" refers to the phenomenon where a person's cognitive and physical limitations so severely limit exploration of his environment that interest in his world fades and learning ceases.

The research also shows that children who are severely physically handicapped often do not experience critical learning activities that allow them to feel their body moving through space, that is, vestibular motion. Examples of such activities are rocking, swinging, and spinning on a merry-go-round. Instead, their experience is limited to what can be learned from the various positions into which their body is shaped. Deprivation results because of the restricted interactions with people and objects around them. Because stimulating experiences are lacking, the children do not learn cause and effect, choice-making skills, or ways to exert control over their world.

Because stimulating experiences are lacking, children [with severe handicaps] may not learn cause and effect, choice-making skills, or ways to exert control over their world.

The desire, possibly through assistive technology, to allow children with severe handicaps to perform and participate in a broader range of activities by compensating for the lack of specific natural abilities, leads to several common topics found in the literature. These topics include:

- The limited ability of people with severe handicaps to convey and communicate their preferences, often resulting in inaccurate assumptions about their preferences and desires.
- A focus on leisure, social, daily living, and cognitive skills.
- The question of whether a person can learn that, by activating a switch or performing a particular action, he or she is responsible for the resultant change in the environment.
- The need for interdisciplinary training strategies in assistive technology that incorporate proven techniques used in or adapted from other teaching and training areas.
- The range of assistive technology from simple switch closures to voice recognition and eyegaze detection systems that might help people across many disabilities.
- Technology that can also function as an assessment instrument to accurately log and evaluate the choices of a user as he or she interacts with the computer.
- The preponderance of research literature with single subjects which may or may not generalize to larger populations.
- Optimism among the researchers that assistive technology may in fact hold real promise in the future for understanding the needs and desires of people with severe handicaps.

Research Activities

Brinker and Lewis (1982) conducted a study with 21 children, ages 3 months to 4 years, who had mild to severe delays and who demonstrated a lack of interest in their physical environment. The study looked at the ability of these handicapped infants to learn cause-and-effect relationships by using an adapted environmental control system. Using a system capable of recording eight selections per minute by various switches that triggered up to eight output contingencies, they recorded the different body movements and choices made by the children. The subjects could vary their body movements to get a particular contingency, thereby indicating their preferences. Brinker and Lewis found that the children learned to control the consequences in their environment and that they would systematically vary their behavior to explore the specific contingencies. For example, if they had two switches and the foot switch turned a light on, they would kick their foot more than they would wave their hand, an action resulting in a less exciting contingency. The researchers also witnessed at least one child progressing from primary circular reaction of generalized movement to secondary circular reaction of specific procedures for producing an interesting event. This study demonstrates how the use of technology with very young children can teach them to make choices and to indicate preferences.

One study demonstrated how the use of technology with very young children can teach them to make choices and to indicate preferences.

Behrmann and Lahm (1984) conducted a pilot study designed to evaluate the skills needed by infants with handicaps to determine potential benefits of technology intervention. They focused on the development of needed training strategies to teach environmental control beyond initial cause-and-effect understanding to multihandicapped toddlers. The research question posed was whether these children could learn the skill of how to select preferences for environmental control through the scanning process. Using single-subject research designs to evaluate the data, the study began to examine the need to develop a hierarchy of teaching strategies that would help these children achieve the skill of scanning.

The study was conducted with five multihandicapped children, 11 to 27 months old. Environmental objects were controlled through switches interfaced with a computer. The computer system incorporated speech synthesis, single switches, graphic representations of objects, and gradually increasing levels of difficulty for presenting the task of selecting to control an object through scanning. Throughout the study, the children demonstrated both an understanding of the cause-and-effect relationship between their actions and a preference for a toy in their environment. However, none of the subjects successfully learned the scanning process for selecting their preference.

The eight-step teaching sequence of the pilot study was revised, and Lahm (1987) used the new sequence for further research. The research question was similar to that in the pilot study. Again, five multihandicapped children were studied in single-subject research designs. They ranged from 9 months to 2 years mental age but none were over 5 years chronological age. Most of the children advanced beyond the skill levels of the children in the pilot study, but learning the scanning process was still too difficult for them. These findings suggest two areas of research to be explored: (a) the need for appropriate evaluation and proper selection of interfaces between the user and the technology for this age group and ability level and (b) the need for the development of effective teaching strategies for achieving those skills.

Two studies demonstrated the children's ability to understand a cause-and-effect relationship, but learning the scanning process for selecting their preference proved too difficult for them.

Carr, Brown, Cavalier, and Behrmann are currently conducting research with a woman who is severely mentally retarded and physically involved and who is learning to use a speech/sound operated computerized environmental control and communication system (Carr, 1989). The subject has lived in an institution most of her life and she is totally dependent upon others to meet her needs. With the computer system, she can select one of a variety of appliances to activate in her environment by voicing a particular word, phrase, or sound. Initial findings are that although the technology is performing the expected tasks well and the woman appears to understand the cause/effect relationship, she requires extreme prompting for her to exercise the choices on her own (and thus indicating she has learned the concept of control and she has preferences). She has made the connection that she can control her environment with certain speech sounds but she is hesitant to demonstrate her autonomy without some cue that it is permissable for her to do so.

In contrast, Brown and Cavalier (1986) worked with a woman who was severely physically handicapped and severely mentally retarded, and was a long-time resident of an institution. She did learn to voice activate an environmental control system using guttural speech. She quickly learned the relationship between cause and effect and control, she demonstrated distinct discriminations and preferences, and she showed pleasure with her newfound ability to make choices and to control her environment.

These two studies highlight areas which need to be addressed: What accounts for the differences between these two research subjects, and how can researchers predict when and how the technology will be beneficial? What questions must researchers begin to ask and what type of evaluations can be performed in order to achieve a correct match between the user and the technology? What strategies can be developed to help researchers and practitioners better predict what choices to make available to the user so that the systems designed are in fact beneficial and are regarded as useful tools by the user?

Sandler and McLain (1987) also looked at switches, contingent reinforcement, and training. Five multihandicapped children ages 6 and 7 years, nonambulatory and severely retarded, were assessed for their ability to manipulate a switch. The study tried to establish whether the use of an adaptive switch that was reinforced by the delivery of vestibular stimulation would be preferred by the children over food, praise, or visual and auditory stimulation. If a child activated a switch, the seat in which he or she was placed would begin to swing.

Research activities point to the need for proper study design so the students can indicate their preferences using assistive technology.

The researchers found that this vestibular action was chosen significantly more by the subjects than the food and many other reinforcers often assumed to be preferred. These findings again reinforce the need for researchers and practitioners not to make assumptions about what their students like, but to design exploratory situations using assistive technology in which the individual can indicate his or her preferences.

A study by Meehan, Mineo, and Lyon (1985) investigated switch activation training with a young child who was severely handicapped and blind. The researchers successfully taught the child to activate a switch through a series of prompting and fading techniques. The switch in turn activated a monkey which beat a drum and danced. The child first needed the total prompting of hearing someone say "press the switch," putting his hand on the switch, and pressing it down for him. He advanced to where the cues were gradually faded and he could complete the task independently by following the verbal prompt of "press the switch."

Another ongoing study by Brown, Cavalier, Mineo, and Friedman (1989) is a research-and-development project involving eyegaze and headpointing detection technology. The device under development is a communication and environmental control device whereby the user makes selections for environmental control or communication from an array of graphic symbols on the display of the device. The device reads the position of the user's eyes and head and determines which symbol on the array of selections the user is looking. Data are currently being collected on four subjects in public school programs who are nonambulatory, nonverbal, and mentally retarded. Much time and effort has been devoted to the proper seating and positioning of the subjects so that they can successfully access the technology and to teaching the subjects the proper head control strategies needed to use the system. The initial findings from this study are that once the technology is appropriately modified for this population, it is an appropriate application. The subjects are learning to use the eyegaze/headpointing device as a tool to control their environment and to communicate their preferences. They are demonstrating definite preferences and the control appears to be important to them. Practical results of this study are that, once again, effective training strategies are of critical importance and that the issues which affect the subjects on a daily basis, such as the need for proper seating and positioning of the children so they can properly use the technology, cannot be ignored.

In research on assistive technology, practical issues, such as the need for proper seating and positioning of the children using eyescan equipment, are of critical importance.

Recent research provides additional information about the ability of severely multihandicapped individuals to indicate their preferences by using the computer as an assessment instrument. Dattilo (1986, 1987), Dattilo and Rusch (1985), and Dattilo and Mirenda (1987) have been successful in assessing the preferences of individuals with severe handicaps by arranging an environment that presents various opportunities for choice and selection through switch activations interfaced with a computer. Findings indicate that using a computer as a reliable and accurate assessment tool for determining preferences is a practical and efficient application.

In addition, Wacker, Wiggins, Fowler, and Berg (1988) also show that the same population exhibits preferences with regard to the leisure time activity of operating devices in their environment. In this study, the subjects were given a variety of options of activities, including whether to interact with another person. Rather than being by themselves, they overwhelmingly chose to have the teacher come over and give them a backrub, comb their hair, or talk to them. This 3-year project advanced the abilities of these individuals from mastering cause-and-effect interactions to developing choice-making skills with regard to how and with whom to spend their time.

Summary

In the past, one of the biggest challenges for researchers was to identify reinforcers and appropriate stimulants for this population in order to avoid extinguishing a response during the study. There were always the questions of what to provide for the individual and what was appropriate. The new research on environmental control is beginning to show that these individuals do have preferences and that researchers can definitively say "This person prefers to do this," as indicated by the way they interact with the assistive technology. Practitioners no longer need to make assumptions about what in fact is desired by these people—the individuals can communicate their preferences with technology assistance. ■

Researchers no longer need to make assumptions about what in fact is a positive reinforcer—the individuals in the study can communicate their preferences to the researchers.

