Comparison of Three Computer Scanning Modes as an Interface Method for Persons With Cerebral Palsy

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Occupational therapists are becoming increasingly involved with interface assessments. This involvement is improving the ability of persons with physical disabilities to interact with computers, augmentative communication aids, and other devices. The ability to use these devices facilitates participation in activities that would otherwise be much more difficult to pursue, such as communication, education, work, and recreation. The purpose of the present study was to systematically compare three basic modes of scanning—automatic, inverse, and step—with the use of a single-subject experimental design. Six subjects—3 with spastic and 3 with athetoid cerebral palsy—from a local school volunteered for the study. Results indicated that the 3 subjects with spastic cerebral palsy had the greatest difficulty using the automatic scanning mode. The 3 subjects with athetoid cerebral palsy had the most difficulty using the step scanning mode. The results of this study suggest that clients should attempt each scanning mode and that their performance with each mode be compared to ensure the most appropriate recommendations.

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Occupational therapists are becoming increasingly involved with interface assessments for persons with physical disabilities (Bain, 1989; Lee & Thomas, 1990; Milner, Parnes, McNaughton, & Lotto, 1983; Smith, Vanderheiden, & Fox, 1990). For such persons, this involvement provides greater access to all areas of life, including communication, education work, and recreation.

For persons with a physical disability to most effectively use computers and other devices, an interface assessment by a qualified occupational therapist is necessary. A major component of this assessment is a determination of whether the client will be using direct selection or scanning to interact with the device. *Direct selection* refers to the action of pointing with a finger or using another mechanism to indicate the desired item or to make a selection (e.g., using a computer or typewriter keyboard) (Gunderson, 1985; Vanderheiden & Lloyd, 1986). For scanning, only one item of the selection set is available at any one time; as the cursor moves, the user selects the desired item by signaling at the proper moment (Vanderheiden & Lloyd, 1986). Direct selection is considered faster, is less cognitively taxing, and requires more motoric control than scanning. However, the muscle control required to activate a scanning device is considerably less. The user needs only voluntary and reliable control over one muscle group (Fishman, 1987; Gunderson, 1985). When scanning is chosen as the method of choice for a client, it is of the utmost importance that the process be as efficient as possible. The scanning mode recommended should produce the highest degree of efficiency and the least amount of fatigue and frustration.

The two basic scanning methods are linear and row-column. In *linear scanning*, the symbol set is placed in a circle, column, or row. The cursor or indicator highlights each item, one at a time. When the cursor highlights the desired item, the user presses the switch to indicate his or her choice (Vanderheiden & Lloyd, 1986). In *row-column scanning*, the items are scanned in groups, usually in stacked rows. The entire row is selected and then the individual items within that row are scanned.

The empirical literature on the efficacy of various scanning strategies is minimal. Treviranus and Tannock (1987) published a descriptive study illustrating the importance of a scanning-type display in assisting computer access for persons with severe physical disabilities. Two single-subject studies have also been reported. Everson and Goodwyn (1987) used a single-subject design to compare three different switches using the automatic scanning mode as part of a vocational training program. They found that microswitches could be used to elicit reliable physical responses from persons with severe physical disabilities. LeBlanc and Barker (1982), also using a single-subject design, tested the ability of persons with athetoid cerebral palsy to control a two-switch row-column scanning system. The researchers compared four scanning systems: row-column scanning, a user-driven two-switch system, a vertical scanning system, and a horizontal scanning system. The only significant finding was that the subjects performed significantly worse on the row-column autoscan than on the other three systems.

Clinicians who recommend scanning need to be aware of which scanning mode their clients can best control. The purpose of the present study was to systematically compare the three basic modes of scanning—automatic, inverse, and step—with the use of a single-subject experimental design.

