Comparison of Computer Interface Devices for Persons With Severe Physical Disabilities

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This research employed a descriptive case study design to compare subjects' performance using three computer input devices: the Tongue Touch Keypad, the Head-Master, and the mouthstick. The sample consisted of four students with severe physical disabilities enrolled in an adaptive computer class at a community college. Components of performance examined were input speed, accuracy, and level of perceived exertion. Subjects' acceptance of each of the interface devices was also examined. Results showed input speed to be the fastest with the mouthstick, followed by the Head-Master and then the Tongue Touch Keypad. Accuracy of input did not vary significantly. Three subjects rated the Tongue Touch Keypad as requiring the lowest rate of perceived exertion, followed by the Head-Master and then the mouthstick. Overall performance did not necessarily affect subjects' acceptability ratings of the devices. Information from this study will assist therapists in evaluating the effectiveness and desirability of computer interface devices for patients.

With the recent advances in adaptive computer technology, persons with severe physical disabilities can have improved access to environmental controls, education, work, and leisure (Bryant, 1989; Dickey & Shealey, 1987). Computer access training during rehabilitation for persons with quadriplegia allows independent performance of some activities of daily living (O'Leary, Saxena, Linder, & Perkash, 1990). Daily activities include written communication, environmental control, recreational pursuits, financial planning, and information retrieval (Vanderheiden, 1987). In one computer-skills training program at a rehabilitation facility, inpatients with severe disabilities were observed to attain psychological benefits such as increased self-esteem, social interaction, and expressed enthusiasm for newly acquired computer skills (Links & Frydenberg, 1989).

In the last 5 years, many computer interface devices have become commercially available to persons with disabilities. Adaptive devices range in price from $30 for a mouthstick to $12,000 for a voice-activated system (Mann & Lane, 1991). It is important for therapists to know the usefulness of these devices for the intended population before recommending that their patients invest time and money on the device. Only 10% of computer-related articles found in occupational therapy periodicals were reports of research (Angelo & Smith, 1993). A review of the literature revealed few comparison studies on the performance of computer interface devices. In addition, there has been limited investigation of the attitude and personal acceptance of a person with severe disabilities toward head-operated computer interface devices.

A patient with a C-4 spinal cord injury at the Veterans Hospital in Richmond, Virginia, described his personal experiences in evaluating various interfaces. “For a high level quadriplegic, being able to access and use a personal computer efficiently is only the first step; the ultimate goal is vocational training that could lead to meaningful employment. Taking full advantage of the available technology and pursuing it to the fullest is a significant personal accomplishment” (Bryant, 1989, p. 7).

The recent boom in computer technology can provide valuable tools for the rehabilitation and treatment of persons with disabilities. Burkhead, Sampson, and McMahon (1986) claimed that providing access to computer technology is as important as providing architectural accessibility. Computer technology is pervasive in many aspects of daily life, such as education, employment, and banking. Without devices to access computer technology, persons with disabilities will be further excluded from society (Burkhead et al., 1986).

There are many computer interface devices on the market for persons with disabilities. The diversity of input and output devices makes the computer readily accessible to persons with orthopedic dysfunction as a result of congenital, developmental, or traumatic causes (Spicer & McMillan, 1987). Literature about performance by per-
sions with severe disabilities on computer interface devices is limited. Only two published studies have investigated computer interface performance. A single-subject research design measured typing scores of the Long Range Optical Headpointer (Smith et al., 1989). Another single-subject experimental design compared computer scanning modes for persons with cerebral palsy (Angelo, 1992).

"The widespread use of computers has increased employment opportunities for many individuals with disabilities" (Enders & Hall, 1990, p. 221). With worksite adaptation including adaptive interface devices and specialized software, jobs that require use of a computer can be accessible to persons with quadriplegia. Technology combined with an appropriate training program will reduce the physical demands of a job so that persons with physical disabilities can compete in the job market.