Access to Instruction

Access to instruction is a vital area of research for three reasons:

1. Technology has a definite role in education. If equal access to education is to be provided to low incidence disabilities, then equal access to the technology that delivers much of the instruction must be provided as well.
2. Access to technology can be transferred to other kinds of educational materials like toys, books, papers, calculators, and others.
3. Results from research addressing access to computers by people with disabilities benefits nondisabled individuals as well. If something makes the computer faster or easier for a child with disabilities, it makes it that much faster or easier for a nondisabled child.

Research in three areas of disability (physical, sensory, and cognitive) will be presented here. These concerns cut across disabilities, and affect nondisabled children as well.

Physical Aspects

The primary concern for individuals with physical disabilities is control. The unmodified keyboard is not sufficient for accessing a computer system. There are three major strategies for addressing this problem. One is to modify the person's own behavior by giving her a headstick, splints, mouthsticks, or some other means of altering her behavior to control the computer. Another strategy is to adapt the standard computer system itself: to put a touch screen on it, to have alternatives to using the mouse, to install key latches so that an individual can use the shift key with one-finger typing, or to put key guards on so that erratic movements will not result in mistyping. A third means for providing alternate physical access is to customize a computer system and then link that customized system to the standard computer. For example, an eyegaze control system uses a separate computer and monitor to display the input selection menu which then controls a second computer system that actually runs the applications program.

These methods of providing physical access to the technology are essential for this population. A nondisabled child does not go to the classroom without pencil and paper, but for some children with physical disabilities, pencil and paper are not functional writing tools. If the computer is an appropriate substitute, they should not be deprived of its use.

A nondisabled child does not go to the classroom without pencil and paper, but for some children with physical disabilities, pencil and paper are not functional writing tools. If the computer is an appropriate substitute, they should not be deprived of its use.

New types of access systems are constantly being developed. For some individuals, voice control is the only input option because other movement systems are paralyzed. For others, research is beginning to evaluate the speed and efficiency of eyegaze control or voice control compared to gross movement controls (e.g., hand or head movements) as a potentially more direct means of accessing a computer (Dabbagh & Damper, 1985; Serota, 1983; Thomason, Chopra, Frajian, & Abazid, 1988). Looking directly at the item on the screen may be a quicker and more intuitive way to access a computer system, even if the user has considerable physical control (DeMasco, 1986; Fincke, 1980).

Research suggests, however, that eyegaze access for populations that are disabled will be difficult because there is more variation in eye movements, due to tremors. Similarly, disabled speech is also more varied than normal speech patterns. Brown (personal communication, 1989) reported that their speech recognition systems identified the disabled speaker after training with 76% accuracy. Another study looked at the ability of untrained systems to recognize speech produced by speakers with cerebral palsy (Coleman, 1988). Using single syllable, consonant-vowel utterances, the computer was able to recognize at better than chance level which of 12 syllables the person was producing. This was far below what it could do with the nondisabled speakers, and it was not enough to use indiscriminately to control actions. Many of today's barriers may be overcome technologically, but the fact that many people with physical disabilities do not have good, consistent control over their speech system will be a problem for researchers to address in years to come.

The focus of much current research is the search for improved input strategies, in particular for greater speed and efficiency of existing access techniques. The human-factors engineering literature concerning nondisabled individuals provides insights and spots potential problems associated with alternate access (Card, English, & Burr, 1978; Chubon, 1988; Haller, Mutschler, & Voss, 1985; Karat, McDonald, & Anderson, 1985). For instance, one study compared head pointing on a computer screen with a headstick and light pointer (Radwin, Lin, & Hu, in preparation). As expected, the light pointing was faster and more efficient because the user did not have to shift focus from the keys to the monitor.

Caution must be taken in generalizing the findings from research on nondisabled individuals to people with disabilities, however. For example, another study compared a sip-and-puff switch with Morse Code to mouthstick control, two input strategies that use the same basic mechanism (Levine, Gauger, Bowers, & Khan, 1986). For nondisabled individuals the mouthstick was significantly faster than sip-and-puff Morse Code even after training in Morse Code. A disabled individual who uses Morse Code as his only system was then tested. He proved to be as fast on the slower system (Morse Code) as the nondisabled people were on the faster system (mouthstick). The findings show that due to the variations in control and the effect of experience on individuals with disabilities, one cannot assume that the fastest strategy for nondisabled individuals will necessarily be the most efficient for persons with disabilities as well.

In researching input strategies, one cannot assume that the fastest strategy for nondisabled individuals will necessarily be the most efficient for persons with disabilities as well.

Another study examined one person's long-term use of access mechanisms to control speech output and writing (Smith et al., 1989). The sip-and-puff Morse Code strategy was recommended as the fastest means for accessing the computer system, but a year later the individual was using an entirely different system which utilized a light pointer. The pointer system was not as fast, but other factors influenced the change. The user preferred the light pointer because it made him appear less disabled, while the sip-and-puff system interfered with other activities like walking and talking. Consequently, in addition to research-indicated preferences based on the evaluation of speed and accuracy, other variables can affect the choice of an access device.

A problem in the implementation of access devices within this population relates to translation of an access technique from one system to another system. There is a need to generalize switches and interfaces for a variety of access options. For example, many eyegaze systems are limited both by what type of computer they are compatible with and by what software they can operate. Research in this area is underway, but to date there has been little progress (Schauer, Rodgers, Vanderheiden, & Kelso, 1988; Vanderheiden, 1984). It is an area that deserves more emphasis because of its importance to disabled and nondisabled students who need to access all computers within an educational setting. For example, any modifications made on a computer to allow for its use by individuals with disabilities should not prohibit its use by nondisabled persons.

Sensory Aspects

Input strategies vary depending on the population served. For example, access issues for persons with visual impairments center not on control of the system, as it does for persons with physical handicaps, but on comprehension of the output and the ability to access the information on the screen.

For people with hearing impairments, access issues usually center around communication and language characteristics rather than control or use of the system. Some ongoing barriers include auditory-only signals (such as beeps) or auditory transition modes (such as the telephone). These software concerns, however, will not be addressed in this paper.

Access issues for the population with visual impairments include both hardware and software concerns related to information input and output. Some of the visual impairment research overlaps with individuals having visual processing problems, as manifest in some learning disabilities.

The primary concern for persons with visual impairments is not control of the system, but rather comprehension of the output and the ability to access the information being returned on the screen. Two types of access are commonly available: (a) the dynamic transfer of screen-printed information into printed Braille and (b) the dynamic transfer of screen-printed information into voice output. These output techniques are limited to the type of application program being used and the skills of the user. Only 25% of people with visual impairments and approximately 5% to 6% of people with deaf/blindness know Braille. Additionally, children who are learning disabled and have visual processing problems typically do not know Braille. If the input and output mechanisms providing access to a speaking or writing system demand that the user know Braille, only a small segment of the population will gain access.

Some input mechanisms also create barriers for nonvisual access. Many newer application programs available use mouse technologies for the method of input. Mouse-based programs are inherently visually based and consequently, prohibit access by individuals who are visually impaired. The development of substitute techniques for mouse control is a growing area of interest for researchers (Durre & Schmidt-Lademann, 1983; Vanderheiden, 1988).

Because of the limited use of Braille within the visually impaired population, new types of output are being developed, particularly in the area of improved speech synthesizers. People with visual impairments tend to evaluate the acceptability of speech synthesizers using different criteria than their nondisabled counterparts (Durre, 1987; Young, 1984). For the person with visual impairments, the first priority is speed, to allow the user to scan through the information as quickly as possible; intelligibility of the synthesizer is of secondary importance. Specific research on speech synthesis techniques is discussed later under Speech Technology.

Field-driven research studies examine features of talking word-processing systems for people who are visually impaired. Sighted users typically scan the material, determine major points, and develop a mental picture of how the material is structured before reading it. These techniques are not readily available to the person who is visually impaired and thus the fast scan feature of a talking word processor or screen reader is very important. Though verbal scanning is helpful, auditory information is transitory. Therefore, good screen techniques for reviewing information must also be available to avoid overtaxing the memory system of the user. Other studies are investigating the tactile or auditory duplication of visual information presented in the actual organization of the text, such as paragraphs, which provide a visual cue to sighted readers (Lechelt, 1988; Morrissette, 1984; Young, 1984).

In addition to the presentation and review of textual information, there is a need to access visual materials, such as pictures, graphs, and icons. This is relevant to the cognitively and chronologically young population, who are not yet reading, as well as young children with visual impairments. For those functioning at this cognitive level, computer information is typically presented pictorially along with text, although neither mode is appropriate for some individuals. Work has also been conducted on the tactile presentation of picture information, but an efficient method has not been developed to date (Lee & Vanderheiden, 1988).

Some related research on the different effects of presenting auditory versus visual information is being conducted in Germany (Durre, 1987; Durre & Durre, 1986; Durre & Schmidt-Lademann, 1983). These findings will impact the design of software across all disabilities, and determine how much auditory versus visual information should be presented. Auditory stimuli are transitory, thus affecting memory, cognitive load, and comprehension differently than do visual stimuli. Some preliminary findings suggest that children who rely solely upon visual input information, rather than a combination of visual and auditory, are slower and have poor overall comprehension of concepts. Another study looks at the implications of a dual vision/hearing disability on comprehension and the need to present and receive information tactilely (Mathy-Lakko et al., in preparation; Griffith, Robinson, & Pangos, 1983).

Cognitive Disabilities

Input mechanisms and software designs can interfere with the ability of the individual who is cognitively low functioning to access a computer system. Different access techniques have different effects on cognitive load. One general assumption in the field is that direct selection is faster and cognitively easier than scanning. There is some research that suggests that nondisabled children as old as 12 years of age still have trouble with scanning (Ratcliffe, 1987). They have less comprehension and more errors than when using the direct selection technique with the same task.

