Objective. Functional written communication, an important goal in the rehabilitation of persons with tetraplegia, frequently is met through the use of personal computers and alternative computer access systems. To make informed decisions about alternative access systems, the therapist needs information on the efficacy of the available choices. The purpose of this study was to investigate the effectiveness of two commercially available systems for text entry, the traditional mouthstick and the Prentke Romich HeadMaster.

Method. Participants were a 25-year-old man and 76-year-old woman who both functioned at a C5 neurological level. Neither participant had previous experience with either system for text entry. A single-subject research design was used whereby Participant 1 experienced six phases of treatment (i.e., CBCBCB, where C = mouthstick and B = HeadMaster), and Participant 2 experienced four phases of treatment (i.e., BCBC).

Results. Participant 1 achieved a maximum rate of text entry of 5.85 wpm with both the HeadMaster and the mouthstick, whereas Participant 2 achieved a maximum rate of 7.15 wpm with the mouthstick and 4.85 wpm with the HeadMaster. Results from this study were similar to the results from previous comparison studies of persons with severe disabilities who had no experience with alternative computer access systems.

Conclusion. Both participants were able to use both systems successfully; however, their respective rates of text entry were too slow to be functional in most employment situations.

Because of advances in medical technology, persons with spinal cord injury (SCI) are more likely to survive and to live longer than they would have in the past. The National Spinal Cord Injury Statistical Center (1997) reported on life expectancy for persons with SCI who survived the first 24 hours after injury. It reported that the mean life expectancy for persons with low tetraplegia (C5-C8) is 38.4 years for those in the 20-year age category, 22.4 years for those in the 40-year age category, and 9.1 years for those in the 60-year age category. In response to this improved survival rate, society has recognized the need to promote the independence of persons with physical limitations and their integration into the mainstream. New laws have mandated environmental accessibility, legislated work incentives and nondiscriminatory employment practices, and supported advances in technology (Krause & Crewe, 1991). The Rehabilitation Act Amendments of 1986 (Public Law 99-506) require that microcomputers used in government offices be accessible to all employees, regardless of level of disability. The Americans With Disabilities Act of 1990 (Public Law 101-336) requires employers to provide "reasonable accommodation" for workers with disabilities.
There are numerous alternative computer access systems commercially available that provide reasonable accommodation for persons with physical limitations. However, a review of the literature revealed limited discussion and minimal empirical evidence to support the comparative and relative benefits of such technology for persons with tetraplegia. Tetraplegia is a condition resulting in impairment of function in the arms as well as in the trunk, legs, and pelvic organs (Ditunno, 1992). Vanderheiden and Yoder (1986) agreed that the proper application of rehabilitation technology has great potential for persons with disabilities, yet there is also evidence that the misapplication of these technologies can lead to a waste of monetary and human resources. Proper selection and successful use of alternative computer access systems enable persons with tetraplegia to use computers and potentially improve occupational performance in both vocational and avocational activities. Occupational therapists need more information to help their clients evaluate and select appropriate technologies.

Persons without disability generally use a keyboard and mouse to access the computer. These same tools that provide access to persons without disability are substantial barriers to persons with tetraplegia. When providing access to the computer for a client with tetraplegia, the clinician must provide an alternative input system.

Persons with tetraplegia may use any of a wide range of alternative computer access systems that are commercially available to produce written communications. The rehabilitation literature discusses high-technology systems such as keyboard and mouse emulating interfaces, eye-tracking and eye-gaze systems, Morse code input methods, voice input, and single-switch and dual-switch scanning systems. Recent literature generally describes the standard mouthstick as an inexpensive, low-technology assistive device commonly used to improve functional communication and recreational skills. A mouthstick can be used for writing, turning pages, typing, dialing a telephone, moving and repositioning small, lightweight objects; and completing computer input tasks (Angelo, 1997; Angelo, Derending, & Weisman, 1991; Anson, 1997; Lau & O'Leary, 1993; Smith, 1991; Tinnelly, 1995).