Method

Scanning Modes Defined

Definitions for the three scanning modes examined in this study were taken from the *Operator's Manual for the Adaptive Firmware Card* (Don Johnston Development Equipment, 1984):

1. *Regular, or automatic (auto-), scanning*—When the user presses the switch, the cursor scans the items automatically. When the cursor is over the desired item, the user again presses the switch to indicate the desired item.
2. *Inverse scanning*—The cursor will only advance while the switch is held down. The user indicates the desired item by releasing the switch. The item that the cursor indicates when the switch is released is the item presented.
3. *Step scanning*—The user presses the switch successively to advance the cursor item to item. When the cursor is over the desired item, the user releases the switch. The absence of a switch press is the signal that a selection has been made.

Subjects

Six subjects with cerebral palsy from a local school volunteered for this study. Three of these subjects had athetoid cerebral palsy and 3 had spastic cerebral palsy. All were between the ages of 18 and 20 years and had some vocal communication ability. These particular subjects were chosen because they had not used any scanning method and therefore would not bias the results due to familiarity. All of the subjects had the ability to understand what was required of them while participating in the study and were capable of following my directions. This was determined through a discussion with their elementary school teacher. Each subject required a powered or manual wheelchair for mobility. Each was paid $100 for participating in the study.

Instrumentation

The Single-Input Control Assessment (Milner, Parnes, McNaughton, & Lotto, 1983) was used to determine switch type and location. This program was written for the explicit purpose of assisting health care professionals in making clinical judgments for switch recommendation and switch placement. Cook (1988) stated that this assessment was the most comprehensive single-switch evaluation. The data were collected on an Apple IIe computer.[1]

The program for comparison of the three scanning modes was written by an experienced Hypercard[1] programmer. A Macintosh II computer was used to collect the data. The program presented practice trials as well as test trials and collected data on scanning mode, accuracy, and speed.

Procedure

Several factors usually associated with scanning were kept constant to eliminate as many confounding variables as possible. The horizontal row was selected as the preferred scanning plane. LeBlanc and Barker (1982) found no significant differences between vertical or horizontal scanning. Because horizontal scanning is used in the Single-Input Control Assessment, it was used in the present study.

For both practice and test trials, the program presented 1-in. by 1-in. boxes on the screen. Three boxes were used for the practice trials and six boxes for the test trials. The boxes were centered top to bottom and right to left. To eliminate confusion about the location of the target item, only one box contained the item; all of the other boxes were empty. The target item was a drawing of a face, which was used throughout the study for both practice and test trials. For each trial, the cursor always started in the box furthest to the left, as in the Single-Input Control Assessment. The cursor was indicated by a slight shading of the box. The cursor scanned and stopped in each box for a predetermined length of time appropriate to the subjects' capabilities. The program allowed for modifications to provide the optimum program environment for each of the scanning modes. The cursor speed could be increased or decreased by half seconds, depending on the subject's ability.

Because three distinctly different actions were required with the use of each mode, the subjects were given time to become accustomed to the required actions. Three boxes were the minimum necessary to allow for practice without an undue amount of waiting while the cursor completed its path. For the actual testing, six boxes were used. Because the Single-Input Control Assessment uses five places for testing autoscanning, the six boxes used in the present study seemed an appropriate and manageable number consistent with prior test practices.

[1]Manufactured by Apple Computer, Inc., 29525 Marianai Ave., MS 43S, Cupertino, CA 95014.

Cursor speed. The speed of the cursor can drastically change the subject's performance with the use of each mode. Two speeds were used for the purposes of this study. The first, slower, cursor speed was set so that the subject could achieve 90% accuracy. The second, faster, cursor speed was increased until the subject achieved only 10% accuracy. These two speeds were used for each mode during data collection. Slow (90% accuracy) and fast (10% accuracy) cursor speeds were determined for each subject in both the automatic and inverse scanning modes.

For the step scanning mode, a slightly different procedure was followed. The cursor moves as fast as the user can press the switch. What makes the scanning process faster in the step scanning mode is the acceptance time, that is, the length of time that the cursor highlights an item before that item is chosen as the desired one. If the acceptance time is set for a half second, the user must press the switch within that time to move the cursor to the next item, otherwise the item that the cursor is highlighting will be accepted as the item of choice. The cursor speed was first set for 90% accuracy and then for 10% accuracy.