Minimum cognitive levels for using many of the different selection techniques have been suggested. The touch screen, positioned over the computer screen, has been found to be successful with children as young as 2 years of age when other techniques are not an option (Chapman, Dollaghan, Kenworthy, & Miller, 1983). The direct connection between the child's action and the reaction on the screen is key to the success of this technique. The mouse, on the other hand, is an unreliable access device for children under the age of three or four because it requires the child to click a button and drag the device at the same time (Olsen, 1988). There also appears to be a conceptual problem with knowing that the pattern made by the hand in a small horizontal space affects the pattern of cursor movement on the screen.

Different access techniques have different effects on cognitive load. ... Minimum cognitive levels for using many of the different selection techniques have been suggested.

Recent federal legislation ensures that all government employees will have access to government computers. However, some employees are cognitively disabled, putting new emphasis on cognitive requirements for accessing computers. The government is also trying to determine those levels of cognitive functioning that preclude computer use. A more legitimate concern for the government is to assess which tasks the computer is functional for, since some tasks, such as training for cause and effect, do not fall within the role of government employees. The challenge that remains for this low functioning population is to determine how access issues affect the task performed and how the task affects the access. ■

Augmentative Communication

Augmentative communication refers to all communication that enhances or supplements speech; it ranges from "standard" components such as facial expressions, head nods, telephones, and computers to "special" augmentative components such as manual signs, switches, and special communication software

Augmentative communication (AC) means all communication that enhances or supplements speech (Vanderheiden & Yoder, 1986). The initial goals of augmentative communication were to enhance the daily communication skills of individuals with severe speech impairments. Today, however, AC also is used to facilitate the development or return of natural speech and/or spoken language comprehension, to assess comprehension of language, to develop communication skills, and to provide access to basic human interaction. AC aids and techniques encompass both standard and special components offering multiple options for expression to individuals unable to speak and/or write. See Vanderheiden and Lloyd (1986), Musselwhite and St. Louis (1988), Fishman (1988), and Borden and Vanderheiden (1988) for detailed information.

Standard communication components are the nonspeech techniques used by most people (e.g., facial expressions, gestures, head nods, telephones, typewriters, and computers). Additionally, special augmentative components such as manual signs, communication boards, Etrans, electronic communication devices, switches, computers with special communication software, hardware, and firmware are used. Following are two examples:

1. A 12-year-old child who is severely physically handicapped, speech and writing impaired, with intact cognition, has a communication system comprised of some speech (i.e., speech approximations) and the following standard and special augmentative components: vocalizations, smiles, eye movements, and Etran board, miniboards for special activities, a dedicated communication device mounted on his wheelchair serving also as a keyboard emulator to a desk top computer in his classroom and at home (with a modem, as well).
2. A 4-year-old child who is severely retarded, ambulatory, with minimal expressive communication skills and demonstrates no understanding of language uses the following standard and special components: gestures, vocalizations, a few manual signs, objects that depict certain events (e.g., time to go to the bus). In addition, he is being taught to activate a looptape recorder to greet his classmates each morning. (The notion of linguistic "prerequisites" for AC intervention is disputed in recent language. See Kangas and Lloyd (1988) for a discussion.)

Research Activities

Current barriers to research in augmentative communication are:

1. Methodological (i.e., the population is small and diverse; there are a multitude of variables to measure; and single case study designs make generalization of results difficult);
2. Limited research base (i.e., studies are often not grounded in theory. Other relevant literature from related areas must be applied to AC with caution);
3. Limited number of researchers active in AC;
4. Limited funds for research;
5. Difficulty with information exchange. Many mechanisms exist to facilitate these activities (e.g., the journal *Augmentative and Alternative Communication*, professional and consumer organizations, conferences, etc.).

Despite barriers, AC research is an active area. Our research can be divided into three categories: demographic, technical and clinical.

Demographics

To date, limited demographic information is available on adults in the U.S. who use augmentative communication techniques. Three published studies reveal 2.4% to 6% of school-age (5 to 22) children enroiled in special education in the U.S. can benefit from AC intervention (Aiello, 1980; Matas, Mathy-Laikko, Beukelman, & Legresley, 1985; Burd, Hammes, & Fisher, 1988). Implementation of recent early childhood legislation (P.L. 99-452) will increase these numbers. Most (76%) of this population is mentally handicapped; many (66%) have severe multiple handicaps. Although initial attention in AC tended to focus on those with cerebral palsy and relatively intact cognition, the needs of other individuals with more severe handicaps are now being addressed more aggressively. Children who are unable to speak and/or unable to use a pencil to write are without the tools necessary to receive an appropriate education. These data define the need to provide AC techniques to children in educational settings in compliance with P.L. 94-142.

Of school-age children enrolled in special education in the U.S., 2.4% to 6% can benefit from augmentative communication intervention—percentages that are expected to rise with implementation of recent early childhood legislation (P.L. 99–452).

Within the technical domain there are two primary areas of investigation: speech output and rate enhancement.

Speech Output

Speech synthesis research pertinent to AC has focused on issues related to the intelligibility of synthesizers available in communication devices (Kraat & Levinson, 1984; Hoover, Reichle, VanTasell, & Cole, 1987) and the attitudes and preferences of normal listeners who might interact with individuals using specific synthesizers (Buzolich, 1983; Gorenflo, 1989). Until 1988, intelligibility studies yielded poor results. However, the newer technologies in some AC devices reveal vastly improved intelligibility data (Mirenda & Beukelman, 1987). Recent studies show increased acceptance by individuals who may or may not be familiar with synthesis or individuals with speech handicaps. (See Blackstone, 1988, for discussion.)

Current areas of research also address questions of consumer satisfaction: What do individuals who use speech output devices think? want? prefer? How does synthetic speech affect learning? Many AC users have difficulty processing information presented with synthesized speech. Although the normal brain can adjust to a synthesizer's "accent," individuals with learning disabilities, sensory impairments, and mental retardation may experience more difficulty. Conversely, preliminary findings (Romski, personal communication) suggest speech output may actually facilitate the ability of some children with severe/profound mental handicaps to attach spoken words to specific referents. Perhaps this is because the speech output generated by a communication aid is always repeated in the same manner. This provides a consistent stimulus condition, not probable with natural speech.

Prosodic Features: A major complaint of consumers, families, and clinicians is the uninflected male voice of low-cost synthesizers. Some devices now sing and actually produce a female voice. Most of this technical research and development occurs outside the AC area. However, the Rehabilitation Engineering Center (REC) in AC at the A.I. DuPont Institute (U.S.) and the Royal Institute of Technology in the Department of Speech Communication and Music Acoustics (Sweden) are involved in developments that promises ways to express emotion, sarcasm, and the like. (See Carlson, Granstrom, & Hunnicutt [in press] for discussion.) Natural language research is being applied to text-to-speech algorithms. Also, work on an automatic diphone generator is being done with goals to generate multiple natural-sounding, intelligible voices (DeMasco, 1989).

Multilingual speech output devices: In the U.S., speech outputs needs are being addressed with devices offering digitized speech technology. Studies comparing devices offering digitized speech output are not available. Multilingual text-to-speech output devices are now commercially available in British and American English, German, French, Italian, Spanish, Norwegian, Danish, and Swedish (Carlson, Granstrom, & Hunnicutt, in press) with continued development underway. Also, some U.S. companies are working in this area to develop widespread applications, not just for AC users.

Rate Enhancement

A major barrier to successful communication with current augmentative communication devices is the slow rate with which users transmit messages but new rate enhancement techniques are being sought and researched.

A major barrier to successful communication with current augmentative communication devices is the slow rate with which users transmit messages. Rate enhancement techniques are available in the software of many devices, such as linguistic prediction, abbreviation expansion, and other coding techniques. These techniques reduce the number of inputs (i.e., keystrokes/hits) needed to produce a given output/message.

Specifically, coding techniques, which include the Morse code, semantic compaction (Minspeak™), and various letter/number abbreviation expansion techniques require users to learn and remember codes. Devices are programmed (often by clinicians, teachers, and families) to interpret these codes. Linguistic prediction techniques predict intended messages as the user types/inputs each letter. Predictions are at the letter and word level and are based on a frequency-of-occurrence and/or frequency-of-use word list. Users make decisions to accept or reject each prediction. The current research focuses on three areas:

1. The application of natural language processes to linguistic prediction. Areas of investigation include adding syntactic and semantic information to improve prediction algorithms (DeMasco, 1989; Hunnicutt, 1989).
2. The cognitive demands of rate enhancement techniques, specifically the effect on learning time and automaticity of memory and decision-making requirements. Researchers are evaluating "cognitive load" in relation to ease of recall, efficiency of expansion algorithm, and user behaviors.

Questions also address the resources required to teach rate enhancement strategies (Light, Lindsay, & Parnes, 1988). Current results suggest more clinical attention should be paid to variables affecting both learning and recall. There is a need for communication devices to do more for the user and to decrease cognitive loads, that is, to become more user friendly.

3. The development of a lexicon/corpus that directly reflects an individual user's needs and abilities. See later discussion in vocabulary selection.

Two additional areas of technical research related to AC (and not described in this paper) are:

1. Ergonomic barriers to standard computer-based equipment. (Contact the Trace Research and Development Center for information, S-151 Waisman Center, University of Wisconsin-Madison, 1500 Highland Avenue, Madison, WI 53705.)
2. New accessing techniques, for example, eye gaze, speech recognition, gross gestural input, proportional input, and user center systems. (See discussions in the chapters on "Access to Instruction" and "Information Feedback.")

The presence of technology does not make an individual a successful augmentative communication user. Discussion of the four major areas of AC clinical research follows.

Communicative Competence

This broad area accounts for most current research. It grew out of naturalistic studies done by clinicians in the late 1970s and early 1980s (Harris, 1982; Calculator & Luchko, 1983; Beukelman, Yorkston, & Dowden, 1985.)