Although all these systems are of some use, only limited research has compared the effectiveness of high-technology versus low-technology systems. Using single-subject research methods, Smith et al. (1989) compared the effectiveness of a text-input system with the traditional mouse-and-keyboard and a Trace Long-Range Optical Pointer (LROP)™ and 10-Branch Abbreviation Expansion™1, which allows a user to type by aiming a light pen at the computer screen from several feet away. Participants included a heterogeneous group of five volunteers, including four with severe disabilities and one without disability. Three participants with SCI had no writing method available to them other than dictation transcription; one participant with polio had "excellent head, neck, and trunk motion" (p. 53) and was very familiar with the mouthstick. During each of six sessions (3-5-min duration), the participant experienced with using a mouthstick typed a typical business letter at a text-entry rate ranging from 17 wpm to 24 wpm. It was not clear whether this participant's success was attributable to his mobility, his experience with the mouthstick, or to other factors.

The Prentke Romich HeadMaster™2 and FreeWheel™3 allow the user to apply interfaces that work in conjunction with an on-screen keyboard to operate the actual keyboard and mouse functions. Angelo et al. (1991) compared speed of input between the LROP and the FreeWheel on an IBM-compatible computer and the HeadMaster on a Macintosh computer. Findings showed that speed and accuracy were higher when using the LROP or HeadMaster interface systems and lower when using the FreeWheel. Rate of text entry with the HeadMaster varied from approximately 3 wpm to 10 wpm.

More recently, Lau and O'Leary (1993) reported results from a descriptive case study completed with four students with severe physical disabilities, including two with C5 SCI and two with Duchenne muscular dystrophy. Dependent variables were speed (characters per minute [cpm]) and accuracy, as measured by 3-min typing tests. The study compared the participants' performance using the mouthstick, the HeadMaster, and the NewAbilities Tongue-Touch Keypad™4 and found no significant differences in accuracy of input for three of the four participants. The participants performed fastest with the mouthstick, at approximately 40 cpm or 6.6 wpm, and second fastest with the HeadMaster, which averaged approximately 20 cpm or 3.3 wpm.

Shafer and Hammel (1994) studied three consumers' preferences of three adaptive computer access devices (i.e., commercial, lightweight, telescoping mouthstick; HeadMaster; Tongue-Touch Keypad). All participants had high-level SCIs and used each device for 1 month. After using all devices, participants rated each device on five aspects of performance and usability. The mouthstick was rated highest on ease of installation and setup, and the Tongue-Touch Keypad was rated highest on comfort level, sensitivity of the device, and aesthetics. The HeadMaster was rated the lowest on comfort level and sensitivity. Additionally, data were collected, but not reported, on speed and accuracy of text entry and cursor manipulations. The authors further

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1For information on the Trace Long-Range Optical Pointer™ and 10-Branch Abbreviation Expansion, contact Trace Research and Development Center, S-151, Weisman Center, University of Wisconsin Madison, 1500 Highland Avenue, Madison, Wisconsin 53705.

2HeadMaster is now upgraded to HeadMaster Plus and is available from Prentke Romich Company, 1022 Heyl Road, Wooster, Ohio 44691.

3FreeWheel is available from AbiliTech, Inc., PO Box 659, Thief River Falls, Minnesota 56701.

indicated that positioning was an important variable and concluded that assessment data such as those reported in their study are important in “continuing to produce and provide quality, reliable computer access options to consumers with disabilities” (p. 396).

When working with a client to select appropriate technologies for computer access, it is important for the therapist and client to have knowledge about the relative strengths and limitations of various systems. As previously described, the rate of text entry is a commonly considered variable. In addition, it seems logical to consider accuracy in text entry because errors can be time consuming to correct and can lead to communication misunderstandings. In this era of cost containment, price of equipment must also be considered.

The purpose of this study was to investigate the effectiveness (i.e., speed and accuracy of text entry) of two systems. One was a relatively high-cost, high-technology system, the Prentke Romich HeadMaster. The second was a relatively low-cost, low-technology assistive device, the Fred Sammons Telescoping Mouthstick\textsuperscript{TM}. In rehabilitation clinics, persons with disabilities use both systems for functional text entry.

The present study was designed to answer the following questions:

1. Is there a difference in the rate of text entry (i.e., wpm of completed text) with use of the HeadMaster system compared with the mouthstick?

2. Is there a difference in percent accuracy (i.e., number of words containing errors, total number of words of completed text) with use of the HeadMaster system compared with the mouthstick?

