students are frequently given the option of asking him for answers. However, more often than not, Mr. Jones does not know the answer and the student must find another way to get the desired information.

The second program, on the reverse side of the videodisc, concerns a young deaf girl who takes the bus alone for the first time in order to visit a friend. Her mother carefully explains how to get to the friend's house, but the girl does not pay attention on the bus and gets off at the wrong place. At this point the student is asked, via the computer, to define the problem. Once again, there are two acceptable definitions and several successful solutions for each definition.

Field testing to date has shown that students react positively to the instruction and find it fun. They generally like playing "detective" and solving the food-coloring mystery, and they identified with the young deaf actress who portrayed the lost child in the second program. In general, the programs prompted student involvement and positive response, and field testing showed that the instruction had an educational impact.

Examination of the student responses revealed that the learner used certain decision-making strategies, especially in evaluating hypotheses. After realizing that a particular branch or path was leading nowhere, students would often retrack and select another path that appeared more promising. The structure of the program prompted testing and elimination of hypotheses in a systematic manner, and students were able to work toward a correct solution.

As with most software, however, field testing revealed some problems. Some of the computer-generated segments contained linguistic structures that were difficult for hearing-impaired students to comprehend. In addition, portions of the branching structure in the food-coloring program were found to be too complex, and a few students became frustrated when they did not appear to be making progress toward a correct solution.

The positive aspect about the program and hardware design is that the computer-generated text and computer-controlled logic can be modified fairly easily by rewriting certain sections of the computer program. The visual material on the videodisc can remain intact, while changes in the computer software modify the instructional program to more adequately meet the unique learning needs and styles of hearing-impaired students.

MICROCOMPUTER AUGMENTATIVE COMMUNICATION DEVICES

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The computer programs described here turn personal microcomputers into comprehensive communication and control prostheses for the most profoundly motor-handicapped, nonverbal individuals. A wide variety of switches has been developed to allow for almost any handicapped individual's residual skills. The simply modified computer accepts the switch input and allows the individual to use a variety of selection techniques to form messages. Optional versions of the programs allow the printing of messages, speech synthesis, and environmental control. The evaluation, training, and prescription of an augmentative communication device for the handicapped individual is facilitated by the automated evaluation system.

Introduction

It is estimated that ten thousand children are born with cerebral palsy every year. Muscular dystrophies, dystonias, and other degenerative neuromuscular diseases affect thousands more annually. Diseases such as multiple sclerosis and amyotrophic lateral sclerosis claim adult victims. Other adults join this population of severely handicapped individuals by suffering internal neurological accidents such as strokes or externally induced brain or spinal cord injuries. Of this large population, many can be classified as profoundly handicapped because of their inability to interact with their world: they cannot communicate.

The neurological defect that produces the profound handicap often does not directly affect the ability to think. (In many disorders the thinking process may be variably affected.) Frequently, an active mind is locked into a useless body. Frustration is ever present for the afflicted individual, for the family, and for the professionals who try to care for the individual. Although medicine cannot yet cure any of these disorders, recent advances in a variety of fields now allow a higher level of rehabilitation than ever before.

However, the advances in rehabilitation technology and therapy are available to only a small number of the myriad handicapped individuals. The distribution of the new knowledge and applied technologies is painfully slow. The introduction of microelectronics to the field of rehabilitation engineering makes great advances possible, but the advances in microelectronics are so rapid that local rehabilitation experts cannot keep up with the latest innovations. On the other hand, the engineers and technicians who develop microelectronic devices are rarely cognizant of the intricate biomedical, bioengineering, and psychosocial aspects of the profoundly handicapped individual's needs.

I have combined my training as a physician with my knowledge of electronics to develop augmentative communication devices that can be operated by the severely handicapped user and modified if the user's capabilities change. Furthermore, the three systems described below use readily available microcomputers and accessories, making these augmentative communication devices affordable and locally available.

The Word-Com/Picture-Com Evaluation System is an extensive series of programs that allow a profoundly handicapped individual to communicate by using a microcomputer as an augmentative communication device. The system was originally targeted for children who are severely affected with cerebral palsy (nonverbal, with little or no motor control), but it is equally applicable to individuals with a wide variety of neuromotor handicaps.

Evaluation System

Simple electric toys (including a barking dog, a locomotive, and a racing car) form the first element in the Word-Com/Picture-Com Evaluation System. The toys have been modified so that they can be controlled by special switches. These switches, the second element in the Evaluation System, are specially designed to accommodate each user's specific handicap. They include switches activated by raising an eyebrow, rotating the forearm, extending the neck, thrusting the tongue, and adducting the knees. A neuromotor examination and trials with the toys permit the custom design of an appropriate switch. This first step in the evaluation serves several purposes: (a) an appropriate switch can be prescribed, (b) the child learns (often for the first time in his life) that he can reliably control something in his environment, and (c) the child has the positive experience of playing with a toy (also previously precluded by his handicap).