Determination of position and switch site. During the first session and before data collection, three factors were determined, which were used throughout testing. The first two factors were establishment of the most appropriate switch and switch position. These were determined with the use of the Single-Input Control Assessment. After the switch and switch position were identified, the third factor, cursor speed, was determined with the use of the scanning assessment program developed for this study.

Three boxes with slow and fast cursor speeds were used for practicing. First, the subjects were shown three boxes with the use of one of the modes chosen randomly. Next, they practiced for as long as they needed to become familiar with the procedure. The average practice time for each mode was approximately 10 min. The subjects used that particular mode until they achieved 90% accuracy over 10 consecutive trials. The cursor time was then adjusted so that they could achieve 10% accuracy. The cursor speeds were applied to each scanning mode.

Data were collected on three different occasions with at least 1 day between collections. Each mode was presented on each day in a randomly determined order. To familiarize themselves with the required motoric control, the subjects practiced with three boxes using the slow speed before each data collection phase. For each mode, the slow cursor time preceded the fast cursor time to allow for familiarization and initial success.

Each subject was told that he or she would be shown six boxes on the screen. The subject was to activate the switch when the cursor was over the drawing of the face. The subject was encouraged to ask questions anytime that he or she did not understand the directions.

Table 1
Scanning Modes Arranged by Mean Using Slow Speed

Subject	Fastest Mode	Intermediate Mode	Slowest Mode
1 (Spastic cerebral palsy)	Inverse	Step	Automatic
2 (Spastic cerebral palsy)	Step	Inverse	Automatic
3 (Spastic cerebral palsy)	Inverse	Step	Automatic
4 (Athetoid cerebral palsy)	Inverse	Automatic	Step
5 (Athetoid cerebral palsy)	Inverse	Automatic	Step
6 (Athetoid cerebral palsy)	Automatic	Inverse	Step

Testing began with a blank screen. The subject pressed his or her switch to indicate readiness. When the switch was pressed, the screen presented six boxes, one containing the target. The subject would then press the switch when the cursor was over the smiling face. Testing took approximately 1 hr for each session. There were 20 trials per session. Fewer trials would have been insufficient for the subject to become comfortable with the mode. If more trials had been added, a fatigue factor could have confounded the results.

Results

Figure 1 shows each of the subject's scores. Subject 6 was only able to complete the task of pressing the switch with the slow cursor speed (90% accuracy), therefore his graph displays scores for 90% accuracy only. The modes for each graph were placed in alphabetical order to allow for easier visual comparison. The trials within each mode are in chronological order, beginning with the first trial of the first session and ending with the last trial of the last session. For comparison between the modes, the Kruskal-Wallis test was performed. The dependent variable was the number correct. The results were not significant.

Visual examination of the graphs revealed variations between modes, and a pattern began to emerge across the 6 subjects. Table 1 shows the modes for each subject, from greatest accuracy to least accuracy. Table 2 shows the total mean scores for slow and fast speeds. The 3 subjects with spastic cerebral palsy—Subjects 1, 2, and 3—had the greatest difficulty using the automatic scanning mode. Two of these subjects, Subjects 1 and 3, had the

Table 2
Accuracy Mean Scores For Scanning Modes

	Automatic		Inverse		Step	
Subject	Slow	Fast	Slow	Fast	Slow	Fast
1 (Spastic cerebral palsy)	8.3	11.0	16.3	11.0	14.6	12.6
2 (Spastic cerebral palsy)	10.0	3.0	15.6	10.3	18.6	16.0
3 (Spastic cerebral palsy)	11.3	12.0	19.3	18.6	14.0	18.0
4 (Athetoid cerebral palsy)	11.0	3.6	11.3	7.3	3.6	0.0
5 (Athetoid cerebral palsy)	18.3	10.3	19.3	14.3	9.3	7.3
6 (Athetoid cerebral palsy)	39.0	0.0	7.0	0.0	6.6	0.0

Note. A higher score indicates a greater number of accurate responses.