Besides the influence on the functional capacity of a person with a disability in a vocational setting, technology can greatly influence avocation performance. Play, recreation, and leisure are important parts of the learning process and technology can provide more normalized access to these activities (Enders & Hall, 1990). Leisure skills through computer games, graphic programs, and desktop publishing applications can be made possible by adaptive computer equipment (O'Leary, Mann, & Perkins, 1991).

In the arena of technology, the primary challenges faced by occupational therapists are to develop knowledge related to technology application, to contribute in the design and development phases, to promote patient acceptance and use, and to systematically evaluate the appropriateness of products and treatment approaches (Lawlor, 1991). Vanderheiden (1987) reported the importance of appropriate therapy and training with any selected rehabilitation technology. The patient needs training not only in the operation of the technological aid, but also in its effective use to meet his or her needs. This adaptive technology, along with proper training, will increase the quality of life of persons with severe disabilities by allowing them to participate in life roles and increasing their opportunity to become more independent persons.

To date, there are few studies on the acceptability of high technological adaptive devices by persons with disabilities. Personal acceptability is defined as the extent to which the consumer is psychologically comfortable in using the device in public or private, including the cosmetic appearance of the device (Batavia & Hammer, 1993). Occupational therapists who adopt new technology need to conduct research to evaluate its performance. Descriptive studies may be used to assess use and acceptance (Lawlor, 1991).

The purpose of this study was to compare the performance of persons with severe physical disabilities on three interface devices specifically designed for this population. These devices were a mouthstick¹, HeadMaster², and Tongue Touch Keypad³. This study also examined the acceptability of the device for the person with a disability. Degree of acceptability will affect how much a person will use the interface in daily life.

Method

Subjects

This descriptive case study recruited subjects from local agencies and schools that serve persons with disabilities. Potential subjects were interviewed by the researcher to ensure that they demonstrated and met the following study criteria:

- adequate vital capacity to operate a sip-and-puff device as measured by the ability to blow enough air into the switch to make a selection on the computer
- sufficiently observed tongue tip elevation, retraction, and lateralization for using the tongue switch
- ability to hold a mouthstick with a sustained bite for at least 30 min
- tolerance for an upright position in wheelchair for a minimum of 3 hr
- enrollment in high school with at least a 2.0 grade point average
- adequate cervical range of motion to operate the mouthstick and HeadMaster.

Four subjects were selected for the study. All had severe physical disabilities involving their four extremities, were male, and were between the ages of 17 and 21 years. Two of the subjects (B and C) had spinal cord injury at the C-5 level and the other two subjects (A and D) had Duchenne type muscular dystrophy.

The subjects had varied computer experience but no experience with two of the computer interface devices used in this study, the HeadMaster and Tongue Touch Keypad. Each subject was using a different typing aid—the flexor hinge splints with a typing clip, bilateral universal cuffs, built-up pens, and a regular pencil with eraser tip—and each reported that his typing aid was ineffective or physically tiring. After meeting subject criteria, they were enrolled in the Adaptive Computer Application class at Foothill College in Los Altos, California so that they could receive college credit for their participation in the study.

Interface Devices Used in Study

The mouthstick and HeadMaster interface devices were chosen to compare performance of low-technology ver-

1Manufactured by Adalab Incorporated, 5142 Bolsa Avenue, Suite 106, Huntington Beach, CA 92649.
2Manufactured by Proline Ronich, 1022 West Road, Wooster, OH 44691.
3Manufactured by Nis Ablines System (formerly Zephyr Incorporated), 1940 Galow Street, #2, Mountain View, CA 94043.
sus high-technology aids, given their different cost and training requirements. The third device, the Tongue Touch Keypad, was selected because it had infrared technology similar to that of the HeadMaster but required a different anatomical site for input.

The mouthstick is often prescribed by occupational therapists for direct selection on the computer keyboard (see Figure 1). The AdLib mouthstick used in the study was made of lightweight aluminum with a rubber Y-shaped bite plate. Its bendable distal end was used to type on a standard keyboard. When not using the mouthstick, the subject placed it on the clamp-on docking station.

