An alternate interface to computers for the physically handicapped—the auto-monitoring communication hoard

by GREGG C. VANDERHEIDEN, ANDREW M. VOLK, and C. DANIEL GEISLER

University of Wisconsin-Madison
Madison, Wisconsin

INTRODUCTION

For many individuals severe physical handicaps have completely cut off most avenues of personal development and employment. Their physical involvement bars them from any constructive or creative activities requiring physical or manipulative abilities. Moreover, their inability to speak, write or efficiently operate even simple communication devices severely impairs their ability to develop and exercise their mental capacities. This latter problem is basically an output problem in which a normally functioning intellect is trapped within a body having no effective means of communicating or interacting with the environment. Fortunately with today's technology, especially microelectronics and the computer, new avenues are being opened for these individuals which promise them not only a chance for a more effective education and a more meaningful mode of self expression, but also a means of self support through employment.

The major problem in trying to realize the full potential of these individuals is in finding efficient means of communication for them. Information output should consist of both written communication and discrete commands with which they can control certain elements or devices in their environments. This paper will describe a new approach (The Auto-Monitoring Technique) and a new aid (The Auto-Com) which help to solve this problem for many severely physically handicapped people.

It will also describe how the computer can multiply the speed and effectiveness of this communication, further increasing the potential of these individuals. Implications for the education, employment, and overall enhancement of life for the physically handicapped will be discussed.

THE AUTO-MONITORING TECHNIQUE

The first problem in applying the potential of the computer to severely physically handicapped individuals involves providing an interface which they can control efficiently. There are basically three approaches that have been used to allow them some measure of control: encoding techniques, scanning techniques, and techniques employing a direct selection such as a keyboard.

The encoding systems utilize one or more switches which the person operates in a repetitive fashion to encode his output. The Morse code, for example, might be used in such an encoding system. This approach works best with people who have small but quick and well controlled movements such as might be found in the breath control of a paraplegic. For people with cerebral palsy and other afflictions which render them weak or limit their coordination, these types of aids are very slow and often cannot be operated without many mistakes.

The scanning systems are the most prevalent form of communication aid available today. Unfortunately, few of them are computer compatible in their present form. In these devices, the alphabet is usually arranged in a rectangular matrix approximately seven by seven. The device steps an indicator or cursor across the columns until signalled by the individual using the device. The cursor then moves down the column until the individual signals the device again. The letter thus selected is then printed out on a typewriter, strip printer, or other output device. To control the scanning device, the person operates a single switch especially designed to take advantage of some one movement over which he has control. Because the scanning indicator must pause at each letter long enough for the user to activate the switch, this scanning process is very time consuming. This is especially true if the person has sporadic movements or cannot make a discrete response quickly. This approach does have the advantage that it can be used by almost any individual no matter how severe his physical disability. However, if the person can find some other means of control, it should be explored because of the very slow speed of this technique.

It was in trying to find an aid for those individuals whose movements were too sporadic or uncoordinated for the encoding systems and yet not restricted enough to resort to the scanning technique, that the auto-monitoring technique was discovered. The problem at hand was that of developing a communication aid for those individuals who have some gross pointing skills but who are unable to operate a key-
board of any kind, even with special modifications. A scheme whereby the user would directly select each output letter was deemed most appropriate for these individuals because of their ability to point and the inherent simplicity and speed of a direct selection technique. The problem then was one of finding a way to optimally utilize their limited pointing skills.

After many experiments, a solution was found to lie in the combination of a matrix of proximity switches located beneath a smooth surface and the use of a delayed activation mechanism. Using this technique, the operator need not push or pull any levers, buttons or switches. He need only slide a pointer into the vicinity of a switch and hold it near the switch for a short time (see Figure 1). In order for the system to respond, the particular switch involved must be closed continuously throughout the short, though adjustable, period of time. If the switch is opened before that period expires, the system resets, ignoring the switch closure. This feature means that switches only momentarily activated due to the passage of the pointer over them are ignored. Only when the pointer is kept within the sensitive area of a switch uninterruptedly for the set period of time, will the automonitoring system acknowledge the switch closure.