The third element of the Evaluation System is its programs, which facilitate use of the Apple II microcomputer by a computer-naive evaluator (whose field of expertise may be speech pathology, special education, psychology, physical therapy, or occupational therapy) to determine an appropriate augmentative communication device for the handicapped user. The switch is plugged into a simple adapter attached to the microcomputer. The evaluator, following simple step-by-step instructions offered by the computer, teaches and tests the user in several basic selection techniques: scanning, stepping, row-column stepping and scanning, and direct selection. The programs allow testing with pictures and symbols (for preliterate users) or words. The evaluation starts with the selection by the user of one of three objects drawn on the video screen and progresses gradually, as the user's success dictates. The evaluation programs provide increasingly complex pictorial and symbolic communication screens. If the user can read, the programs also include multiple screens containing English vocabulary. The Evaluation System allows rapid training in, and prescription of, an augmentative communication device that permits the user to function at the highest level of achievement.

> *"I have combined my training as a physician with my knowledge of electronics to develop augmentative communication devices that can be operated by the severely handicapped user and modified if the user's capabilities change."*

Word-Com and Picture-Com Programs

These programs turn the microcomputer into a complete augmentative communication device by allowing any of 12 modes of selection, using single or dual switches, joysticks, or a combination of input devices. The Picture-Com programs use line drawings or Bliss symbols (a nonverbal symbolic language) and allow the illiterate user a high level of visual communication. The Word-Com programs offer a far more extensive vocabulary, using English words and letters. The vocabulary offered is readily altered and expanded as the user's needs change. A preliterate user can progress from the Picture-Coms to the Word-Coms, thus increasing his level of communication without purchasing an expensive new communication device.

In each Word-Com or Picture-Com program, as each word (or each picture representing a word) is selected, that word is written at the bottom of the video screen underneath the selection area. Entire sentences and paragraphs are displayed for communication. With an optional printer (controlled by the user) attached to the computer, the message can be printed.

The Word-Com/Picture-Com System thus offers the evaluator a tool for prescribing the most appropriate augmentative communication device for any handicapped individual. The system offers the profoundly handicapped nonverbal individual (who may have the ability to control only one muscle reliably) a tool for communication. And the system inexpensively accommodates to growth or decline in the user's abilities.

Special Application Programs

The first of these special programs allows the user to control the microcomputer and to program it using BASIC. The same input devices (switches) and selection modes are available for the program. The second special application program is an automated version of the French pictorial intelligence test for evaluating IQ in children from two to eight years old. Scanning, stepping, and pointing modes of selection can be used so that severely motor-handicapped children can be evaluated.

The Communication Device System

The Communication Device System carries the microcomputer communication device to the limits of the state of the art, while maintaining affordability by using stock components. All the programs in the Communication Device System use English word vocabulary and row-column scanning. They use a readily available TRS-80 Model I or Model III microcomputer with a simple modification to allow input from any of a variety of switches (identical to those used in the Word-Com/Picture-Com System), requiring only minimal motor input. The target population for the Communication Device System originally was literate adults with an acute debilitating disease that precludes verbal or written communication (as is often found in modern hospital intensive care units) or with chronic static or progressive neuromotor diseases that may affect the motor system by paralyzing the individual while leaving the mind intact (such as amyotrophic lateral sclerosis, muscular dystrophies, or stroke). Such temporarily or permanently "locked-in" states produce tremendous frustration in the individuals affected and in those caring for them. The complete Communication Device System gives the affected individual the ability to communicate and it offers maximal benefits for minimal cost to the most profoundly handicapped individuals.[1]

The Basic Communication Device. The basic Communication Device program offers the user several screens, each containing a complete vocabulary dealing with some aspect of everyday life (symptoms, nursing care, feelings, simple requests). The choices occupy the top of the video screen, and the words or phrases chosen by the user are displayed at the bottom. The displayed message is easily edited or printed via an attached printer, which is controlled by the user. The user also controls the speed of the scanning cursor. An alphabet screen allows the user to spell out words not available on the vocabulary screens. The vocabulary screens can be altered or expanded easily to suit the individual.

The Speaking Communication Device. This program uses an inexpensive speech synthesizer to achieve more normal, audible communication. The message stored on the screen is chosen from the same screens described above and can be edited prior to activation of the voice synthesizer.

The Communication and Control Device. This program has all the communication screens of the Communication Device program but adds an additional device control screen, giving the individual control of any electrical device in his environment. The computer interface uses carrier current remote switches for simplicity and low cost; no direct connection is required between the microcomputer and the controlled devices. To use the device control screen, the user simply chooses (via row-column scanning) "TV On" to turn on the television or "Light 1 Off" to turn off light number 1.

"For less than $2000, a totally paralyzed, nonverbal individual can now communicate in writing or speech and control his environment."

The Speaking Communication and Control Device. This program combines the properties of the above three programs. For less than $2000, a totally paralyzed, nonverbal individual can now communicate in writing or speech and control his environment.