In addition to these research questions, the participants were asked to identify favorable and unfavorable characteristics of the HeadMaster system and the mouthstick.

Method

Participants

Two adults from the rehabilitation population at Good Samaritan Hospital in Puyallup, Washington, participated in this study. Neither had previous experience using the HeadMaster system or the mouthstick.

Participant 1 was a 25-year-old man who had sustained a C5 SCI as a result of a motor vehicle accident. He completed inpatient and outpatient rehabilitation and, at the time of this study, was 2 years postinjury. He attended SCI clinic for regular follow-up. Participant 1 had limited anti-gravity upper-extremity strength in the shoulders and elbow flexors and no distal upper-extremity function. His injury was classified by the American Spinal Injury Association (Ditunno, 1992) as B, indicating that he had a motor complete and sensory incomplete lesion. He had intermittent problems with spasticity in both upper and lower extremities but was able to feed and groom himself with setup and use of bilateral wrist cock-up splints with universal cuffs and adaptive equipment. Participant 1 was dependent in all remaining areas of daily living activities, except he independently used a local shuttle that was part of the public transportation system. At the time of this study, Participant 1 lived in an apartment with a full-time caregiver. Before his injury, he had graduated high school and was employed as a forestry worker. His experience with typing or computer use included a computer programming class in high school and limited instruction on a computer drafting program. He was interested in learning computer skills for possible vocational endeavors.

Participant 2 was a 76-year-old woman who, at the age of 74, experienced onset of Guillain-Barré syndrome, an acute, rapidly evolving form of polyneuropathy characterized by muscular weakness beginning in the distal muscles and ascending rapidly over the entire body (Fredericks & Saladin, 1996). She plateaued with a neurological level of function equivalent to C5 for her right upper extremity and C6 for her left upper extremity. She had limited shoulder motion and elbow flexion, with proximal and distal joint contractures and limited range of motion (ROM) that inhibited the use of available muscle strength. Participant 2 completed inpatient and outpatient rehabilitation and was able to feed herself with minimal assistance and adaptive equipment. At the time of this study, she was 1 1/2 years postonset, lived in her own home with full-time caregivers, and independently used the public transportation system. Participant 2 graduated high school, completed 1 year of business college, and retired after 30 years as an accounting clerk and auditor. During her career, she had used a manual typewriter and, later, an electric typewriter. She was interested in using a computer for writing to friends and family members.

Instruments

Access systems. Participant 1 used the Prentke Romich HeadMaster and the Fred Sammons Telescoping Mouthstick, and Participant 2 used the Prentke Romich HeadMaster Plus\textsuperscript{TM} and the Fred Sammons Telescoping Mouthstick. Both participants used the smallest mouthpiece commercially available for the mouthstick. The original HeadMaster and the HeadMaster Plus are high-technology computer accessibility interface head-pointing systems that emulate the mouse. For text entry, these systems need to be used with a separate program called an on-screen keyboard. The HeadMaster and HeadMaster Plus differ only in the con-
struction of the headset. In this study, the HeadMaster headset was connected to an interface receiver box placed on top of the computer monitor. In addition, a puff tube consisting of a dentist's suction tip in conjunction with a pneumatic pressure switch was mounted on one side of the headset. The participants held the puff tube with lip pressure in their mouth. Puffing on the tube produced a click of the mouse button. The participant watched the computer screen and moved his or her head up, down, or side to side to move the standard mouse pointer. The features of the HeadMaster Plus are the same as those of the original HeadMaster, except the headset is more adjustable, lighter in weight, and better padded.

The HeadMaster control unit, which determines how much cursor motion results from a given amount of head motion, was placed on top of the computer monitor. To produce approximately equal head motions for the HeadMaster and mouthstick, specific settings were predetermined so that the ROM required for on-screen keyboard access was as close as possible to the ROM required for mouthstick keyboard access. The HeadMaster control unit sensitivity was set at low (i.e., the lower responsiveness to both intentional and extraneous movement) and the Macintosh mouse control panel was used to set the mouse tracking speed at 1 (1 = slow, 4 = fast).

For text entry, the participants used ScreenKeys™, an on-screen keyboard that looks and acts like a standard computer keyboard. To select a character, the user points to a character on the on-screen keyboard using the HeadMaster headset and puffs into the suction tip of the puff tube to activate the pneumatic switch. Both participants required physical assistance from the investigator to set up the HeadMaster.

