A Comparison of Two Computer Input Devices for Uppercase Letter Matching

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Objective. To determine whether the Touch Window or the mouse with an enlarged on-screen arrow was more effective or efficient for an on-screen letter-matching task completed by a boy 9 years of age with spastic quadriplegic cerebral palsy and visual and cognitive deficits.

Method. A single-subject research design of 5 treatment phases, A1, B1, A2, B2, and A & B, was used. The total percentage of correct letter matches per treatment session, the total percentage correct per letter, and the amount of time needed to match 5 consecutive letters correctly were evaluated.

Results. The range and variability of letters correctly matched per session decreased and trends for correct letter matches accelerated when the participant used the mouse interface. Accuracy with matching 18 of 26 (69%) letters of the alphabet increased when selections were made with the mouse interface. The participant was faster when using the Touch Window to match 5 consecutive letters correctly; however, regardless of the interface device used, letter matching remained slow and tedious.

Conclusion. The mouse with an enlarged on-screen arrow and cursor was the more effective interface device with this child. Making a minor adjustment such as increasing the size of the on-screen arrow can make a common piece of equipment accessible to a person with disabilities.

Although computer use can enhance the acquisition of many functional skills in children with disabilities (Ried et al., 1995; Shuster, 1993), motor impairments can affect use of traditional access methods such as the mouse or keyboard. In such cases, specialized input devices such as a Touch Window (Edmark Corporation, 1994), expanded keyboard, or trackball can replace the traditional keyboard or mouse and can improve physical accessibility to the computer (Hertel, Kallam, & Rettig, 1989). In addition to motor impairments, vision deficits (e.g., legal blindness, visual acuity or visuoperceptual deficits, cortical blindness, visual field cuts) and hearing deficits can affect accessibility (Ried et al., 1995). For example, the small size of the on-screen arrow and cursor that are used with the mouse makes it difficult for persons with visual impairments to locate them on the screen (Riviere & Thakor, 1996). To compensate for visual deficits, the size of the on-screen arrow and cursor may need to be enlarged.

The Touch Window, a flat, pressure-sensitive screen, is an adapted interface that allows the user to make selections or respond to software by touching the corresponding section of the screen or window. When attached to the computer monitor, the Touch Window replaces the regular keyboard (Battenberg & Merbler, 1989). Touch screens have been found to support more accurate responses than other...
regular and adaptive interface devices (e.g., keyboard and Power Pad) in persons who are typically developing as well as persons with disabilities (Battenberg & Merbler, 1989; Hertel et al., 1989). Touch screens have also been found to be easier to use than traditional keyboards for children with and without developmental disabilities (Battenberg & Merbler, 1989).

Touch screens, however, are not without limitations. Reaching up to the screen to provide computer input can become quite tiring, even for persons without disabilities. Additionally, the user’s arm or finger may block part of the screen from view when making selections (Lin & Schmidt, 1993). Unlike the mouse, a touch screen does not allow manipulation of the input device in a small space nor does it offer a direct relationship between the speed and direction of the movement of the hand and the speed and direction of the movement of the on-screen arrow (King & Alloway, 1993). Although the effectiveness and efficiency of the mouse as an interface device for children has been examined (Crook, 1992; King & Alloway, 1992, 1993), the size of the on-screen arrow has not been mentioned as an issue or concern.

The purpose of this study was to determine whether the Touch Window or the mouse with an enlarged on-screen arrow and cursor was the more effective or efficient interface method for a child with both motor control impairments and visual impairments when matching uppercase letters of the alphabet. It was believed that the enlarged arrow would increase visual attention to the screen, thus improving accuracy and speed of performance.

Method

Participant

The participant was a boy 9 years of age with spastic quadriplegic cerebral palsy, impaired visual acuity from visual field cuts in both of his eyes, and the cognitive level of a child 3 to 4 years of age when evaluated by psychological testing. The participant was in a functional academic classroom in an elementary school and was receiving 60 min per week of direct occupational therapy services with computer access as a primary focus.

The participant had been using the Touch Window for 2 years as his primary access method on both an Apple II GS computer in the classroom and on a Macintosh LC 575 in the classroom and occupational therapy settings. This input method was selected on the basis of the participant’s developmental level and visual skills, although he had the necessary motor skills required to accurately maneuver and click a standard mouse. The enlarged on-screen arrow addressed his inability to visually locate the standard-size arrow provided with the mouse.

During the 2-year period, the participant had used various software programs (e.g., Early Learning Games, Jokus Workshop [Ahead media AB, 1994]) that were compatible with the Touch Window to master shape matching, color matching, and uppercase letter matching. Although he had success with shape and color matching, letter matching (which was part of the prereading and prewriting program on his individualized education program [IEP]) continued to be a challenge and remained remarkably inconsistent.