See Kraat (1985) for a comprehensive review of interaction research, that is, dyads comprised of a natural speaker and an AC user. To summarize, individuals who used AC were:

- Not using communication aids, as prescribed or expected.
- Relied on multiple modalities (with an emphasis on standard components).
- Rarely initiated communication.
- Had a limited number of communication partners.
- Expressed a limited range of communication acts.
- Rarely engaged in more than one conversational turn.
- Experienced a large number of conversational breakdowns.

Communication partners of individuals who used AC techniques:

- Primarily asked "yes/no" questions.
- Often interrupted.
- Did not provide time for individuals to respond.
- Took several conversational turns.
- Avoided interaction.
- Asked questions they already knew the answer to.

It was also noted that some individuals and dyads were far more effective than others, particularly those using conversational repair strategies effectively.

Current studies of communicative competence in AC are defining the linguistic (symbols, syntax), operational (knowledge/use of equipment), social (pragmatics), and strategic(how best to get the job done) competencies (Light, Col-

A broad research area in augmentative communication involves the communicative competence of both individuals who use augmentative communication and their communication partners.

lier, & Barnes, 1985 a,b,c; Light, 1989) of both individuals who use AC and their communication partners. The results (mostly descriptive studies in naturalistic and elicited contexts) have affected clinical practices, i.e., the need to train communication partners, deliver services in naturalistic settings, use a multimodality approach, and train individuals to accomplish specific types of communication acts and discourse functions.

A closely related research area looks at the impact of instructional strategies on the development of communication skills. Studies typically employ single-subject designs. Examples include prompt-free approaches (Mirenda & Santogrossi, 1985), facilitator training techniques (Calculator & Luchko, 1983; Culp & Carlisle, 1988; Light, 1989); facilitative play (Kaouri, 1988); and peer tutoring (Cassett-James, in preparation).

Because the ability to read and write is often the only access children who are unable to speak have to language, the acquisition of literacy skills is recognized as critical. Researchers are currently investigating (a) how reading and writing skills are acquired by individuals with cerebral palsy and (b) the effect of context (i.e., support systems of family and community) on their acquisition (Follensbee & Corley, personal communication, 1989; Koppenhover & Yoder, in press; Beukelman, 1988). A retrospective study (Koppenhover & Yoder, in press) of individuals who had already acquired literacy skills reveals the importance of active parents, normalized school experiences, and ongoing access to reading materials. A prospective study (Light, personal communication, 1989) reveals a difference between 2-to 6-year-old able-bodied and nonspeaking children with physical handicaps with regard to parental priorities (physical needs take precedence), access to literacy materials (less access), and perception of responsibility for teaching literacy skills (mother's perceived self as responsible). Finally, Kelford-Smith, Thurston, Light, Parnes, and O'Keefe (1989) examined the skills of adolescents and young adults who developed literacy "late"; they found out that these individuals had difficulty with syntax. They raised an important question about the impact graphic symbol systems have on learning and the use of literacy skills.

Selection Decisions

An increasingly active area of research relates to decisions on selecting such components as symbol sets, vocabulary, and methods of access.

An increasingly active area of research relates to decision-making models. For example, what symbol set/system should be taught? What vocabulary should be included on a communication display? What methods of access should be used?

Early research demonstrated that low functioning individuals could learn augmentative symbols. Investigations that followed related to symbol transparency and translucency; that is, the ease with which "normal" partners could attach meaning to a particular set (Amerind) or system (Blissymbols) of symbols (e.g., Luftig & Bersani, 1985). More recently researchers have considered how AC users might acquire symbols. For example, Locke and Mirenda (1988) suggest a hierarchy for symbol acquisition; i.e., objects to traditional orthography. They conclude, however, that diverse abilities in recognizing symbols necessitate symbol selection decisions being approached on an individual basis. Mineo (personal communication, 1989) and Romski (personal communication, 1989) are currently investigating the impact of various features of symbols (shape, size, figure/ground) as they relate to people who use them.

Symbol research can assist teachers and clinicians to select symbol sets/systems for individuals in a more systematic way. Presently, these decisions are often based on the familiarity and availability of symbol sets (largely reflecting pragmatic and marketing issues) rather than concerns related to teaching the comprehension and use of symbols in interactive situations to clinical populations.

Research has found that the vocabulary of AC users is unique, idiosyncratic, and dynamic (Beukelman, Yorkston, Poblete, & Naranjo, 1984). Nonspellers rarely have access to more than 500 symbols. In fact, large vocabularies make selection arrangements, storage, and retrieval more complicated and time-consuming. See Blackstone (1988) for discussion. Recent attention has focused in two areas:

- Identifying functional vocabularies for various clinical populations. A major focus of current research is the use of vocabulary source lists (Yorkston, Dowden, Honsinger, Marriner, & Smith, 1989). Fried-Oken (personal communication, 1989) is currently developing a database of single-word expressive vocabulary for children who are 3-to 6-years-old. Other researchers are working with other populations to investigate the type of language generated by AC users and their age-matched peers (i.e., Beukelman et al. in Lincoln, Nebraska; Yorkston et al. in Seattle, Washington).
- Identifying clinical procedures to optimize vocabulary selection. Morrow (1988) compared three vocabulary selection techniques and found informants preferred using source lists. However, Blackstone (1988) reported clinicians rarely rely on source lists. The only approach that everyone reported using was caregiver interviews.

A projected outcome of this research area is a computerized "Tool Box" to assist clinicians to select vocabulary. Software for the Macintosh computer is being developed at the University of Nebraska to provide a contextually-based vocabulary database, vocabulary frequency analyzer, and a guided interview (Beukelman, personal communication, 1989).

Research in accessing techniques is covered in the "Access to Instruction" chapter. However, it is important to note that several decision-making models are being proposed to aid clinicians to make decisions about which accessing techniques and communication devices are best. To date, these models are not widely implemented and lack a systematic evaluation of their effectiveness.

Determining the Impact of Augmentative Device Users on Partners and Society

Research questions have addressed attitudes toward different output modes as well as attitudes toward individuals themselves. Blackstone (1989) summarized this area as follows:

1. After a brief exposure, adults who are not familiar with AC express significantly more positive attitudes toward persons who use high technology than those who use nonelectronic or unaided approaches (Gorenflo, 1989).
2. Unfamiliar listeners express negative attitudes toward most synthesizers in communication aids. Crabtree (1989) recently found that while younger and older subjects continue to prefer a "natural voice that is age and gender appropriate," subjects rated as "acceptable" the Smooth Talker 3.0 in Prentke Romich Company's *Touch Talker* and Adaptive Communications Systems' *Real Voice*.
3. Many familiar partners prefer communication boards to high tech aids because they can be more actively involved in the communication process (Mathy-Laikko & Coxon; 1984; Buzolich, 1983).

Further research is needed to assess the value of augmentative communication intervention to the individuals who use it and their caregivers.

To date, few systematic attempts have been made to determine what individuals who use AC techniques and caregivers think about AC intervention (Smith-Lewis & Ford, 1987).

Measurement and Quality Assurance

The AC area is developing rich documentation of clinical processes through descriptive case studies. (See Beukelman, Yorkston, & Dowden (1985) and the March 1989 issue of the Journal AAC for examples.) However, few outcome measures and/or consumer satisfaction measures of clients and AC programs are published. One exception, by Culp, Ambrosi, Berniger, and Mitchell (1986), raised important concerns about follow-up issues. A discussion of current concerns and practices (Blackstone, 1989) as well as several examples of how to measure effectiveness are available (Beukelman, 1986; Calculator, 1988; Culp; 1987; Romski & Sevcik, 1988). ■

Information Feedback

Development of effective instructional programs or assistive devices for individuals with severe disabilities first requires a good understanding of the characteristics that affect learning. This low incidence population is an extraordinarily heterogeneous group with vast differences among individuals.

Learner Characteristics

The characteristic mentioned most frequently in the literature is language deficits. Auditory processing delays manifest themselves in poor language comprehension and production, and in poor performance on tasks requiring verbal memory and verbal problem solving (Varnhagen, Das & Varnhagen, 1987). This clearly affected the kind of feedback and instructions that should be provided to an individual with severe handicaps. Many of the currently used speech synthesis technologies are perceived by many individuals with severe disabilities simply as noise. The technologies are not effective either as a reinforcer stimulus or an antecedent stimulus to set the occasion for a response.

Individuals with severe disabilities are an extraordinarily heterogeneous group with vast differences among individuals; the common characteristic mentioned most frequently in the literature is language deficits.

Another characteristic commonly found is an attentional deficit resulting in individuals responding to a relatively small number of components or features of a stimulus complex (Zeaman & House, 1979). Given discrimination problems that can be solved on the basis of more than one stimulus dimension or cue, persons with severe handicaps tend to use fewer cues or dimensions in responding than do other persons (Anderson & Rincover, 1982; Lovaas, Koegel, & Schreibman, 1979; Wilhelm & Lovaas, 1976). They focus in or attend to one aspect of the stimulus complex, and that feature then guides the response. Oftentimes the feature selected is not the one that will produce consistent correct responding. For example, to identify functional sight words, a child must attend to the shape of the letters and to their location in the word unit rather than their color or size. The important features are shapes and sequence of the letters, but all of the other aspects of the letters (e.g., size and color), page (e.g., size, color, shape, and graphics), and surroundings (e.g., people and furniture) are stimulus dimensions that the individual could focus on and use as a means for guiding responses. Occasionally, responses to the irrelevant features may be correct and subsequently reinforced, thereby further strengthening the incorrect stimulus-response association. This attentional deficit has been referred to as stimulus overselectivity (Lovaas, Schreibman, Koegel, & Rehm, 1971). Stimulus overselectivity has frequently been implicated as the reason for the difficulty many persons with severe handicaps have in learning new discriminations.

Researchers and practitioners have found that many persons with severe handicaps exhibit position biases during trial-and-error discrimination training (Glenn, Whaley, Ward, & Buck, 1980; Meador, 1984; Smeets & Lancioni, 1981). For example, the student responds to the item placed on the left in a two-choice task regardless of the item's critical features. Unless the instructional procedures are modified to counter this position bias, or stimulus overselectivity, the student will respond correctly and perhaps be reinforced approximately 50% of the time. This reinforcement schedule may be sufficient to maintain responding based solely on position. Many commercially available computer-assisted learning programs use variations of trial-and-error formats that are highly susceptible to instructional failure due to stimulus overselectivity based on position.