The other device studied was the Fred Sammons Telescoping Mouthstick, which weighs 2.2 oz. It consists of an intraoral portion (mouthpiece) designed to fit small or medium mouth sizes and is held between the upper and lower teeth. The mouthpiece is covered with a disposable plastic sleeve for hygienic purposes. An extraoral, telescoping aluminum shaft is attached to the anterior portion of the mouthpiece and extends from the user's mouth. The shaft length is adjustable from 16 in. to 23 in., is angled at the terminal portion, and includes a rubber tip. The user moves his or her head to move the distal end of the mouthstick to the appropriate keycap on the standard computer keyboard and presses downward for direct selection.

The process to select a common or preferred type of mouthstick for this study involved a mail survey, which was completed with 100% return rate from six rehabilitation centers in Washington State. Five rehabilitation centers reported use of the mouthstick as a treatment modality for persons with tetraplegia in order to improve independence. Four of these five rated the Fred Sammons Telescoping Mouthstick as the most preferred and commonly used commercially available mouthstick. Only two of the five centers reported that they have custom-fitted mouthsticks for long-term users.

**Computer system.** Both systems previously described were used with an Apple Macintosh LC™ computer equipped with System 7.1 software. The computer system contained an 80-MB hard disk, a 12-in. Apple RGB Color Monitor™, and an Apple Keyboard [IT™ with standard QWERTY layout. The Kensington Turbo Mouse Trackball Version 4.0™ was connected between the computer keyboard and the HeadMaster control unit. Though it was not used by either participant, the trackball enabled the investigator to quickly make necessary adjustments to setup, manage menus and files, and manipulate the screen before and during the session without interfering with the participants' performance.

**Software.** Macintosh System 7.1 has an extension called Easy Access that includes a software keylatch called "sticky keys." This feature allows one key function to input uppercase characters or dual-key functions. More specifically, sticky keys allows the user to select the shift key one time to type in uppercase, then automatically returned to lowercase for subsequent letters until the shift key is pressed again. To lock capital letters, the user selects the shift key twice, and all subsequent letters are capitalized until the user selects the shift key one time to turn off the capital lock feature. The HeadMaster was used in conjunction with a separately installed program called ScreenKeys to display an on-screen keyboard. The on-screen keyboard program automatically activates and uses its own sticky keys function.

Microsoft Word 5.1™ was used for text entry with both computer access systems. The word and character count feature counts the characters of completed text, including letters, numbers, punctuation (i.e., period, comma, quotation mark, apostrophe, colon, question mark), tabs, spaces, and returns. The character count of completed text excludes the shift, arrow, and delete keys. OmniProof Software Version 1.02™ was used to detect errors and score accuracy by identifying the differences between the participant's text file and a correct text file.

During each session, participants copied typed narrative from a typewriter to the computer, typed narrative to a typewriter, typed narrative to dictation software, and typed narrative to a computer keyboard.
Specific reading grade levels of the text to be 6.9 to 7.9 according to reading level and content. Thunder 7.0™ and GhostWriter Macintosh Version software determined the specific reading grade levels of the text to be 6.9 to 7.9 Flesch grade reading level.

Positioning
An experienced occupational therapist positioned each participant ergonomically at the computer workstation for use of each system. The participant sat upright with hips flexed at 90° to 100° in his or her own wheelchair in front of a computer terminal, which was placed on an adjustable-height table. The table height was adjusted so that the line of sight from the participant to the center of the top of the display was at or below eye level. The top of the monitor was positioned at a distance 20 in. to 30 in. from the participant's eyes. The pretyped narrative text was placed to the left and in the plane of the computer screen.

For mouthstick use, the workstation was adjusted so that the participant used the mouthstick to strike the keys on the keyboard within a maximum of 60° neck rotation and a maximum of 30° active neck flexion or extension. A goniometer was used to determine these degrees of movement. A standard keyboard was placed on the tabletop and adjusted at a slight 15° to 20° incline. A docking station was not used in this study. The investigator held the mouthstick before and after each session. Before each session, the workstation was measured and set up according to the criteria just described.