Thus the switch matrix is sensitive to lack of motion rather than to discrete motions as in normal switching arrangements. Pointing briefly to other switch locations as the user moves the pointer around over the surface will cause no false triggering. Nor will mistakes occur due to movements or momentary loss of control by the individual while trying to point to a given switch. If the operator loses control of his motion, the system just waits "patiently" until the operator regains his control. By adjusting the activation area of these proximity switches to the proper size, errors due to small tremors and inaccuracies of pointing were also almost entirely eliminated.

It should be noted that this delayed-action proximity-switching technique was modeled after the same process that a second person would use if he were to monitor a handicapped person's movements in trying to point to various letters painted on the surface of a board. Hence the term auto-monitoring.

Using this technique, it is possible to locate a large number of switches within an individual's range of motion without causing any problems due to accidental triggering of switches adjacent to the desired one. Moreover, because the proximity switches are located beneath the surface of the board, the operator need only slide the pointer around over the smooth surface of the board, never having to pick his hand up or support its weight in the air. The removal of the necessity to suspend his hand above the switching array and the removal of the vertical dimension from the required movement patterns have greatly increased the hand control of the cerebral palsied individuals worked with. The combination of all of these features has allowed even very severely cerebral palsied children to use devices which utilize the auto-monitoring technique.

THE AUTO-COM

The first application of the auto-monitoring technique is in the Auto-Monitoring Communication Board (Auto-Com). In the present model of the Auto-Com, the auto-monitoring technique is realized with a matrix of 84 magnetic reed switches mounted on 13/4 inch centers. Each switch is located directly underneath the center of a letter painted on the surface of the board and can be activated by a magnet anywhere within a 5/8 inch radius of this center (Figure 1). Both visual and auditory feedback have been provided to aid the person using the board.

The Auto-Com itself is completely contained within a 18X24X13/2 inch wooden case (Figure 2). It weighs about 83/4 pounds and is designed to mount directly onto the arms of a wheelchair in the same manner as a lapboard would. In fact, the Auto-Com has been designed so that it can be used as a lapboard when not in use as a communication device.

In addition to the Auto-Com itself, there are two other necessary components of the system—a magnet and an output device. The magnet is mounted on whatever object or part of the body the child can best point with. In most cases the magnet is mounted on a handpiece consisting of a clear plexiglass base with a custom molded hand-grip (see Figure 3). The magnet, which functions as the pointer for the child, is mounted well away from the hand-grip. This affords maximum visibility of the letters as the child slides the magnet over them. To facilitate the sliding motion, the bottom of the handpiece is partially covered with felt. This handpiece serves both to stabilize the operator's hand and to smooth and damp his motions.

The principal output form of the Auto-Com at the present time is an ordinary television set equipped with a commercially available TV controller that allows the user to print letters on the television screen. This particular output
Figure 2—Exploded diagramatic view of the Auto-Com system showing major functional blocks

has been chosen because it provides good visibility, feedback, portability, and correctability. The Auto-Com has also been used with other output devices: teletypewriters, special typewriters, and strip printers. Any output device using the standard ASCII Code can be used with the Auto-Com; the exact output form of which is a 20 milliamp current loop with the information in standard 110-BAUD 11-bit serial format. Thus the Auto-Com can interface directly with any computer accepting this standard serial input. Figure 3 shows a photograph of the Auto-Com with two of its output devices.

Operation of the Auto-Com is simple and straightforward. Even children can operate the Auto-Com with only minutes of instruction. To print a letter the user simply grasps the handpiece (a velcro strap arrangement is provided for individuals who have no grasping abilities) and slides the magnet over to the letter he wants printed. For those who cannot use the handpiece, the magnet can be mounted on a ring, headstick, shoe, or anywhere else that would be advantageous for him.