Prompting Strategies

A major concern for instructional designers is how to focus the attention of a student with severe disabilities on the critical features of communication, rather than the irrelevant ones.

A major concern facing instructional designers is how to focus the student's attention to the critical features, rather than the irrelevant ones, and establish appropriate stimulus-response relationships. The typical method for teaching a new discrimination is to present stimuli either simultaneously or successively, and then to reinforce responding to the target stimulus and to withhold reinforcement following responses to the others. One very consistent finding is that persons with severe handicaps frequently fail to learn discrimination in this manner (Lambert, 1980).

Researchers and practitioners have found that prompting strategies (i.e., additional cues to facilitate correct responding) are an important and necessary component of an effective instructional program (Schreibman, 1975; Touchette, 1968). Prompts that have been used include verbal instructions and hints; models of the response; cues such as color coding, positioning, and highlighting; and physical guidance. Generally, the prompt is provided simultaneous with the stimulus, and then following successive correct responses the prompt is gradually eliminated or faded away. Unfortunately, these prompting procedures are often unsuccessful because many persons with severe handicaps become "hooked" or dependent on the prompt and respond correctly only when the prompt is present (Schreibman, 1975; Wilhelm & Lovaas, 1976). Researchers have also found that features sometimes included to enhance attention (e.g., music) but with little or no relevance to content frequently inhibit learning rather than facilitate it (Gadberry, Borroni, & Brown, 1981).

A variety of prompting strategies, however, have been proven to be successful. One approach, called within-stimulus or criterion-related prompting, involves drawing attention to or exaggerating the critical features of stimuli during the initial phases of instruction, and then subsequently fading them in a systematic manner (Schreibaum, 1975; Wolfe & Cuvo, 1978). For example, one could use this approach for teaching letter discrimination by accentuating the curvature or angularity of particular letters.

A second approach is based on the "tunnel vision" hypothesis of overselectivity, which emphasizes the importance of the relative location of cues in a discrimination task; that is, that many people with severe handicaps fail to adequately scan the entire stimulus complex before responding. Rincover and Ducharme (1987) found that discrimination learning improved as the distance between the stimulus components decreased. This suggests that bringing the stimulus elements closer together and placing prompts very close to the training stimulus during the early stages of instruction, and gradually increasing distance following successive correct responses could facilitate learning.

A third approach involves animation or dynamic presentation of the stimuli (Gerstein, White, Falco, & Carnine, 1982). This approach involves movement of the stimulus display to present sequences of positive and negative examples of the concept to be learned. For example, when teaching the concepts of in and out, an object could be manipulated on screen so that it moves inside or outside of a box.

Response Consequences

Limited response repertoires, limited opportunities to interact with the environment, and sensory and cognitive impairments have a large impact on the response characteristics of each individual.

A combination of limited response repertoires, limited opportunities to interact with the environment, and sensory and cognitive impairments have a large impact on what events or stimuli serve as reinforcers for a particular individual. Many of the things and events that are often assumed to be reinforcers by programmers and instructional designers might be totally ineffective for a person with severe handicaps (Fehr, Wacker, Tresize, Lennon, & Meyerson, 1979). For example, food is often assumed to be an effective reinforcer, but for many persons with severe handicaps food has the opposite effect—it is something to be avoided. For some individuals, food elicits choking responses and is associated with unpleasant mealtime experiences. Similarly, smiles and verbal praise are not necessarily effective reinforcers. Sandler and McLain (1987) found that swinging was a more effective reinforcer than either food or praise for four out of five of their participants.

Satiation and reinforcer fluctuation are two additional complications when selecting reinforcers. An event that is an effective reinforcer at one point in time might lose its effectiveness shortly after, even though it was presented on only a few occasions. This variability could be related to changes in metabolism, seizures, fatigue, etc. Consequently, an event cannot be assumed to be an effective reinforcer at all times. It must also be remembered that an event that serves as a reinforcer for one response might not be effective for a different response.

Identifying stimulus events that serve as reinforcers for persons with severe handicaps is a critical component for any instructional program (Bourland, Jablonski, Allen, & White, 1984). In order to accomplish this task, systematic procedures for evaluating potential reinforcers must be employed. Three strategies have proven to be effective for this purpose. The first of these strategies, verbal choice, involves giving the learner the opportunity to choose from a menu of items or to specify a desired event. Reinforcer sampling, the second option, involves giving the individual the opportunity to experience each of the available items and then recording the number of times each item is selected.

The final strategy is a sequential technique for analyzing reinforcer preferences (Wacker, Berg, Wiggins, Muldoon, & Cavanaugh, 1985). This process involves identifying a response within the individual's repertoire and then pairing two or more potential reinforcers with the response in a counterbalanced order. The stimulus that produces the highest rate of response is then selected as the reinforcer of choice. In Wacker, Berg, Wiggins, Muldoon, & Cavanaugh (1985), a variety of battery-operated toys and devices were sequentially activated by head or arm movements via a microswitch. They evaluated both the frequency and duration of switch activations to determine the participants' reinforcer preferences.

Reinforcers must be presented immediately to be effective. Due to hardware and software limitations there might be a slight delay in delivery of the reinforcer. In such cases, it is important that some additional event, such as an auditory signal, be presented following the response to help bridge the gap. A response might be followed by two types of consequences, or a reinforcement complex, that could consist of an immediate event followed by the principle reinforcer. For example, in the design of a communication aid, a button activation could be followed immediately by an audible signal or a highlighted symbol on the screen, which would then be followed by the production of the desired utterance. This signal or highlight would bridge the gap between button activation and the milliseconds it takes for the processor and storage device to locate and produce the speech that is associated with the response.

In addition to serving as a reinforcer, the consequent events can also serve as a discriminative stimulus for the next response. This is particularly true when the stimuli and responses are part of a behavioral chain. For example, in a spelling task the appearance of a letter following a button press could serve as a

Software and hardware developers must be concerned with feedback—its timing and content—for both correct and incorrect responses.

reinforcer for the correct key press and also as a discriminative stimulus for selecting the next letter in the word. In order to serve this dual role, however, the consequent event must be presented in such a way as to orient the individual's attention to the critical features of the stimulus. Some instructional programs produce loud noises or flashing graphics that can startle or cause other reflexes in persons with severe handicaps which inhibit attending to the task.

Finally, software and hardware developers must be concerned not only with the feedback following correct responses but also the feedback following incorrect responses. The events that follow incorrect responses, such as exploding ships or noises, may serve as reinforcers for the incorrect responses, increasing the occurrence of errors, and therefore inhibiting learning (Adams, Matlock, & Tallon, 1981; Liberty, Haring, & Martin, 1981). Generally, feedback following errors should encourage continued attention to the task (e.g., "try again"), or prompt correct responding (e.g., accentuate a critical feature of the correct choice). Researchers have generally found that the best time to provide prompts for correct responses is before the response is to occur rather than after an error has occurred (Day, 1987; Zane, Walls, & Thvedt, 1981).

Recommendations

Based on current research in the area of information feedback for low functioning individuals, four recommendations can be made to product developers. There is a need for an adaptive output interface much like an adaptive firmware card that would give teachers and others the capability to select and create individualized outputs to activate a wide variety of reinforcers. This device would need both software and hardware components so that in addition to producing an effect within the applications software, other devices could also be plugged into it and activated by the software. For example, the "adaptive output firmware" would enable the teacher to plug in a student's favorite battery operated toy and control the reinforcement schedule for activation of the toy.

The second recommendation is the need for "smart" software for reinforcement selection, monitoring, and revision. This software should also enable educators to determine effective reinforcers and to collect and analyze information concerning reinforcer effectiveness throughout training. This software should provide information and recommendations to the educator concerning the need to modify the reinforcement procedures, including the type of reinforcer used and the reinforcement schedule. Perhaps this is a role for expert systems technology.

Another potential role for expert systems or artificial intelligence technology involves recording and analyzing student errors. Error analysis frequently provides as much information and sometimes more information about the ongoing learning pattern than does analysis of correct responses. Systematic error analysis can lead to the identification of competing response patterns (e.g., position preference) and information about the generalization of the response (Albin & Horner, 1988; Horner, Albin, & Ralph, 1986). This information can then be used to modify the instructional program to facilitate learning and generalization.

The fourth recommendation is the need to provide greater control over computer-generated prompting techniques. Most software programs do not allow the instructor to alter the kinds of prompts that are provided. Methods for selecting and evaluating different prompting strategies are needed. Such procedures might include systems that gather and analyze information about the student's learning styles, particularly the effectiveness of various prompting alternatives. In order for the power of computer technology to be made available to persons with severe handicaps, input and output alternatives and customizable software must be provided. ■

Graphics

Individuals with cognitive impairments have difficulty accessing assistive technology. This is due in part to the complexity of many of the available interface techniques. Another factor contributing to this difficulty is the incomprehensibility of the medium used for representing meaning, which in most cases is text-based. The prevailing assumption has been that a "picture-based" representational system would improve access to educational software and communication systems. Recent research, however, indicates that graphics systems are not the panacea that they were assumed to be, and that all graphics systems are not uniformly decipherable.

Despite the many problems individuals with severe impairments face in accessing assistive technology, graphics—a "picture-based" representational system—has many potential uses for this population.

The types of graphic representation under discussion are not limited to the use of pictures to convey meaning (as on a language board), but also include the use of other types of graphics found on computer screens. The graphics typically used in computer-assisted instruction (CAI) tend to be inappropriate for people with severe and profound cognitive impairments for a number of reasons. Among these is the fact that members of this population often lack the abstraction capabilities necessary to understand the kinds of graphics produced on computers typically found in the schools. Such images tend to be less than realistic renditions of the items they are intended to represent. Unless the individual has the abstraction capabilities to make the leap from real life objects to rudimentary representations, graphics on today's systems are not going to function as intended.