For use of the HeadMaster, the control settings were adjusted so that the ROM required for on-screen keyboard access was as close as possible to the ROM required for the previously stated goniometric measurements. The workstation was adjusted and set up according to previously described, except the control unit was placed on the monitor and was 28 in. to 30 in. from the headset microphone.

Procedure
Before data collection began, the participants completed three 60-min sessions that included an introduction, setup of the workstation to provide ergonomic positioning, and training on use of both input systems. The participants received instruction and practice in the use of the HeadMaster and mouthstick, but training did not include other operations of the computer, such as menu or file management. The training sessions allowed the investigator to demonstrate the input systems and answer questions. Further, the sessions allowed the participants to practice using the input systems. On completion of the training sessions, the participants were administered a competency test that evaluated their ability and readiness to perform the minimum requirements for both systems of text entry.

Intervention sessions were scheduled and executed 6 consecutive days per week, extending over 6 weeks (36 sessions) for Participant 1 and 4 weeks (32 sessions) for Participant 2. However, data for Participant 2 are reported for only 31 sessions because data were lost due to a power failure during the sixth session of Phase 1. Each session lasted 20 min. Participants completed six to eight consecutive sessions using one intervention (e.g., mouthstick), then alternated to use the other intervention (e.g., HeadMaster) for the next six to eight consecutive sessions. After the final session, the investigator asked the participants five open-ended questions regarding both favorable and unfavorable characteristics of each system.

Instructions for participants were standardized for each session. As the investigator pointed to the first word, she said, "Type exactly what is written on this page, starting here. Work as quickly and accurately as possible. Ready, set, go." The investigator informed the participant when he or she had 10 min and 5 min left to work.

Procedural Consistency
Procedural consistency (Billingsley, White, & Munson, 1980) for workstation setup, procedural instructions, and process to obtain data was monitored three times per week (56% of the sessions) by a person not involved in the study. The point-by-point agreement ratio (Kazdin, 1982) was used to determine whether there was agreement on each occurrence of the observed behavior listed on a procedural consistency checklist developed specifically for this study. Average procedural agreement for all sessions was greater than 99%.

Research Design
A single-subject design (Kazdin, 1982) was planned such that each participant would experience four phases of treatment, with each phase extending for 6 days. For Participant 1, the design was CBCB (where C = mouthstick and B = HeadMaster), and for Participant 2, it was BCBC. However, after completing the designated four phases with Participant 1, a decision was made to continue for two more phases because it was believed that he had not had sufficient time to optimize his performance. Additionally, the therapist working with this participant believed that it was difficult changing phases after only six sessions and suggested extending phase lengths to eight sessions for Participant 2. The first input system used with Participant 1 was randomly selected; the alternate input system was used for Participant 2's first phase.

Results
Rate and percent accuracy of completed text were graphically displayed and visually analyzed for each participant.
separately. In addition, participants completed a questionnaire that asked them to identify favorable and unfavorable characteristics about each system.

**Participant 1**

Participant 1 performed at about the same rate of text entry with the mouthstick and HeadMaster (see Figure 1). The median rate of text entry per phase with the mouthstick gradually increased from 4.1 wpm for Phase 1 to 4.4 wpm for Phase 3 and 5.0 wpm for Phase 5. With the HeadMaster, the median rate progressively increased from 4.0 wpm for Phase 2 to 4.4 wpm for Phase 4 and 5.2 wpm for Phase 6. Participant 1's percent accuracy of completed text was high with both systems (see Figure 2), ranging from 94.3% to 100% (median = 98.9%) for the mouthstick and from 96.6% to 100% (median = 99.1%) for the HeadMaster.

**Participant 2**

With the HeadMaster, Participant 2's median rate for text entry increased from 3.0 wpm for Phase 1 to 3.9 wpm for Phase 3, initially typing at a slower rate than Participant 1. However, slight upward trends occurred during both Phase 1 and Phase 3 (see Figure 3). Participant 2's rate was slowest with the HeadMaster during the first session in which she required two readjustments and stated, "I'm a little nervous. I don't want to make mistakes."

Overall, Participant 2 typed at a higher rate with the mouthstick than with the HeadMaster. Her median rate of text entry with the mouthstick improved from 5.3 wpm for Phase 2 to 6.4 wpm for Phase 4. During the final mouthstick phase, her data appeared to plateau. At the change between Phase 2 (mouthstick) and Phase 3 (HeadMaster), her rate of text entry dropped approximately 2 wpm.