This simplicity of operation, combined with the two-dimensional movement feature of the auto-monitoring technique, has proven so desirable that several centers have indicated a desire to secure Auto-Coms to use with some of their students who now can use specially modified typewriters. The reasons they cite for wanting an Auto-Com despite its higher cost are ease of operation, reduction of mistakes, and increased use time before fatigue.

Future developments

The present program for the Auto-Com is centered around its development as a communication aid. A large emphasis is being placed on making it as flexible as possible and increasing its utility in the educational setting. Toward these ends, emphasis is being placed on the development of these features:

Complete portability

A portable model of the Auto-Com, which runs on batteries and contains its own miniature strip printer, has been designed. With this unit an individual will be able to move
freely about his school or home and always have his "voice" with him. Attached to his chair and doubling as a lap board, it will always be with him requiring no special set up for each use.

In addition to the strip printer, this portable Auto-Com contains a small FM transmitter which will enable it to control the TV controller without hookup wires. A large screen television set with TV controller could then be placed nearby and controlled by the individual from anywhere in the room. This feature is seen as particularly powerful in a classroom setting where the student could move about freely and participate in class discussions much like the other students by using the TV screen printout as his voice. The selection of either the strip printer or the serial ASCII telemetry unit is controlled by the user. In this manner the operator, when working in a computer environment, could easily switch back and forth between the printer (for communication) and the telemetry unit (for communication with a computer). He would also be able to talk to the computer from any position in the room, thus lessening his mobility problems.

Printed copy

Printed copy may be obtained at any time by simply connecting the Auto-Com to a teletypewriter or modified typewriter instead of the TV controller. However, this eliminates the feedback and correctability features of the television set. To provide for both printed copy and correctability a transfer option is being developed which will automatically transfer the contents of the television screen to a printing device on command from the Auto-Com surface.

Price

Throughout the design, heavy emphasis has been placed upon keeping the price of this aid to an absolute minimum. The rapid advance of integrated circuit technology has made this type of aid possible and economically feasible. As the technology increases, the cost will continue to decline. A major component of the Auto-Com cost still lies in the output device. For this reason, a large portion of our research effort has been directed toward securing or developing inexpensive output modes. If the Auto-Com were used in conjunction with a computer system, where it would be used mostly as an "alternate keyboard," the cost of the output system would be eliminated and the price further reduced.

An Auto-Com system, then, can take two basic forms depending on its intended use. It can take the form of a complete system if it is going to be used as a communication aid, or it can take the form of a simple keyboard if it is to be used as an interface with a computer or other data processing system.

When used as a communication aid, the final Auto-Com system will consist of two parts, each designed to handle different functions in communication.

(1) The portable Auto-Com. Highly mobile, this unit has a miniature self-contained, strip printer for its output. When used alone, it is designed primarily for conversation. With the FM output, it can also control a stationary output system.

(2) The stationary output system. These television and output printer media provide the feedback and page format most useful in educational settings and for extended independent work. The system will be designed so that several individuals, each with his own portable Auto-Com, could share a common printer or CRT display.

When used as a keyboard for data entry, the Auto-Com can take either the form of the full portable Auto-Com as described above, or a simpler form of the Auto-Com having no strip printer and deriving its power from the computer or a separate power source.

The Auto-Com wordmaster

A natural next step in the evolution of the Auto-Com as a communication aid is the addition of entire words to the surface of the board. With this option, the operator could then cause entire words, phrases, or sentences to be printed out by pointing to a single square on the Auto-Com. This would permit him to communicate in a word-by-word fashion as in speech rather than having to spell everything out. For computer use, commonly used words, phrases, or symbol sets could be substituted for the words.

An attachment dubbed the "Wordmaster" has been developed to do this. Now under initial evaluation, the Wordmaster/Auto-Com is expected to provide an increase in speed of approximately 2-4 times over that of the original Auto-Com. Moreover, it will enable even more people, especially children, to use the Auto-Com. The ability to spell will no longer be a prerequisite for use of the Auto-Com. It also opens up the possibility of using pictures on the surface of the board to specify the output words. This technique may
be used either to accelerate reading skills or to provide communication for those who are prereaders or who have reading problems, but do possess adequate expressive skills.