The HeadMaster consists of a lightweight ultrasonic headset and pneumatic switch connected to a sending unit above the computer (see Figure 2). In the study, it was used as a mouse emulator in conjunction with the WordWriter 1.0' virtual keyboard. The subject moved the cursor on the screen by using the headset and selected characters on the virtual keyboard by puffing into the pneumatic switch. The word prediction feature on the virtual keyboard was not used in the study because it could not be used with a mouthstick.

The wireless Tongue Touch Keypad is a viable interface device for a person with limitations in head mobility and all extremities, because it is operated by intraoral tongue movements. The 1991 prototype Tongue Touch Keypad, version 90.12 (the one used in this study), is a battery-operated radio frequency transmitting device similar in appearance to an orthodontic retainer. It contains nine Braille keys selected by elevating the tongue tip to the roof of the mouth. The Tongue Touch Keypad

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*Manufactured by McIntyre Computer Systems, 22809 Shaghark, Suite 101, Birmingham, Michigan 48010.*
activates a controller that sends infrared signals to the computer (see Figure 3).

As with the HeadMaster, the Tongue Touch Keypad was used in our study as a mouse emulator in conjunction with the WordWriter to select characters on the screen. The tongue was used to press a key that corresponds to a specific direction on the virtual keyboard. Once the cursor was on the desired character, it was selected by pressing the middle key of the Tongue Touch Keypad.

Procedures and Measures
Subjects were seen for a 2 1/2-hr session once a week for 12 weeks. Before their performance on the three devices was measured, they were required to reach a baseline performance level defined as the ability to type a sentence containing letters, numbers, and symbols keys within 15 min with 80% accuracy. To reach the baseline, subjects were given a maximum of 3 hr of instruction and training on each device. Each subject was trained and tested on the mouthstick first, HeadMaster second, and Tongue Touch Keypad third. Training continued for each device until baseline was achieved and then measurements were taken on each device. Training averaged 30 min for the mouthstick, 60 min for the HeadMaster, and 2 1/2 hr for the Tongue Touch Keypad to achieve the baseline performance. The subjects used the mouthstick for approximately 3 weeks, the Headmaster for 4 weeks, and the Tongue Touch Keypad for 5 weeks in training, testing, and measurements.

Three performance components were measured: speed of text input, accuracy, and level of perceived exertion.
Dental acrylic molded to fit against the hard palate

Figure 3. Tongue Touch Keypad and computer station.

TongueTouch Keypad

Teeth clasps

TongueTouch™ Keypad

Personal Computer

ComputerLink

RF Receiver, Display and IR Transmitter

Zofcom Controller

tion. Speed of text input was measured by the number of characters typed per minute in typing tests taken from a standard typing book. Accuracy rate was determined by the number of characters correctly entered divided by the total number of characters entered per minute. Nine speed and accuracy typing tests lasting 3 min each were given for each device in the 12-week period. The rating of perceived exertion using the Borg’s scale (1982) was given after speed and accuracy testing and before the questionnaire on personal acceptability. Typing drills lasting 30 min were given with 10-min interval ratings of perceived exertion for the computer activity. After training and testing were completed, a questionnaire composed of Likert-type questions regarding personal acceptability of each device was administered.

Results

Accuracy

There were no significant differences in accuracy of input for three of the four subjects. Subject A had lower accuracy using the Tongue Touch Keypad, averaging 89% when
compared to the mouthstick (96%) and HeadMaster (98%). The other three subjects performed with all three interface devices with no accuracy scores below 92%.

**Speed**

Subjects performed the fastest with the mouthstick, averaging 40 characters per minute, and second fastest with the HeadMaster averaging approximately 20 characters per minute (see Figure 4). The slowest input was with the Tongue Touch Keypad. Subjects also had the most difficulty learning to use the Tongue Touch Keypad, which required learning to elevate the tongue to the roof of the mouth to activate separate distinct keys. There was a relation between how long each subject took to learn to use the Tongue Touch Keypad and how fast each subject performed with it. For example, subject B used the Tongue Touch Keypad quickly, averaging about 17 characters per minute. This subject reported that he had a very mobile tongue and that it was easy for him to isolate the keys. In contrast, subject A was not able to achieve the baseline performance with the Tongue Touch Keypad. During a maximum 3 hr of training, subject A entered only approximately 2.3 characters per minute. His problems in locating the separate keys were related to the limited elevation and flatness of his tongue.