Participant 2's percent accuracy of completed text with the HeadMaster ranged from 82.5% to 95.4% (median = 92.1%). Her percent accuracy with the mouthstick was similar, ranging from 85.4% to 96.1% (median = 92.0%) (see Figure 4).

**Questionnaire Results**

After data collection was completed, the participants were administered a short questionnaire that included five open-ended questions. The questionnaire asked them to identify favorable and unfavorable characteristics of the mouthstick and HeadMaster systems, especially as related to accuracy and rate of text entry.

When given a choice regarding which computer access system they preferred to use, both participants chose the mouthstick, reporting that the mouthstick provided better control, making it easier to select characters. However, both believed that with more practice, the HeadMaster also would be a good choice for computer access.

When specifically asked about the HeadMaster system, Participant 1 reported that he liked it because he did not have to look down at the keyboard, and Participant 2 reported that she liked it because “it was completely new and different.” Participant 1 used the original HeadMaster headset and reported that it needed to be lighter and have improved fit with softer cushions. These modifications are available with the HeadMaster Plus. Participant 2 used the newly designed HeadMaster Plus headset and made no comments about its fit. However, she commented that it was difficult to properly adjust the mouthpiece. She re-

![Figure 1. Rate of text entry for Participant 1.](http://ajot.aota.org/pdfaccess.ashx?url=/data/journals/ajot/930028/)
quired assistance to don the headset and noted that it required considerable effort to get the pointer “in sync.” In addition, she reported that when she swallowed, it was difficult to control the air in her mouth, which caused her to double puff, resulting in errors.

When asked about the mouthstick, Participant 1 believed that he had more control in striking the keys on the keyboard and reported it to be “more accurate to hit the keys on the keyboard” compared with the HeadMaster. Even though he perceived his text entry with the mouthstick to be more accurate, percent accuracy of the completed text revealed minimal difference between systems. Participant 2 stated that she liked the mouthstick because she could independently put it in her mouth.

When participants were asked their opinions regarding the mouthstick, Participant 1 reported that it needed to be made out of lighter-weight material because it was hard to bite down and hold in his mouth. Participant 2 reported that the mouthstick needed to have a smaller mouthpiece and needed an adjustable bend in the shaft. She also stated
that after about 15 min of typing, her mouth began to fatigue. Neither participant reported fatigue with the HeadMaster system.

Discussion

The results of this study indicated that both participants were able to use the HeadMaster and the mouthstick for slow, but relatively accurate computer text entry. The results for rate of text entry were different for each participant, as Participant 1 typed at about the same rate with the mouthstick and the HeadMaster, and Participant 2 was faster with the mouthstick. Both participants initially typed at a slower rate with the HeadMaster; however, both demonstrated improvement over time. These results suggest that more practice and time were required to improve proficiency with both systems. However, the results, while favoring the mouthstick for one participant, did not clearly show that one system was better than the other.

Clinical Implications

Neither participant in this study had previous experience with either system for text entry. Participant 1 attained a maximum speed of 5.85 wpm with both the mouthstick and the HeadMaster, whereas Participant 2 attained a maximum speed of 7.15 wpm with the mouthstick and 4.85 wpm with the HeadMaster. Rates of text entry for these participants were similar to results from previous comparison studies for persons with severe disabilities who also had no previous experience with either system. Lau and O'Leary (1993) reported that participants with severe disabilities typed with the mouthstick at a rate of about 40 cpm, or approximately 6.6 wpm, and typed with the HeadMaster at a rate of 20 cpm, or approximately 3.3 wpm. In Angelo et al. (1991), seven of eight participants had no previous experience with the HeadMaster. These participants had severe disabilities and used the HeadMaster to enter text at rates from about 3 wpm to 10 wpm. It is clear that the rates of text entry for participants in the present study, as well as those in Angelo et al.'s study, would not be vocationally functional in a typical clerical job requiring speed of text entry. For some persons, however, this level of skill for speed and accuracy may be practical for some leisure or avocational pursuits.