THE USE OF COMPUTERS WITH THE AUTO-COM AND OTHER COMMUNICATION AIDS

There are two basic ways in which the computer and communication aids can be combined to augment each other. The first is an arrangement in which the communication aid serves as an "alternate keyboard," allowing handicapped individuals with no previous means of access to a computer to benefit from the computer's capabilities. In the second relationship, a computer is used to augment the communication aid by increasing the speed, efficiency, and utility of the aid.

As an alternate keyboard

When used as an alternate keyboard, the purpose of the communication aid is to provide the user with an interface that is specifically designed for his particular abilities. The simplest form of communication aid which can accomplish this purpose is the "guarded" keyboard. IBM makes special keyboard handguards and armrests for most of their typewriter models including their I/O typewriters. The Cerebral Palay Communication Group has also developed a special keyboard guard for the Teletype Model 33 teleprinter. Using this keypad, a cerebral palsied student at the University of Wisconsin-Madison has successfully completed the requirements for a B.A. Degree in Computer Sciences. For programming, he operated the modified teletype terminal from his dormitory room, using the time-sharing facilities of the University's Univa 1108 computer. In this manner, he was also able to overcome the transportation difficulties associated with constant travel to and from the Computing Center.

For individuals too severely handicapped to use any of these guarded keyboards, the Auto-Com may provide a solution. Because it has been designed to output in 110-BAUD serial ASCII, the Auto-Com is directly compatible with any computer which accepts input from a teletypewriter. Although the scanning and encoding aids available today are not directly compatible with computer inputs, they too could be modified to permit them to be used as computer interfaces for the handicapped. Thus, any person, no matter how serious his physical handicap, or what form it takes, can be outfitted with an aid which would allow him to readily communicate with a computer.

The relative unimportance of speed in working with a computer, either a dedicated mini-computer or a larger timeshared computer, opens up the possibility of computer-related jobs for the physically handicapped. The computer does not get impatient and the user is unhurried—he is able to work at his most comfortable and efficient rate. Moreover, the computer also offers the handicapped person the opportunity to remain at home while working. Phone lines provide him with a direct link between his home and the computer. Since mobility, and sometimes nursing care, are major problems for the physically handicapped, the ability to work directly from his home or from a rehabilitation center, can make the difference between a person being employable or not.

Access to computers also opens up to the physically handicapped the whole world of individualized instruction. In the education of the handicapped, where individualized instruction is very often needed but rarely available, the computers can provide the educational programs these students need at a pace in keeping with their physical abilities.

The power of the computer in individualized instruction is well illustrated by the PLATO project at the University of Illinois, Champaign-Urbana. This computer-based educational system is designed to handle up to a thousand remote terminals all communicating with a central computer. The system has educational programs ranging all the way from pre-kindergarten through post-doctoral studies. The PLATO terminal uses a standard computer keyboard as one of its input forms. These keyboards could easily be replaced by communication aids specifically designed for use by the handicapped, thus allowing them access to the PLATO system. The Auto-Com, for example, can be interfaced with the PLATO system by simply using a patch-cord.

To expand the function of a communication aid

When used in conjunction with a computer, the power of a communication aid can be greatly expanded. With limited ability to produce output signals, the handicapped person's rate of communication can only be increased by increasing the information sent by each of his commands. The use of computers, with their immense information storage capabilities and flexible peripheral devices can greatly increase the information transfer rate of the handicapped.