Research Design

To examine accuracy of letter matching when using the Touch Window interface method versus the mouse with an enlarged on-screen arrow interface method, we used a within-subject replication research design of four treatment phases, A1, B1, A2, and B2 (A treatment phases, Touch Window; B treatment phases, mouse). The length of each phase was determined by the stability of the data as well as the length of the school year. After completion of Phases A1, B1, A2, and B2, a condition of alternating treatments A & B (A treatment phases, Touch Window; B treatment phases, mouse) was implemented to examine relative rates of performance. The withdrawal and reimplementation of each treatment permit the establishment of functional relationships between treatments and outcomes (Kazdin, 1982; Schloss & Smith, 1994).

Setting and Instruments

The investigation was conducted in the school’s occupational therapy office. The participant was seated in his manual wheelchair with the computer directly in front of him on an adjustable table. The computer screen was at his eye level and was easily within reach of both hands. The mouse was positioned below the computer screen on the computer desk and to the right side of the participant’s midline because he was right-hand dominant.

The on-screen arrow on the Macintosh LC 575 computer was enlarged to .63-cm long by .63-cm wide, using a shareware software program, Fat Cursor 1.2.1 (Abatecola, 1993-1995). The Jokus Workshop software, which had been used occasionally by the participant during the past 2 years, was the program used during this study. Jokus Workshop allows a computer to be accessed through various regular and alternative interface devices and has clear and simple graphics.

Procedure

The participant completed the letter-matching task by using each interface access method. The letter-matching task con-

1Dunamis, Inc., 3423 Fowler Boulevard, Lawrenceville, Georgia 30244.
2Apple Computer, Inc., 1 Infinite Loop, Cupertino, California 95014.
3Apple Computer, Inc., 1 Infinite Loop, Cupertino, California 95014.
sisted of a 5.08-cm tall by 5.08-cm wide letter appearing in random order on the screen delivered by a helicopter, train, or truck. The large letter was placed on the right side of the screen, and 5 to 6 choices for matching, 1.27-cm high by 1.27-cm wide, were presented on the bottom of the screen and centered in the middle of the monitor. Each letter presented for matching was outlined by boxes that were 1.90 cm by 1.90 cm. The participant then touched or clicked on the letter he thought was an accurate match. The letters presented for matching were consistent from time to time; for example, each time “A” was presented, the same five choices in the same order were presented at the bottom of the screen.

A computer-generated noise was made for an incorrect letter match. If the correct letter was selected, an item beginning with that letter moved onto the screen, and the participant was given verbal feedback by the computer, such as “A is for airplane.” The participant was provided with verbal rewards from the primary investigator for a correct match and verbal encouragement for an incorrect match.

For the Touch Window phases (with A1 serving as the baseline phase), each session lasted the length of time it took the participant to match 20 letters. Once the letter-matching choices were presented, the participant was required to reach up and select one of the letter squares. He received auditory feedback from the computer only if he touched one of the letters. If the participant did not touch within the 1.90-cm square box, the computer did not acknowledge that a choice had been made. If the participant did not make a selection within 1 min, the practitioner reminded him to look at all of the choices and make a selection.

For the B data collection phases, the participant was able to perform basic mouse functions independently but had no prior experience with the adaptation of the enlarged on-screen arrow. The participant was required to manipulate the mouse by moving the on-screen arrow onto one of the letters presented for matching. Once the arrow was inside the box outlining the letter, the participant was required to click on the mouse button to make the selection. The participant did not receive auditory feedback from the computer for clicking on other areas of the screen. Verbal feedback remained the same as described above.

Rate Evaluation

After completion of the initial four phases of this study, an additional phase (A & B) was implemented to examine rate of performance; data were collected on the amount of time it took the participant to match 5 consecutive letters correctly. Each data session in this fifth phase consisted of 4 trials, 2 with each interface device. A coin toss determined the initial interface device used, with the alternative device used in a counterbalanced manner.

Data Collection

Data were collected during the participant’s scheduled occupational therapy treatment time for 15 to 20 min, 1 to 2 times per week by the first author (who was the participant’s occupational therapy practitioner). Both the uppercase letter presented and the letter selected as the correct match were recorded. The percentage of correct letter matches per session was calculated as well as the percentage correct per specific letter. Data required for the evaluation of comparative rates of performance were collected as previously described. Data collection was the same for both the Touch Window and mouse interface methods during all 5 phases.

The data for treatment phase A1 was retrieved from IEP records. Data collection for treatment phase B lasted for approximately 12 weeks (18 sessions). Data collection for treatment phase A2 lasted for approximately 6 weeks (10 sessions), and data collection for treatment phase B2 lasted for approximately 3 weeks. Data collection for the rate evaluation phase lasted for approximately 2 weeks (6 sessions).