The results from the present study and previously published studies indicate that the typing speeds are slow for persons with tetraplegia or other severe disabilities who have limited experience using computer access devices. Smith et al. (1989) found that more experience with a system may increase proficiency. The participant in their study had no upper-extremity function and had been using a mouthstick with an electric typewriter as a writing system for many years before the study. During the study, the participant typed at a rate of 17 wpm to 24 wpm with the mouthstick.

As previously discussed, the rate of text entry for both participants in the present study was not adequate to meet the typical speed requirements for competitive employment. This suggests that during vocational planning, vocational performance requirements and the person's actual speed of text entry need to be considered. The speed com-
ponent may need to be evaluated with various computer access systems and in conjunction with word prediction or abbreviation expansion software.

Because neither device functions only as a text input system, their use in other functions must be considered. For example, the mouthstick is useful for turning pages and dialing the telephone. Likewise, the HeadMaster is useful for performing mouse functions such as moving icons and making menu selections.

In addition to rate and accuracy of text entry, the endurance component should be evaluated as a possible side effect of prolonged use. Even though the endurance requirements in the present study were limited, Participant 2 indicated that after approximately 15 min of typing with the mouthstick, her mouth began to fatigue. Buckley (1957) found that improperly fitting mouthsticks cause several problems, including damage to the anterior teeth, eruption of the posterior teeth and eventually whole-mouth distortion, pain related to temporomandibular joint (TMJ) dysfunction, and fatigue. Several years later, Masterson and Lotz (1975) reported that use of any oral device for extended periods can cause TMJ dysfunction if the required mouth opening is greater than that in the physiological resting position (2–3-mm vertical opening).

In this era of medical cost containment, it is important to thoroughly evaluate a variety of options, considering the client's goals, vocational or avocational performance requirements, and financial situation. The outcome of this study suggests that there was a minimal difference between the high-technology and low-technology systems for text entry for adults with tetraplegia, and, consequently, the clinician should be cautioned against assuming that the high-technology option is the optimal solution. The client's subjective opinion about the equipment should also be considered. In this study, both participants chose the low-technology option as their preferred system for text entry. However, this should be viewed cautiously because use of the device for other computer functions was not evaluated.

Of concern even in this study, which extended over 36 sessions for Participant 1 and 32 sessions for Participant 2, is that it was not possible to make an optimal decision regarding a text-input system. For both participants, a slight upward trend was still evidenced in the final phase with the HeadMaster, suggesting that they had not reached their potential with this device. Therefore, the clinician should be cautioned about making final decisions during brief evaluation sessions. Instead, rental or loan of expensive text-input systems should be considered to extend the evaluation period and enable trials in the client's home and work environments.

**Study Strengths and Limitations**

Four strengths were identified in this study. First, both participants completed all scheduled sessions. The 20-min sessions were long enough to realistically accomplish a reasonable amount of text entry, yet short enough to avoid excessive fatigue and discontinuation or refusal of future sessions. Second, the single-subject design controlled for the possibility of changes in physical status affecting the results. Third, neither participant had previous experience in text entry with either system, which decreased the possibility of preconceived opinions and device preference that could have influenced their performance with either system. Fourth, the structured written procedures for conducting data collection sessions resulted in excellent procedural consistency, thus adding strength and credibility to the results.

The primary limitations of this research were that only two participants, two interventions (the mouthstick and the HeadMaster), and two dependent variables (speed and accuracy of text entry) were studied. However, when the results from this study are compared with those from previous research involving persons with severe disabilities, understanding of this complex issue is increased.

**Directions for Future Research**

Further research in five main areas is merited. First, research is needed to evaluate participants' endurance and effects from the use of computer access systems over time. The endurance component could be evaluated over longer sessions, using a variety of participants with their comfort levels, neck movement, and trunk and neck posture as dependent variables. Second, research is needed to investigate efficiency (i.e., speed, accuracy) in the use of computer access systems with other aspects of computer input, including menu and file management, data entry, and drafting. Third, research is needed to explore the long-term effects of technology options for computer access. Fourth, given the slow rate of text entry demonstrated by both participants in this study, use of other, possibly faster methods of text generation (e.g., Morse code, speech input) by participants with limited or no upper-extremity function should be studied. Finally, research is needed to examine the vocational and educational use of alternative computer access devices by persons with tetraplegia.

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