A second, and somewhat related, reason for difficulties with computer graphics is that many individuals with cognitive limitations have difficulty with visual closure, and thus cannot create a unified image from a fragmented one. Finally, beyond abstraction and visual closure requirements, a certain level of language ability is useful because it tends to help the individual make the cognitive leap from a very crude graphic to what it is supposed to represent. The fact that this population has linguistic impairments secondary to the cognitive impairments often precludes this type of language-based mediation.

Graphics in Special Education Technology

There are a number of potential uses of graphics in special education technology. In addition to their use in traditional CAI applications for the provision of instruction, they may be used to provide stimulation. Researchers are unsure about what an individual with profound retardation actually sees when looking at graphics on a computer screen. The prevailing assumption is that they see the picture that the developer intended them to see, but it is possible that all they discern are scattered splashes of color. If the program is animated, the movement may be apparent, but it is difficult to be certain about exactly what these individuals perceive and comprehend.

At the very least, it could be that a moving display of color is very reinforcing and that the stimulation it affords might be something that could be programmed to be an effective motivator or reward. As examined in the previous section, it is often difficult to determine what events serve as reinforcers for this population. The traditional graphic reward—such as a jumping frog—may not be perceived by these individuals the same way that it would be perceived by a nonhandicapped student. It may be true, however, that although nothing about the frog is appealing in the assumed sense, its greenness and its motion across the screen might be positive factors. It becomes crucial to understand what these individuals see when looking at images presented on a computer screen.

A fourth application for graphics with this population is in communication systems. Although it is agreed that the use of augmentative communication systems is appropriate for individuals with severe and profound cognitive limitations, their access to these devices is severely limited by what can be represented on the systems. At this level of functioning, graphics are relied upon because most of the individuals are nonreaders. Unfortunately, the choice of graphics to be used on these systems is often made haphazardly.

A final area of application for graphics is cuing. In traditional CAI applications, the use of conventions such as flashing cursors or little hands that move across the screen is common. With this population, one cannot assume that these cuing techniques are effective or that they are perceived in the way that was intended.

Although there is little research available on the use of graphics with this population, what does exist addresses three issues. The first concerns the many different types of graphics used for representation. The second examines the linguistic or cognitive requirements for using these types of graphics, and the final area concerns the limitations of the technology currently found in most schools.

Types of Graphics

Research in the area of graphics for special education applications began to appear in the literature only recently. College students served as subjects in the early studies designed to identify the relative transparency of symbols used in a variety of communication systems. These students were asked to look at different types of symbols and guess what each might represent. The symbol was designated as transparent, if, just from looking at it, the students could guess what it represented.

Recent research on graphics for special education applications indicates that rather than defining a hierarchy of types of graphic representations by the ease with which each can be understood, the relative importance of individual features, such as color or realism of the object, should be explored.

Subsequent versions of these early studies were undertaken with nonhandicapped preschoolers and just recently with some more severely involved populations. The ultimate goal of this work has been to define a hierarchy of types of graphic representations by ease with which each can be understood. In another approach, subjects were presented with representations at a variety of levels of abstraction, ranging from real objects through color photographs, black-and-white line drawings, and commercially available symbol systems. The relative ease with which the subjects moved from real objects to one of these levels of abstraction was measured. A methodological problem with these studies is that the examiners failed to control for the variability across all dimensions of the test stimuli. For instance, a color photograph representing "pretzel" and a black-and-white line drawing representing "pretzel" may vary along the dimensions of color, quality (photographic versus nonphotographic), and size. In the face of such variability, it becomes impossible to determine which feature or features most significantly affect an individual's performance.

As previously mentioned, stimulus overselectivity has been found to be a problem with severely handicapped learners. Thus, the consideration of features becomes crucial. On the other hand, students functioning in the mild to moderate range of retardation, and many functioning in the upper range of severe retardation, readily move from real objects down through the hierarchy to abstract symbols.

A basic assumption in the field is that the "easy-to-difficult" hierarchy should proceed from things that look most like the real objects, such as full-size, full-color photographs, down through black-and-white photographs, line drawings, and miniaturized with representatives, to some of the more basic commercially available symbol systems. Recent findings suggest, however, that attempting to define a hierarchy may not be the most productive and practical direction for research (Mineo, in preparation). Trying to identify the level of the hierarchy at which individuals are functioning is not as straightforward as one might expect because of the range of individual characteristics and preferences mentioned previously. For some individuals color appears to be the crucial feature, and it does not matter whether a full-size representation or a very small representation is employed. If color remains constant, the individual is able to make that transformation. For another student, the crucial variable may be preserving the realism of the object through the use of a photographic representation rather than one that is nonphotographic. It is suggested that research on types of graphics should focus on an examination of the relative importance of features rather than on defining an immutable hierarchy of difficulty for the various types of representations available.

Cognitive and Linguistic Loading

Most of the studies examining "special education applications" have involved tasks that did not require high levels of cognitive or linguistic ability. Developmental studies of nonhandicapped children from infancy through age eight reveal that the ease with which youngsters deal with representations is dependent on the task they are required to perform. If the task is matching, children can perform successfully as early as a few months of age with certain types of stimuli (DeLoache, Strauss, & Maynard, 1979). The understanding that pictures can convey information which can then be used to solve a problem is acquired at about 2 to 3 years of age (Steinburg, 1974). Studies that have looked at the ability of students to use pictured information in an expressive sense or to understand pictured information of a complex nature indicate that children generally are not successful until they are 6 to 8 years of age (Kose, Beilin, & O'Connor, 1983; Murphy & Wood, 1981).

These findings have implications that extend far beyond the population of individuals with severe and profound cognitive limitations. Many educational textbooks, workbooks, and most CAI programs are graphics-based. Many assessment materials are heavily dependent on the comprehension of graphic stimuli. For example, the *Peabody Picture Vocabulary Test* (Dunn & Dunn, 1981), which is comprised entirely of black-and-white line drawing stimuli, is frequently used to determine the mental age of individuals with severe to profound retardation. Without a better understanding of the interplay between cognitive level, individual differences, and representational levels, definitive conclusions based on such materials are lacking in validity.

Research in the use of graphics by low-functioning individuals has yet to be conducted using assistive technology. No studies can be found that examine the use of graphics with the population within a CAI program or in a communicative context using an augmentative communication system. We are beginning to understand the complexities inherent in the use of graphic representations but

More research is needed on the interplay between the cognitive level of the user, individual differences of users, and the representational levels of the graphics.

are far from having definitive answers. At this point, it is important that developers and researchers are sensitive to the obstacles they face when providing graphics-based information and assistive technology to these students.

Technology as a Limitation

New technologies, including the addition of movement to static representations, are either available now or on the horizon; such improvements will greatly expand the use of graphics in special education technology.

The greatest limitation to the use of graphics with this population is the technology itself. Very expensive, high capacity equipment is needed to produce the kinds of graphics appropriate for individuals with severe and profound cognitive impairments. Production of photographic-quality images requires a high amount of memory and rapid processing time. Systems capable of meeting the requirements of these applications are not typically available in the schools.

There are some new technologies available and on the horizon that will permit an expanded use of graphics. Videodisc and CD-ROM technologies are two examples, although the ability to move images within and across screens needs to be developed further. Manipulation of images also requires extensive memory and processing time. Additionally, the use of animation must be more extensively developed, and its clinical application be examined more closely. It is very likely that adding movement to static representations, particularly those depicting actions, will enhance their comprehensibility by individuals with limited cognitive abilities.

Speech Technology

Speech is an important component in software and hardware designed to meet the needs of persons with severe handicaps. Concerns over the quality of speech output employed in various programs and devices center around issues of intelligibility and naturalness. How the speech signal is generated affects both of these areas.

Generation of Speech By Machine

Machine generation of speech can be divided into two broad categories, synthesis and digitization.

Machine generation of speech can be divided into two broad categories, synthesis and digitization. These two basic methods take very different approaches. Synthesized speech is generally used to refer to speech generated entirely by rule while digitized speech is human speech digitally recorded. Before being incorporated into computer software or hardware this digitized sample is usually compressed in some way. These two differing methods are also referred to as synthesis by rule for speech synthesis and synthesis by analysis for digitized speech (Simpson, McCauley, Roland, Ruth, & Williges, 1985). A wide variety of actual techniques for speech generation fall under the two broad categories. Many approaches to speech output used in special education technology are in fact hybrids of the two approaches. We will consider those approaches most commonly used in programs and devices for the low incidence population.

In terms of naturalness and intelligibility, the highest quality speech output can be achieved by human speech digitally recorded at a sampling rate of at least 10,000 to 25,000 samples per second.

Insofar as naturalness and intelligibility are concerned, an acceptable speech output can be achieved through digitization at a sampling rate of at least 10,000 to 25,000 samples per second. Each sample can then be stored in a byte of computer memory, but this means that only very short segments can be stored in a microcomputer with 128K of memory (LaRiviere & Sherblom, 1986). Using digitized speech in augmentative devices poses a further problem. With a totally prerecorded sample of highly intelligible phrases and sentences, spontaneous communication is impossible as use is restricted to the samples stored. Even if memory weren't a problem with digitized samples, and you got around the spontaneity issue by recording individual words, you would not end up with natural sounding intelligible speech. Klatt (1987) outlines the reasons for this:

> It might seem more practical to store natural waveforms corresponding to each word of English, and to simply concatenate them to produce sentences, particularly considering the low cost and large capacity of new laser disk technology. However, such an approach is doomed to failure because a spoken sentence is very different from a sequence of words uttered in isolation. In a sentence, words are as short as half their duration when spoken in isolation-making concatenated speech seem painfully slow. The sentence stress pattern, rhythm, and intonation, which depend on syntactic and semantic factors, are disruptively unnatural when words are simply strung together in a concatenation scheme. Finally, words blend together at an articulatory level in ways that are important to their perceived naturalness and in-

telligibility. The only satisfactory way to simulate these effects is to go through an intermediate syntactic, phonological, and phonetic transformation. (p. 738)

Pure waveform coding is seldom used for machine speech output. The use of compressed waveform code is popular, however. There are varying approaches to accomplish signal compression (Bristow, 1984). In our field, the most commonly used signal compression technique is Linear Predictive Coding (LPC). Here the human voice is digitized, and then a LPC algorithm is used to compress the data. If whole phrases and sentences are LPC encoded, then intelligibility and naturalness are good. Encoding words in isolation and then concatenating them results in the problems cited by Klatt. A combination of the two approaches can lead to acceptable speech output.