Data Analysis

The percentage of letters correctly matched per session was calculated for each treatment phase by using the following formula:

\[
\text{Percentage Correct} = \frac{\text{Number of Correct Matches}}{\text{Total Letters Presented}} \times 100
\]

The totals for each treatment phase were then visually compared. Least squares regression procedures were used to establish straight-line trends for each treatment phase and are included in Figure 1 as judgmental aids. In addition, variability in the data, as indicated by the amount of change from session to session, was calculated and examined across phases.

To determine whether the participant’s letter-matching skills improved for individual letters of the alphabet as well as globally, the total number of times each letter of the alphabet was presented for matching, across sessions, was tracked for both interface methods. A percentage of the total number of correct matches per letter was then calculated for each treatment condition with the following formula:

\[
\text{Percentage Correct Per Letter} = \frac{\text{Total Times Letter Correctly Matched}}{\text{Total Times Specific Letter Presented for Matching}} \times 100
\]

Rate, expressed as the number of letters per minute accurately matched, was calculated for each interface method with the following formula:

\[
\text{Rate} = \frac{\text{Number of Letters}}{\text{Duration of Time to Match}}
\]

Reliability

To ensure that procedures were implemented as planned, a 9-item procedural reliability checklist was used to check...
consistency with setup of the computer, software, and input devices; placement of the student; and adherence to experimental procedures and data collection. Procedural agreement was calculated as percentage of adherence to the items on the procedural reliability checklist (Billingsley, White, & Munson, 1980). To establish procedural agreement, the investigator conducted the session while another registered occupational therapist with pediatric experience observed. The observer familiarized herself with the setup procedure and data collection procedure by studying the procedural reliability checklist. Procedural agreement was evaluated 4 times, once during each phase. Procedural reliability was 100% for all phases.

Interobserver agreement on participant performance was established by having an observer collect data simultaneously with the primary investigator. Point-by-point agreement (Kazdin, 1982) was calculated for the letter of the alphabet presented as well as the letter chosen as the correct match by using the following formula:

\[
\text{Interobserver agreement} = \frac{\text{agreements}}{\text{agreements} + \text{disagreements}} \times 100
\]

Interobserver agreement was evaluated 5 times, once during each phase when the Touch Window was the interface method and 3 times when the mouse was the interface method (twice during the first mouse phase and once during the last mouse phase). Interobserver agreement during phase A1 was 100% for the letters he matched correctly and 67% for the letters that were incorrectly matched. During all other phases, interobserver agreement was 100% for all letters matched.

**Results**

Figure 1 presents the total percentage correct per session for each of the phases as well as linear lines of progress calculated for each data set. Baseline (A1) performance reflected scant improvement across time and considerable day-to-day variability. The range of percentage of correct matches per session was 18% to 56% with a median score of 43%. In intervention phase B1, performance rapidly accelerated. Correct matches ranged from 37% to 65% with a median score of 53%. When the Touch Window was reintroduced in phase A2, the average percentage of correct matches continued to increase; however, this increase was slight. Median percentage of correct matches was 55%, and the range was 40% to 70%. After reintroducing the mouse in phase B2, correct matches immediately increased relative to the previous phase. Median score was 68%, and the range was 60% to 75%. In fact, the final datum point in the B2 phase was 20% greater than the median of A2 and 25% greater than the last datum point in that phase. Trends in the data indicated by regression lines were virtually flat or decelerating during the Touch Window conditions; during
the mouse conditions, however, trends reflected substantial acceleration.

In addition to improvements in performance levels and trends during both B phases, session-to-session variability decreased when the participant used the mouse. During phases A₁ and B₁, the amount of change seen from session to session when using the Touch Window to make letter-matching selections was 1% to 36%, and the amount of change seen from one session to the next session with the mouse ranged from 0% to 18%. The median amount of change for the Touch Window was 12%, and the median for the mouse was 9%. During phases A₂ and B₂, the amount of change seen from one session to the next when using the Touch Window was 0% to 30%, whereas the amount of daily change from session to session for the mouse ranged from 0% to 15%. During these same phases, the median amount of change from day to day for the Touch Window was 15%, and the median for the mouse was 10%.

The results for the total percentage correct per uppercase letter of the alphabet were consistently better when the participant used the mouse versus the Touch Window. In evaluating the results of all sessions combined, the participant matched 18 of 26 (69%) letters more accurately with the mouse and only 8 letters less accurately. One hundred percent accuracy was achieved for 2 letters when using the mouse but was not achieved for any letters when making matching choices with the Touch Window.