The Auto-Com with Wordmaster attachment, for example, presents the user with a choice of the alphabet, numbers, and a list of 191 words, a number limited largely by memory storage and display considerations. Sixty-three of the words have been predetermined and are stored in a permanent memory. They are also printed on the board and are accessible through an "upper case" arrangement. The other 128 words are chosen by the individual user and are written into an interchangeable ROM unit. These latter words are printed on interchangeable cards and can be selected in "third" and "fourth case" modes. Using a computer, this vocabulary could be greatly expanded and its display and selection features considerably improved. A large enough wordset could be established so that the user could converse easily in a completely word-by-word fashion instead of having to spell out most of his messages letter-by-letter. Even phrases and whole sentences could easily be stored in the computer, increasing the options of the user still further. At some point the vocabulary size will get so large that it would take more information to specify a specific entry than it would take to spell it out. Work is now being done to identify that boundary and to study ways of developing vocabularies that can be
made fully functional without reaching that point of inefficiency.

The use of computers in the communication problem of the handicapped need not be limited to maximizing output information only. The text storage and editing capabilities available in many present computer terminals could prove of immense value to those physically handicapped who cannot otherwise easily review, correct, or modify their written work. The written work of others could also be stored and transmitted in digital form to the handicapped person in his home or work area. It is not inconceivable that whole books, magazines and other written information could be made available to the physically handicapped in this form (both for recreational and professional use). Answering the phone (perhaps with computer generated speech), controlling a room’s ventilation and lighting, and providing a good measure of self-care are all feasible today through computer controlled devices.

It has been suggested by futurists that within a few decades many workers in the U.S. will be able to perform their jobs from their homes using communication technology now being developed. The video-telephone, two-way cable TV, and computer technology all suggest more flexibility for home-centered employment. The ability of handicapped individuals to use these devices will enable them to take a more useful and rewarding place in that future society.

In other applications, the computer could contain algorithms for controlling machines with complex functions. In this usage, the handicapped person would specify the various operations he wanted performed and the computers would execute the various steps necessary to perform them. One command from the handicapped person could initiate a string of individual commands from the computer, thus increasing the effective speed and efficiency of the handicapped person.

Thus the combination of the computer and communication aids can provide the physically handicapped with many opportunities not otherwise available to them. These opportunities touch many areas: education, personal advancement, employment, recreation, communication, and social interaction. Furthermore, the costs of these systems should continue to decline with the advance of technology and the increase in the development of low cost electronic functional modules. If the concept of home based employment via tele-communication links proves economically and administratively feasible, then the occupational opportunities for the physically handicapped seem to be limited only by the efficiency of the communication and interaction systems that are available. As new and more efficient techniques for utilizing the intact abilities of the handicapped are developed and interfaced with computer systems, the effective capabilities of these individuals will continue to increase allowing their mental capacities to be more and more fully realized and utilized.

ACKNOWLEDGMENTS

We would like to thank all those members of the Cerebral Palsy Communication Group who have contributed to the development of the Auto-Con/Wordmaster. In particular, we would like to note the efforts of David F. Lamers, Warren P. Brown, Gerald A. Raitzer, Robert J. Norton, David E. Church, Deberah Harris, and Claudia L. Scheibel. The technical counsel of Professor Leo Jedynak is also acknowledged.

We would also like to thank all those who have provided the monetary support necessary to carry out this research, especially the University of Wisconsin, the Madison Public School System, the Robert J. Ritger Memorial Fund, the Dane County Chapter of United Cerebral Palsy, the Bacon Foundation, and most recently from the National Science Foundation, who is presently funding our research efforts.

Many industrial concerns have also contributed to the group in the form of information and the donation of products. The most notable of these are Ann Arbor Terminals, Ann Arbor, Michigan; Hamlin Inc., Lake Mills, Wisconsin; Texas Instruments; Intel; Signetics; and Canon Inc.

REFERENCES

4. Hume, B. C., General Manager, Centre Industries, Allambie Road, Allambie Heights, New South Wales.
5. Hackler, N., North Electric, Galion, Ohio (Personal communication).
8. Jefcoat, R., P.O.S.M. Research Project, 63 Mandeville Road, Aylesbury, Bucks.
11. MEFA GmbH Bonn, 518 Eschweiler, Postfach 466, Germany.