**Rate of Perceived Exertion**

Subjects B, C, and D rated the Tongue Touch Keypad as requiring the least amount of exertion over a 30-min work period because it required no head movement, controlled respiration, or sustained bite. They also rated the mouthstick as requiring more exertion than the Tongue Touch Keypad but slightly less exertion than the HeadMaster. Subject A rated the Tongue Touch Keypad highest in perceived exertion because he had difficulty localizing keys with his tongue. He rated the HeadMaster as requiring slightly less exertion than the mouthstick over 30 min of computing.

**Acceptability**

Information from the questionnaire on acceptability revealed that all four subjects preferred the Tongue Touch Keypad to the HeadMaster and mouthstick. They cited the minimal physical energy required for use, the aesthetics of a wireless system, and the comfort level of the Tongue Touch Keypad as determining factors. Opinions on the second preferred interface device were divided equally between the HeadMaster and the mouthstick. Subjects C and D preferred the HeadMaster because it did not interfere with speech or cause discomfort in the jaw from a sustained bite. Subjects A and B liked the mouthstick better than the HeadMaster because it performed faster and did not cause neck strain. Although the mouthstick averaged 40 characters per minute, subject A entered only approximately 2.3 characters per minute. His problems in locating the separate keys were related to the limited elevation and flatness of his tongue.

Figure 4. Subjects' input speed on the three interface devices. TTK = Tongue Touch Keypad.
Discussion

The goal of this study was to compare the performance of four persons with severe physical disabilities on three computer interface devices. Accuracy, speed of input, level of perceived exertion, and acceptability are relevant usage components for adaptive devices in daily activities. No difficulties were evident in producing equivalent accuracy ratings on all three devices. The subjects paced themselves and performed at a speed that produced high accuracy ratings.

All four subjects rated the Tongue Touch Keypad very high on personal acceptability. The ages of the subjects may be an indicator for the high approval of the Tongue Touch Keypad's cosmetic appearance. The Tongue Touch Keypad does not require visible body movements. Most young adults are more concerned about their physical appearance than about any other aspect of themselves (Papalia & Olds, 1986). Younger people may be more concerned about their appearance than about their productivity level while using the computer in an educational setting. Nevertheless, the high acceptability ratings for the Tongue Touch Keypad reminded occupational therapists that the body movement required to use an access device must be personally and socially acceptable to the user.

There were some common advantages and problems noted for each device. Use of the Tongue Touch Keypad required adaption to the intraoral device in order to speak clearly. Subjects initially complained about the size of the Tongue Touch Keypad but adapted after approximately 1 hr of wear. Because the movement of tongue-tip elevation seemed to be more difficult to isolate and control than head movements, the Tongue Touch Keypad was the slowest input device for three subjects. The Tongue Touch Keypad required an assistant for setup and insertion into the user's mouth.

The HeadMaster required assistance for donning the headset. All the subjects complained of pressure from the headset. Securing the headset without creating uncomfortable pressure is a key element for tolerance of this device. To support the HeadMaster and avoid excessive strain and fatigue, the user must have strong neck muscles. The high ratings of perceived exertion from three of the subjects may be different for a population with a cervical injury located higher on the body who would use their neck muscles throughout the day. The current HeadMaster model uses infrared and has no wire connection to the computer. It can be wired into the electric wheelchair battery to allow independent access once the headset is donned. This newer model was not available at the time of the study.

The mouthstick, rated most unattractive by the subjects, produced the highest input speed. It was the least expensive of the three computer interfaces and can easily be used on any standard keyboard without a specialized software program. With a mouthstick and docking station, a person can be set up for independent access to a computer. Additionally, the neck flexion required for mouthstick use was less demanding than the head lateral flexion and rotation needed to use the HeadMaster for three of the four subjects. The noncustom biteplate of the mouthstick used in this study may be more difficult to tolerate for an extended period of use than a customized biteplate. Additionally, there can be potential joint, bone, and soft-tissue damage over time, especially with poorly fitted mouthsticks (Smith, 1989).

