MICROCOMPUTERS AS PROSTHETIC AIDS FOR THE SEVERELY PHYSICALLY DISABLED

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ABSTRACT: Tremendous technological increases resulting from the boom in microcomputer development has had an explosive impact in the development of special aids for disabled persons. Successful applications of technology have lessened the discrepancy between the individual's capabilities and his environmental demands. The artificial intelligence of the microcomputer has been integrated into the design of power prosthetic or robotic manipulators. Another area of prosthetic assistance to the severely disabled has been the development of communication aids; two major categories of communication aids employ microcomputer technology. Numerous factors are included in the selection of a communication device. The particular device selected must possess the capability to be operated independently and by designed to meet the individual's needs. The microcomputer's assistive capacities enable those individuals previously thought completely disabled the ability to assume some measure of productivity. The microcomputer offers the means by which an individual may control his surroundings and himself, as well as communicate with others. The aids discussed in the text represent successful application of advancements in microcomputer technology.

The past few years have witnessed a tremendous increase in technology with the advent of the microcomputer. In conjunction with the explosive impact of the microcomputer has been the impact of individuals and small groups involved in the development of special aids for disabled persons. Interference with mobility, manipulation of the environment and effective communication caused by various neurological and neuromuscular conditions has been overcome with the use of artificially intelligent prosthetic devices. These aids have allowed individuals the ability to be as independent of constant attention as possible and to enhance their way of life.

Mobility has been one of the most acute requirements of handicapped persons. Without mobility the individual's capabilities were severely limited. Good, reliable powered wheelchairs were an outgrowth of the mobility needs of the handicapped. The Wheelchair II Workshop held at Moss Rehabilitation Hospital, December, 1978, recognized that the microcomputer offered vast improvements over existing control systems. The microcomputer provided the sophistication, flexibility and compactness required for such features as automatic speed limiting, programmed acceleration an deceleration, obstacle avoidance, battery monitoring, and component temperature monitoring (Aylor, Johnson & Ramey, 1981).

The University of Virginia Rehabilitation Engineering Center developed a microprocessor-based wheelchair which provided many of the aforementioned functions. Critical characteristics of the control system were varied by programming changes to meet individual needs. A digital filtering system extracted the average value of spastic hand movements of the joystick thus enabling individuals with severe spasticity to smoothly and safely operate the wheelchair. Additional flexibility was obtained by a variety of control inputs such as joystick, sip and puff, and hum control. The microcomputer permitted accommodation of these different inputs by using separate written subroutines. Not only did this accommodate the individual's residual capacity to exercise control of the wheelchair, but it minimized hardware interfaces between the user and the microcomputer. This flexibility made this wheelchair system much more tailored to the unique capabilities of the user. The intelligence offered by the microcomputer made possible a variety of complex features while maintaining hardware simplicity and low power consumption (Aylor, et al., 1981).

Similar technological applications have expanded user control from wheelchair to environment. Past difficulties with robotic manipulators were eliminated by the microcomputer ability to develop and remember complex movement command chains for specific types of activities. The user then directed these routines with only a few commands, thus making complex motions with reasonable speed and accuracy (Vanderheiden, 1981). A number of devices have been developed to provide general motions under the operator's control. One such manipulator was developed by the John Hopkins University for the Veteran's Administration. The operator moved the terminal device to any position in its range by operating one joint at a time. A similar development by the Jet Propulsion Laboratory under the joint sponsorship of the National Aeronautics and Space Administration (NASA) and the Veteran's Administration utilized voice command control (Ramey, Aylor & Williams, 1979). The University of Virginia Rehabilitation Engineering Center developed a single chip microcomputer control system which allowed for joystick or hum control of a wheelchair-mounted manipulator. Another versatile system developed by Ramey, Aylor and Williams (1979) permitted severely handicapped individuals to eat independently using a microcomputers-controlled manipulator. The microcomputer not only moved the eating utensil through a preprogrammed path and rotated the plate, but it also possessed a "learning mode" which enabled its adaptation to tasks other then eating (Freedy & Lyman, 1977).

Further, a programmable robotic arm developed at the John Hopkins University Applied Physics Laboratory was integrated into a functional worktable, thus giving persons without the functional use of their limbs the manipulative capability necessary for reading, eating, and using a typewriter, telephone and personal computer system. Experimental systems with the robotic arm have been proposed and designed in both wheelchair and table-mounted versions. This system was operated by the same controller which ran the electric wheelchair. This arrangement permitted full wheelchair mobility with minimal additional components mounted to the wheelchair, thus maintaining a low-profile wheelchair (Schneider, Schmeisser & Seamore, 1981). The robotic arm/worktable system was designed for the high-level quad who, having no use of his arms or hands, was capable of nearly a full range of head and neck movement and could use a mouthstick for turning pages and operating a keyboard. The controller responded to commands from the user and his environment and commanded the mechanical arm to perform some useful motion. The software design for the controller implemented all tasks necessary for the proper operation of the mechanical arm either as a telemanipulator or as a robotic arm. Through clinical tests of the system, the computer was shown to be a significant factor in the design of the robotic arm control system as well as a key component of the worktable. The designers have planned attempts to broaden the task capability of the device (Hazan, 1981).