Quick-Scan

The Quick-Scan programs use modified scanning techniques to allow rapid alphabetic spelling of messages. Thirteen lines of 64 characters can be displayed in the message area below the three lines of the selection area. A buffer for 3000 characters can store a long message prior to activation of a printer.

The Insta-Speak Program

Insta-Speak is an economical program that allows the nonverbal individual to speak. It requires a microcomputer and a speech synthesizer. It is designed for the nonverbal individual who can use a keyboard using fingers, headstick, or handstick. The keyboard is labeled with the phonemes of English. When each key is pressed, the phoneme is spoken by the synthesizer and the phoneme's representation is written on the screen. The phonemes can be changed using a backspace key. Up to 3000 phonemes can be stored to be spoken at one time. When the "Speak" key (Enter) is pressed, the message is spoken. With a little practice, complex speeches can be typed rapidly. The message can be repeated by again pressing "Speak."

Insta-Print uses the microcomputer and an attached printer. It allows the individual to type and

correct text on the screen and then print the text via the printer. All shifted keys are made available unshifted (via software), thus allowing one-finger or stick input. This program is intended for use by individuals who can type with fingers or the head/hand-stick. It allows them to write, proofread, and

correct prior to printing. It was written for Insta-Speak users who wish to print as well as speak.

NOTE

[1]The initial clinical research is described in the article "CD: A Microcomputer-Based Communication Prosthesis for the Profoundly Handicapped," *Fam. Med. Rev.* **1**(3), 67-75 (Winter 1982).

A LOW-COST COMMUNICATION SYSTEM FOR THE NONVOCAL SEVERELY PHYSICALLY HANDICAPPED

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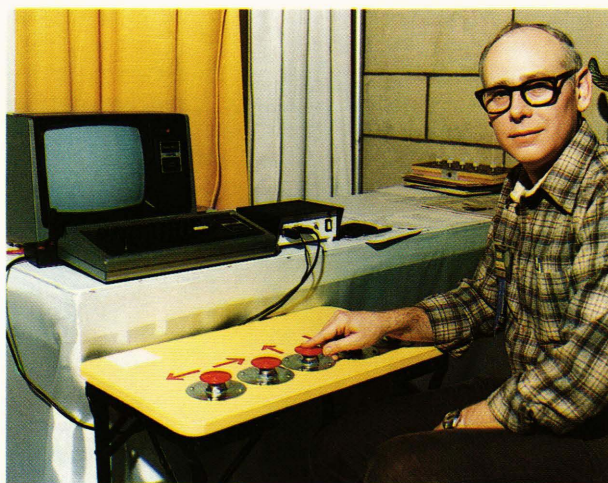
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A low-cost system (under $1000, including computer) permits one or two nonvocal, severely physically handicapped persons to interact, write letters, communicate with others, and control external devices. It also provides a means of evaluating individual language and mathematical abilities and permits tutoring in these areas.

Objective

The system described in this article has been operational since December 1980 and was developed for Lois, who has very severe cerebral palsy and has been completely nonvocal since birth, more than 50 years ago. Although her motor coordination is very poor, Lois does have limited control of her right arm with a minimum positional resolution of 5 to 6 inches. She cannot use a joystick, nor can she grasp a pencil or wand. Her computer system was designed to satisfy the following requirements:

1. She should be able to control all system functions and operations with the fewest number of physical motions and keyboard controls.

2. The hardware and software should be easily adaptable to other home computers and should be readily available.
3. Software should perform the majority of decisions to minimize user activity and maintain keyboard simplicity.
4. The system must be very reliable and affordable by an individual.

Background

Cerebral palsy is normally caused by damage to the motor coordination part of the brain at birth but usually does not affect the person's innate intelligence. The distinction between intelligence and knowledge is quite important here: simply put, intelligence is a measure of a person's ability to learn, and knowledge is a measure of what or how much has been learned. In severe cases of cerebral palsy, such as with Lois, it has been extremely difficult to assess either intelligence or knowledge, primarily due to the person's lack of physical ability to communicate complex thoughts and abstractions. However, with an appropriate interface to a home computer, Lois has shown that not only is she quite intelligent, but also that she has a very well-developed ability to clearly express her thoughts, feelings, and needs.

System Description and Operation

Lois' system consists of an unmodified, low-cost personal computer (Radio Shack TRS-80), a simple interface device that accommodates two users, two custom-designed keyboards, each with only five keys, and a software program that controls the functions of the entire system from either keyboard.

The computer video display presents a list of letters, numbers, and preprogrammed words that can be selected and "printed" in a workspace area at the bottom of the screen (see Fig. 1). Although this basic system concept has been implemented with computers before, the approach described here is novel in its simplicity, low cost, flexibility, and lack of required additional expensive peripherals such as disk drives or large amounts of memory. The 16-line, 32-charac-