Some instructional programs use a combined approach in producing speech which combines a speech synthesizer with digitization of frequently used phrases, such as "Show me the."

All of Laureate's instructional programs use a combined approach in producing speech which runs on Street Electronics' Echo speech synthesizer with a Texas Instruments 5220 chip. In a combined approach, a script is generated for a specific application. Frequently used phrases are digitized in their entirety. Alternately, they can be recorded in shorter segments with the speaker inflecting his or her voice appropriate to the context. This results in smoother transitions when the phrases are concatenated. In an instructional program, phrases such as "Here is the" and "Show me the" can be concatenated with numerous individually recorded nouns to achieve memory savings while still maintaining intelligibility and naturalness. This level of LPC encoding for speech output does not rely on synthesis by rule approaches. When segments smaller than a word are encoded, rule synthesis approaches must be used to produce sentences.

Speech synthesis by rule can be accomplished in a number of ways. Klatt (1987) summarizes these approaches in an excellent overview article. Synthesis by rule methods differ in the set of rules used to generate the speech. Differing rules are based on differing theoretical models of which cues are important for phonetic contrasts. Klatt's own work was primarily in formant-based rule programs. Formants are areas of energy concentration at certain frequencies in the speech signal. Perception of different sounds is based on their formant characteristics. Formant-based rule programs rely on an acoustic theory of speech production that views speech as the product of linear filter excitation by one or more sound sources. The DECtalk synthesizer from Digital Electronics Corporation uses formant-based rules.

Another approach to speech synthesis is concatenation of previously digitized and usually LPC compressed segments. Currently the segment level typically used is the diphone which is the acoustic block from the middle of one phoneme to the middle of the next phoneme. This is the approach used in both the phoneme and text-to-speech modes of the Echo.

Regardless of whether the smallest units used to ultimately generate sentences are created using synthesis by rule approaches or LPC segments, various linguistic level rules must be relied upon to generate sentences. These include phonemic, semantic, and syntactic levels (Klatt, 1987).

Synthesis by rule programs provide the basis for text-to-speech programs. These programs provide for the conversion of text into speech output. A number of popular devices are commercially available for text-to-speech output. DECtalk and the Votrax Type'n'Talk both use straight rule by synthesis approaches while Street Electronics' Echo text-to-speech uses LPC diphones.

Perceptions of Computer-Generated Speech

Unfortunately, there is a dearth of research on the response of persons with severe handicaps to various forms of computer-generated speech output. Even with persons with mild handicaps and normal listeners, researchers have tended to confine their studies to text-to-speech output.

The most extensive evaluation of various text-to-speech systems' intelligibility has been carried out by Pisoni and his associates at the University of Indiana (Green, Logan & Pisoni, 1986). Their most recent article is the culmination of 10 years of research in synthetic speech intelligibility (Logan, Greene & Pisoni, 1989). Using the modified rhyme test (MRT) which consists of isolated monosyllabic words, they investigated the text-to-speech output of 10 different systems. The best intelligibility performance was for DECtalk speaker Paul with an overall error rate of 3.25%. Three low-cost systems had the worst performance scores. The overall error rates for Smoothtalker (27.22%), Votrax Type'n'Talk (27.44%), and Echo (35.56%) far exceeded those for DECtalk.

Chial (1985) used the speech in noise (SPIN) test to measure intelligibility of the Echo-II (TI 5220 chip), Votrax Type'n'Talk (SC-01 chip), and the Votrax Personal Speech System (SC-01A chip) as compared to natural speech. Subjects were required to identify the final word in the presence of background competing voice babble. As Pisoni and his associates found, performance of these low-cost systems was poor. Subjects only identified 18% of the Echo words, 40% of the Type'n'Talk words, and 65% of the Personal Speech System words with the improved chip. These results contrast sharply with a 91% correct score for natural speech under the same noise condition. Chial's results suggest that synthesized speech is very difficult to understand in certain noise conditions.

Research suggests that synthesized speech may be difficult to understand in certain noise conditions.

Two recent studies examined the speech intelligibility of selected communication aids. Kannenberg, Marquardt, and Larson (1988) investigated both word and sentence intelligibility for AudioBionics' Personal Communicator and Adaptive Communication Systems' SpeechPAC. Word intelligibility for the Personal Communicator was 90.5% with sentence intelligibility of 95.2%. These results were significantly better than those of the SpeechPAC with scores for words and sentences of 61% and 83.1% respectively.

Mitchell and Atkins (1989) looked at the intelligibility of the Echo II Plus and the EvalPAC from ACS as compared to natural speech. Single word intelligibility was investigated using the MRT. Mean recognition scores for the natural speaker, Echo II Plus, and the EvalPAC were 100%, 63%, and 66.2% respectively. The difference between the natural speaker and the augmentative systems' condition was significant. However, the difference between the two systems was not significant.

Interestingly, intelligibility appears to improve over time with some forms of speech synthesis and not with others. In a recent study of word and sentence intelligibility, Hoover, Reichle, VanTasell, and Cole (1987) reported a practice effect over time for the Echo II, but none for the Type'n'Talk used in their study. This practice effect was noted only in the condition using high-probability sentences. Upon first hearing the sentences from both synthesizers, performance with Type'n'Talk was better than with the Echo II. By the fifth replication, results were equal.

Another recent study using children with learning handicaps revealed a similar practice effect (Helsel-DeWert & Van Der Meiracker, 1987). Students who had been exposed to the speech of the Echo II over a 10-week period (13.3 hours) performed significantly better in the synthesizer word intelligibility task than did those with limited exposure. Even the extended exposure group still performed more poorly in the synthetic condition than in the taped voice conditions (66% vs. 94%). As with previous studies cited, these authors also looked only at words that had been concatenated with the diphones provided; they did not examine intelligibility of either the custom encoded words Street provides at or a custom encoded sample.

Unlike normally functioning subjects, language impaired students may have difficulty processing even the best commercially available synthesis by rule speech. Massey (1988) compared performance on the Token Test for Children under two conditions, natural speech and synthesized speech using both normal and language impaired children. A Digital Equipment Corporation DECtalk Version 2.0 text-to-speech synthesizer was used with the Perfect Paul (male) voice mode to prepare the synthesized speech test version. Like their adult counterparts in studies previously reported, the normal subjects had little difficulty processing the synthetic speech. There was no difference between their mean test scores in the two conditions. The subjects with learning disabilities, on the other hand, showed a significant difference in performance under the two conditions. These results suggest that unlike normal children and adults, persons with language impairments have difficulty processing synthesis-by-rule speech. The authors point out their results do not mean that children with language impairments would have trouble with other kinds of synthetic speech. Certainly, however, their study raises concerns over the use of text-to-speech or phoneme segment concatenated speech in instructional programs for children with language impairments.

Treadwell (1985) looked at speed and accuracy of speech processing in fluent aphasics. Her subject performed a word categorization task under three conditions: live voice, LPC phonemes (phoneme encoded), and LPC words and phrases (custom encoded). The Echo II Speech synthesizer was used. Accuracy scores under the live and custom encoded condition were similar while the difference between live and phoneme encoded conditions was significant. Similar results were obtained for response time with only the phoneme condition, not the custom condition, being significantly different from the live condition.

When Treadwell's results are combined with the other studies using language impaired children, a bias in favor of using custom encoded speech with the Echo II is revealed. Serious intelligibility problems appear to exist not only with synthesis by rule output from inexpensive devices like the Echo II, but also with high-end devices such as DECtalk. Instructional programs for use by children with language processing problems should be approached with caution if they employ rule by synthesis speech output.

More research is needed on the processing of various forms of speech output by children with handicaps and on computer-generated speech in specific learning contexts.

These few studies suggest an urgent need for further research. Investigators need to look at the processing of various forms of speech output with children with handicaps. Studies also need to be conducted which look at the processing of computer-generated speech in specific learning contexts. Only when we have this information will we be able to make informed decisions regarding the appropriate form of computer speech generation for differing applications. ■

Moving the Research into Practice

Low incidence disabilities present both researchers and practitioners with many challenges in the study and implementation of technology in the service of education needs. The research reviewed here illustrates those challenges but also pulls together much of what we do know about the use of technology with this population. Some of the research is less than conclusive at this point but areas requiring more research have been highlighted and activity in those areas is accelerating.

Cautions should be voiced about implementing technology in the classroom without guidance or support from research. Campbell, Bricker, and Esposito (1980) stated that the indiscriminate use of new technologies may not necessarily result in improved services to students with severe handicaps. Cavalier and Mineo (1987) cautioned that the rush to "technologize" without an adequate knowledge base may at times actually impede a student's progress. Practitioners must be cognizant of when technology can assist them in meeting identified student needs and when positive outcomes are doubtful, or at best uncertain. They must also use effective processes for implementing the technology. Campbell, Bricker, and Esposito (1980) expressed a fear of practitioners using technology as an end rather than as a means to higher level development. These fears can be lessened if the available research is attended to and the remaining challenges addressed.