Each subject had different expectations and priorities of what technology could provide. Subject A expressed interest in using the mouse function primarily for art work, subject B was interested in playing video games with his brothers on the computer, subject C wished to increase his computer input speed for a potential job, and subject D wished to use the computer for reaching educational goals. Depending on the individual computer needs and goals of the person with a physical disability, accuracy, speed, level of perceived exertion, and personal acceptance may vary as priorities.

Study Limitations

One concern about the results derived from this study was that subjects were not solely dependent on head movement for a reliable access site: they had some severely limited upper extremity arm function. Subjects with only head movement may have a different perception of both the exertion and acceptability of the devices. The study compared performance on direct and virtual input methods. Typically, a direct method is preferable to an indirect virtual or scanning method of computer input because the indirect method requires special software and may reduce input speed. Time constraints of the study limited training time and testing trials. With more practice, the subjects might have shown a trend toward improved input speed.

Implications

There are several implications from this study for occupational therapy. One implication concerns the occupational roles and goals of the person with a disability. Persons with spinal cord injuries in their home community have excessive free time, a higher rate of unemployment, and decreased life satisfaction compared to persons without disabilities (Yerxa & Locker, 1990). Computer skills and activities can provide an occupational role as a volunteer, employee, or student. In this age of technology, occupational therapists can include computer activity in a rehabilitation plan. Computers can be a powerful tool and
adaptive aid in the rehabilitation, employment, and fulfillment of social roles for persons with severe physical disabilities.

Training students who have severe physical disabilities to use a computer will give them an opportunity to reach educational and vocational goals that can facilitate the transition to adult roles, such as college student or employee. Before training patients on computers, more exploration must be completed on the different types of computer interface devices available, how well they work for the designated population, and why they work.

Another implication for practice concerns the finding that, when matching patients with interface devices, it is important to explore the patient's values and the personal acceptability of the device. Therapists who often prescribe wheelchairs, adaptive home equipment, and now computer interface devices must be careful not to give a workable piece of equipment to a patient who will rarely or never use it because it is not personally acceptable. The importance of aesthetics, physical comfort, and psychological comfort must be considered. As shown in this study, the best performing interface device may not be the most acceptable to the user. Every subject had personal goals for computer access and for fulfilling different roles in social, work, and leisure settings. Occupational therapists must know the patient's goals and the settings in which the patient will use the computer most often before recommending a system that may be too extensive and expensive for the patient's needs.

Rehabilitation services and private insurance companies have been reluctant to invest in computer interface modifications without objective evidence that the device will be effective in facilitating the patient's educational or vocational program (Britell, 1991). The cost of interface devices was not addressed formally in this study by did emerge as a concern of all the subjects. Although they were introduced to three interface systems, and showed interest in their continued use, they did not necessarily have the financial resources to purchase the HeadMaster or Tongue Touch Keypad.

Occupational therapy that incorporates computer access training can provide work endurance and psychological, cognitive, and occupational behavior information to the rehabilitation team. Speed, accuracy of data input, perceived rate of exertion, and personal acceptability are important in examining the patient's needs. Occupational therapists can provide relevant information to rehabilitation technology engineers and manufacturers, which can lead to improvement in existing interface devices.

Therapists know that computer-related equipment can benefit patients, but the general effect of this equipment on different disabilities and age groups has not been documented (Angelo & Smith, 1995). Research is needed that validates the effective use of computer-related equipment in improving the quality of life for persons with disabilities. Also needed is continued research on the effectiveness, performance, and acceptability of computer interface devices. Some areas to consider are a comparison of direct selection methods, an examination of the effects of long-term mouthstick use, a comparison of input speeds using word prediction function, and a survey of interface devices in use by working adults. Further research in adaptive computer technology will better assist the population of persons with severe physical disabilities to reach their personal and work goals and fulfill life roles.

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