The data in Figure 2 indicate rate of response with each of the two interface methods. Although the median rate of letters matched was somewhat better for the Touch Window (3.23 letters per min) than for the mouse (2.29 letters per min), the data sets are characterized by considerable overlap. Perhaps the most notable characteristic of performance was that letter matching was a slow and tedious process for this participant, regardless of which interface method was used.

Discussion

By simply enlarging the size of the on-screen arrow, the mouse became an effective interface method for this participant and improved his on-screen letter matching skills. Correct letter matching was higher with the mouse device than with the Touch Window, and, for all data combined, the amount or range of variability was 14% less with the mouse. In addition, most of the variability for the mouse occurred in the first 3 sessions when the participant's total percentage correct ranged from 38% to 65%, a difference of 27%. During the last intervention phase, however, the total percentage correct ranged from 60% to 75%, a difference of 15%. This represents a substantial decrease in variability from the initial phase of mouse use.

Figure 2. Rate of letters per minute correctly matched for five consecutive letters by using the Touch Window and the mouse.
It was also noted that the total percentage correct per letter increased with the mouse interface method. Consistent differences, however, were not observed in the speed with which letters were matched.

Limitations

This study has two important limitations. Because the participant had used the Touch Window exclusively for 2 years before the investigation, it is possible that performances that accompanied mouse use could have been enhanced by the novelty of that new device. It could be argued, however, that such an effect would have been offset by his extensive experience with the Touch Window. In addition, decrements in performance across time that might have been expected because the participant habituated to the novelty of the mouse were not observed in either of the phases in which the mouse was used. Nonetheless, it cannot be known whether the results would have differed had both interface devices been new to the participant.

Another limitation was imposed by the use of a single participant. We do not know whether comparable effects would be obtained for other persons having similar disabilities. Given the results, however, it appears that this investigation warrants replication to establish extent of generality.

Implications for Occupational Therapy Research and Practice

Although the letter-matching task showed some improvements in the participant's abilities with the mouse, it did not indicate improvements in other areas that may have been noted had a more comprehensive evaluation been used. For example, after the mouse was introduced, the participant verbally requested to use the mouse instead of the Touch Window each time he worked on the computer. His ability to select what he intended to select seemed to increase, and his time off task and level of frustration appeared to decrease. When the participant used the Touch Window, he would frequently verbalize his intended target but would activate a choice that was within close proximity of his intended selection. This appeared to increase the participant's level of frustration and frequency of stereotypical behaviors. In addition, the teaching staff provided anecdotal reports indicating an overall increase in academic performance as a result of using the mouse with the enlarged on-screen arrow, and that device is now the primary interface method used by the participant in school and at home. The breadth of our knowledge might, therefore, be expanded in future research by systematically evaluating a broad range of outcomes and collateral behaviors (e.g., stereotypies, increases and decreases in communication, functional changes in the classroom) that may accompany the use of various assistive devices.

Although the mouse with the enlarged on-screen arrow appeared to be the generally superior interface method for this participant according to the study findings, the participant had several difficulties with its use that were not issues when using a Touch Window. He would get the mouse stuck against the top or side of the adjustable computer table and was then unable to move the on-screen arrow to the correct location. Although this affected his speed, it did not seem to affect his accuracy or consistency with the letter-matching task. The participant's rates when using the mouse, therefore, might have been improved by having the mouse on a surface that did not have limited boundaries. This particular instance is illustrative of a more general principle—that assistive devices are not used in a vacuum. To most fully realize the potential of such devices, practitioners and educators should consider whether elements of the environment in which those interface methods will be used impose artificial limits on performance and whether those elements can be modified to reduce or remove the limits they impose.

It was noted that the participant performed the task at an extremely slow rate, regardless of the interface device. Both basic and applied research have suggested that fluent performance (i.e., the extent to which performance is both rapid and accurate) can have a substantial effect of the retention, endurance, application, and transfer of skills (Binder, 1996). Although practitioners may be heartened by improvements in accuracy alone, adaptations to both community and school demands may be hindered by performances that are excruciatingly slow and effortful (Barrett, 1979; Billingsley, Liberty, & White, 1994). The merits of particular adaptive devices should, therefore, be evaluated on the basis of their effect on rate as well as accuracy. When available devices fail to promote fluency (even with artificial limits removed), practitioners should determine whether additional supports and modifications can be made to enhance performance.

Finally, evaluating the possibilities of existing equipment is important before making extensive adaptations for a person. Simple adjustments, such as increasing the size of the on-screen arrow, are available and can make a common piece of equipment that was once considered inappropriate accessible to a person with disabilities. Although generalizability of specific findings of this study await replication, the outcomes we observed underscore the necessity of objectively evaluating options and considering possible adaptations to existing technology before dismissing it as viable. This is particularly true in cases like the participant's, where unique sets of disabilities exist.

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