One task of the special education profession is to begin transferring what we know from research on technology with low incidence disabilities into the practice setting. One purpose of this document is to pull together available research information and begin that transfer process. Several barriers related to conducting research with this population will be noted in the following paragraphs as well as barriers related to implementing the technology in the classroom. From this, barriers hindering the transfer of research information into practice will be identified and solutions suggested.

In order to begin moving what we know from research on technology with low incidence populations into the practice setting, several barriers must be overcome.

Research Issues

Several issues arise in conducting research with low incidence disabilities that are not major concerns with other populations. First, at this point in time, the researcher can draw upon only a highly fragmentary knowledge base on the perceptual and processing capabilities of the subjects; thus, conclusions based on observations and subsequent interpretations of findings may be incorrect. The problem can only be resolved through further basic research allowing a greater understanding of these individuals. The technologies may contribute to this

Research barriers include lack of knowledge of the perceptual and processing capabilities of the individuals involved; the effects of learned helplessness; the amount of time required to see gains with this population; and the lack of control groups.

knowledge base, providing a more flexible and powerful medium through which to conduct the research.

Second, learned helplessness is a phenomenon that has been frequently mentioned as a characteristic often present in this population. The task of researching the effects of technological applications or other approaches is often complicated by the prior learning of these individuals and thus, as a consequence, the results across individuals are often inconsistent, allowing very few generalizable conclusions to be made. Alternative explanations for the perception, processing, and behavior of these individuals must be explored to provide better insight into the nature of their interactions with their environment.

The third issue relates to the amount of time required to see gains with this population. They are characteristically very slow learners. The researcher involved in these studies must be willing to commit extended time and often be satisfied with small improvements. It should be noted, however, that researchers and practitioners believe that the tools being investigated, i.e., technology, are the very tools that hold unique potential to provide accelerated gains for this population.

In addition to these three population-inherent issues, another problem issue is present. One of the methodological strengths of intervention research is the use of control groups. Because of their typically slow learning characteristic, it may be unethical to use a control group approach in research with this population. If the treatment is believed to be beneficial, one cannot ask a group of individuals to not receive that treatment for a extended period of time. Also, it is often difficult to match individuals in this extremely heterogeneous population; therefore, a design calling for a matched control group could not be implemented. This often restricts the designs available to researchers in this area to single-subject designs. While these are quite powerful research designs to answer many challenging questions, they place a more heightened emphasis on replications before generalizable knowledge can be claimed.

Implementation Issues

Regardless of the research findings showing positive outcomes, they cannot be implemented if practitioners do not have access to appropriate equipment, training on its use, and other necessary components. These issues can be grouped into two areas: administrative and technology-based issues.

Administrative support for implementing technology is a major issue encompassing both service delivery and support issues. Poor or no planning and inappropriate service delivery systems lead to poor matches between student needs and the technology, which in turn leads to failures. Collaboration between members of the clinical team is absolutely necessary. These failures make it even more difficult to justify the use of technology for other individuals. Administrative support for equipment, training, and time allocation is key to the implementation of technology. The lack of applications knowledge and commitment on the part of the administrators is found to be a frustration to many practitioners. The inconsistent level of training across schools and within teams can make implementation a very difficult process, particularly when the technology is highly specialized, as is often the case with low incidence populations.

Technology-related issues can be summed up in three words, availability, affordability, and appropriateness. The lack of available, affordable, and appropriate technologies that meet the needs of specific individuals is a major implementation barrier. Frequently the raw technology is available but has not been designed, and therefore produced, for the mass market thereby keeping the costs high. Often individuals are trained to use less capable technologies when more sophisticated and appropriate ones exist. The failure to implement the more appropriate technology may also restrict it from becoming more affordable. Research subjects may successfully learn to use a device during a study, only to have it withdrawn when the research is completed. The cost of the research technology may prohibit the device remaining with the individuals now trained to use it, but its removal raises serious ethical questions.

Implementation of research requires both administrative support for equipment, training, and time allocation, and technology-related support in terms of availability, appropriateness, and affordability.

Research Into Practice: Barriers

With low incidence disabilities, there is a major chasm between where research is and where practice is, with respect to sophistication of technology. This presents a barrier to the transfer of research into practice. Researchers are frequently interested in the latest advances in technologies, investigating their potential for low incidence disabilities, and pointing the way for practical applications to follow. These types of studies are useful but their purpose is not to offer immediate solutions to the practitioner in the classroom. Studies with little capability of being implemented due to the unavailability of the hardware do not transfer to the practical setting.

A second barrier appears to be the disparity between the dynamics of change (or progress) in research settings and the dynamics of change in school settings. In the research-and-development arena, change can be quite rapid. In school systems, the range of settings and attitudes in which the change must occur is quite large. It is wrong to assume that change in these settings as a result of the research-based discoveries occurs in a timely manner.

A third and related barrier is the near complete isolation of the research and practitioner communities from each other. They do not typically intermingle; there are no well-defined and systematic vehicles by which information between the two communities is shared.

A fourth barrier is the difference in the languages that the two communities use and through which communication between them flow. Even when researchers focus on phenomena that have immediate, practical relevance, they often label them and report them in terms that make the information appear at best stilted and at worst render it nonconsumable by practitioners:

> We see engaged instructional time; teachers see children reading. We see peer teaching; teachers see one student helping another. Because we have been taught to deal with abstractions (and theory verification is partly finding the right connection between abstraction and concreteness), we use language that does not translate easily into real activities of the teacher. The more we need to generalize to unknown futures, the more our work recedes from the practical sphere of everyday schooling. (Baker, 1984, p. 454).

A fifth barrier to the research-to-practice transfer is the incentive system operating in the academic world, whose members are responsible for the large majority of the research in this area. This incentive system rewards solitary, noncollaborative research endeavors (Baker, 1984) directed at questions that are often not very useful to practitioners (Eisner, 1984) and that are primarily communicated to, and evaluated by, fellow colleagues in academia (Winton & Turnbull, 1982). Each of these attributes runs counter to what is required to advance the application of technology with low incidence disabilities: a team of collaborators that includes both researchers and practitioners who study issues useful to practitioners, who conduct the studies in school settings, and who communicate their findings in the journals, magazines, and conferences geared to the practitioner community. Too often, unless a research project is intended to develop materials for practitioners, there is no time or money remaining as its completion to translate and disseminate the findings to this audience. There is also no status or prestige for researchers in disseminating to this audience (Winton & Turnbull, 1982).

Solutions to the barriers that inhibit the informed use of technology with low incidence disabilities have been suggested by practitioners, product developers, and researchers.

Research Into Practice: Solutions

Several solutions to the barriers that inhibit the informed use of technology with low incidence disabilities have been suggested by practitioners, developers, and researchers who are expert in this field. These suggestions include:

- Linkages and partnerships among researchers and practitioners should be established to facilitate the communication between these two communities of professionals. From the inception of the research topic, developers, researchers, and practitioners should work cooperatively to adequately address the needs of the end user and simultaneously evaluate the technology product.
- Researchers should include more of the equipment typically available in the classroom in their studies so the findings can be immediately applied.
- Public school personnel are becoming more technically sophisticated and should be trained in fundamental research methods to assist researchers in conducting studies in practical settings and to conduct their own evaluations. Preservice teacher preparation programs should provide their students better grounding in understanding and applying research knowledge (with courses and texts such as Borg's *Applying Educational Research: A Practical Guide For Teachers*, 1987), and in conducting in vivo research projects.
- Student evaluations should be conducted as single-subject research studies and the data should be reported and shared with the relevant communities to help build more quickly the knowledge base on this population.
- The value of studies conducted by teachers and clinicians should be recognized, published, and more widely disseminated; school administrators should be induced to provide incentives for their teachers and therapists to increase the systematization of their evaluations and conduct these research activities.
- Researchers should report the strategies used to train the use of the research technology in greater detail for replication and application purposes.
- Research questions should include direct investigation of successful training strategies for this population.
- Research questions should include examining cognitive growth as a result of the technology intervention.
- More research should be conducted in the areas of facilitating leisure time and self-help skills through technology.
- Researchers should "become acquainted with the life of schooling" and gain "an intimate acquaintance with life in classrooms" (Eisner, 1984, p. 450); that is, more research should be conducted in practical settings, including the home setting.
- Colleges of Education should be induced to offer themselves as local resources for teachers and therapists in the surrounding schools who would like assistance in designing and conducting high-quality research in this area.
- Faculty within Colleges of Education should be provided incentives for publishing and presenting research-into-practice reports.
- A publisher should be persuaded to provide a peer-reviewed, high-quality, research-into-practice journal that emphasizes technology applications and technology syntheses similar to *Teaching Exceptional Children* or the *Review of Educational Research*, or, alternatively, the editors of these journals should be persuaded to devote one issue annually to research-into-practice technology reports.
- A teacher-focused, research-into-practice, technology newsletter should be funded.

- Major education-oriented conferences should be persuaded to include research-into-practice technology sections.
- Project directors on technology projects in this area should be induced to include a section in their final reports that translates the findings into practitioner language, at the least, speculates on their implications for practice.
- Practitioners should be trained and persuaded to consolidate their most important informational needs, communicate them to appropriate research and administrative audiences, and advocate for their resolution.

The barriers to the effective transfer of research knowledge into practical application are primarily the result of long-standing and deeply entrenched institutional dynamics. The solutions to these barriers, or more accurately, the outline of solutions to these barriers just presented merely scratches the surface. Some of the solutions can be implemented immediately, the large majority of them deal with system change and therefore will require more time and the coordinated effort of more people for their realization. As the range of research summarized h[illegible] [illegible]monstrates, however, the informed application of special education techno[illegible] [illegible]with low incidence disabilities offers the promise of unprecedented opportunities for them to become active and communicative agents in their own lives and to realize a potential that was heretofore sadly underestimated. Because of this promise, the solutions, be they simple or complex, should begin to be implemented now. ■

The solutions suggested here, although in many cases broad and far-reaching, are needed in order to realize the opportunities that technology offers to low incidence disabilities to become active and communicative agents in their own lives.

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