Erich Sutter of the Smith-Kettlewell Institute in San Francisco has developed a seemingly telepathically controlled computer. To control computers, telephones, lights and other electronic devices the user would gaze at a flashing light; brain waves and computer software would do the rest. To use the system, electrodes like those used for an electroencephalagram needed to be worn. The system utilized a separate light for each device to be turned on or off or for each choice to be made. These lights flashed in a carefully chosen pattern, a repeating sequence taking nearly three seconds to complete. The viewer responded to the flickering with a distinctive pattern of brain waves that changed recognizably as the different lights flashed their sequence. The computer compared the user's brain waves with a pattern in its memory. When a matching pattern was found, the computer knew which light was looked at and operated the device. This system was used to communicate, to command light switches, televisions and even meal-carrying robots. This system even enable those who could neither type nor speak to enter text into a computer by simply gazing at a single character on a display board.

Yet, another area of prosthetic assistance to the severely disabled has been the development of communication aids. The nonvocal disabled person entering the mainstream of society was faced with communication problems more severe and complicated than encountered by individuals in a foreign culture. Oral communication was spoken at such a high rate of speed that few people had the patience or attention span necessary to communicate with a disabled individual using a slow manual communication aid such as a laptray letterboard. To communicate effectively, nonvocal disabled individuals needed communication devices specifically designed to meet their particular and practical requirements within today's society. At the Biomedical Engineering Center of Tufts - New England Medical Center, the communications problems of disabled people were addressed through a coherent philosophy of electronic device development (Thomas, 1981, p.25). This philosophy stressed personal, portable and affordable as key concepts.

Currently, two major types of communications systems for the nonvocal disabled have been manufactured commercially: a scanning system that presurposes a user with voluntary motor control of one muscular action and a direct selection technique, usually accomplished with a mouthstick, hand/arm control, or a headpointer of some type. The Direct-selection technique has required better muscular control than for the scanning system, and fatigue has played an important role in communication speed (Thomas, 1981). Generally, the majority of communication devices utilizing microcomputer technology of late, have been capable of functioning in either of these modes depending on user ability.

One such device was developed by Carol A. Simpson, Ph.S., of Psycho--Linguistics and Douglas H. Williams, Ph.D., who drew on their collective experience in developing synthesized voice systems for NASA. Their talking wheelchair, formally named Versatile Portable Speech Prosthesis (VPSP), adopted existing hardware which was mounted on wheelchair and run off a standard 24-volt wheelchair battery. The system further incorporated a microcomputer, a disk drive, a speech synthesizer, and a modified five inch television set.

The user had three choices to control the system depending on his physical capacities. The easiest and fastest method was the keyboard which could be operated by finger touch or a headstick (Deane, 1982). Using a joystick control, the cursor was moved to the desired word or letter and selected by the press of button. For those too severely handicapped for the keyboard or joystick version of the VPSP, the single-switch mode could be utilized. In the single--switch mode, the computer moved the cursor and the user pressed a button to stop the scan where wanted.

Similar to the VPSP, another wheelchair portable device was developed. With this device, a box in the back of the wheelchair held the electronics, microprocessor and voice synthesizer; a display and printer combination was mounted on the side of the wheelchair where it would be most easily visible to the user; an adaptive joystick was located next to the body part capable of manipulating it-hand, foot, or head, depending on the user (Rahimi, 1981).

Many nonvocal individuals have, however, learned to communicate with others using devices such as the Blissymbolic Board. The Bliss Board was composed of an array of symbols. The handicapped individual relayed a message by indicating the set of symbols representing the intended meaning. Since Blissymbolics is a purely graphic communications system, interpersonal communication has required the presence of an interpreter familiar with the system for translating Bliss Syntax into English. A significant advance for Bliss users was the development of computerized talking Bliss Boards such as the Semantically Accessible Language (SAL) Board. SAL combined microprocessor and speech synthesis technology to create a portable lap Bliss board permitting the nonvocal user to more freely communicate by producing synthesized English speech from Bliss symbols (Bennett, 1982, p.111). These devices also allowed users to compare ideas before speaking (Rahimi, 1981).

Summary

The previously mentioned prosthetic aids for the severely physically impaired were developed as a direct outgrowth of the microcomputer boom. Artificial aids -- communication or otherwise -- can improve the quality of life for the disabled. With technological advances such as they are, the resources are available to build aids to compensate for many disabling conditions. Microcomputers have brought independence for the disabled closer because so many assistive devices are functionally dependent on computer software rather than expensive hardware ideally, prosthetic and communicative aids require customizing for individual needs. With the programming abilities of microcomputers, inexpensive software and standard devices such as plug-in memory modules, plug-in keyboard layouts, and modular display or audio-output options, the severely disabled individual is able to participate more fully in the mainstream of society. The aids discussed in this text are but a few of the products of the creativity in design boosted by the microcomputer.

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