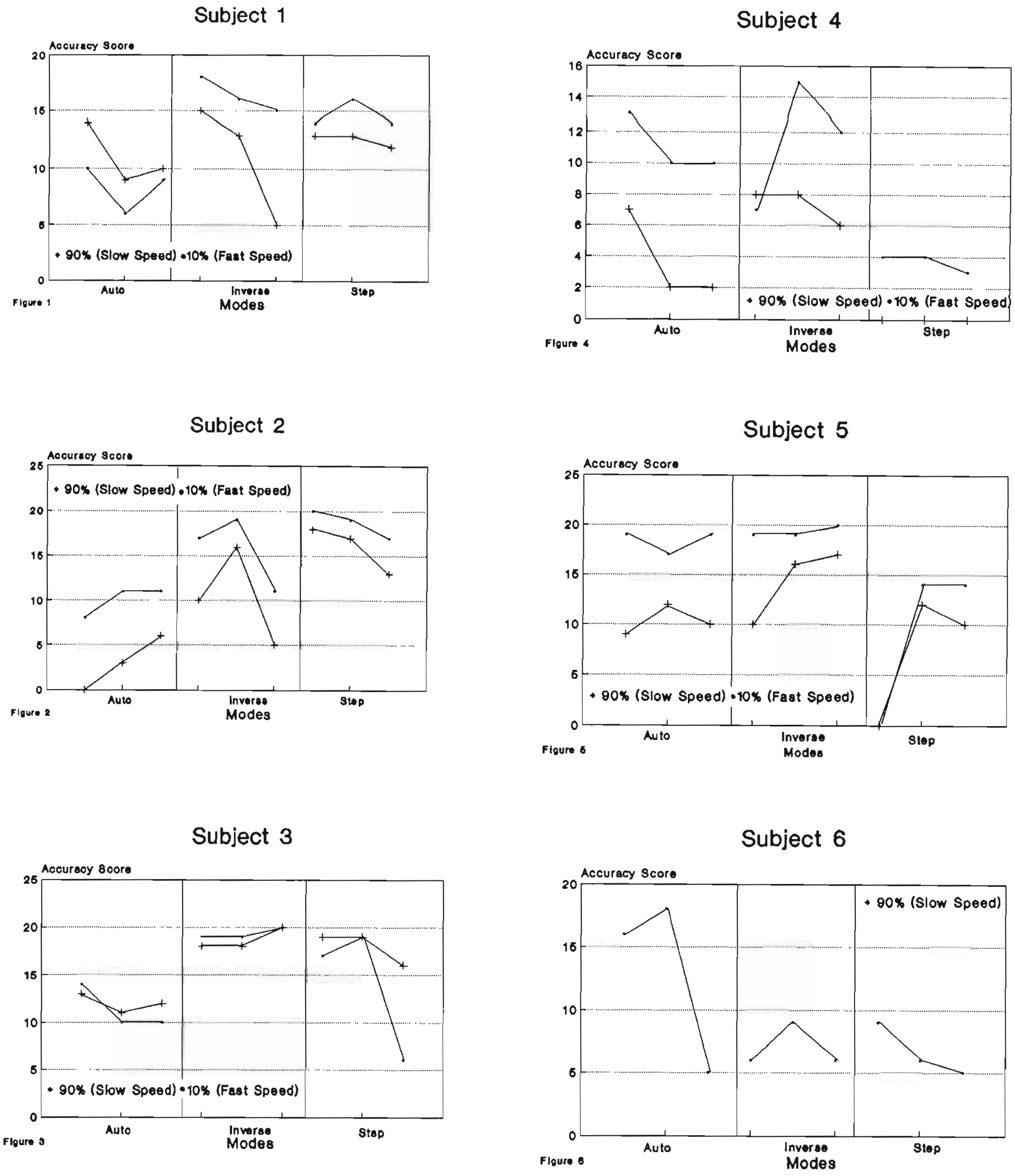

Figure 1. Subjects' accuracy scores on the three scanning modes—automatic (auto), inverse, and step.

greatest accuracy using the inverse scanning mode. Subjects 4, 5, and 6, who had athetoid cerebral palsy, had the most difficulty with the step scanning mode. Subjects 4 and 5 performed best using the inverse scanning mode. Four subjects (Subjects 1, 3, 4, and 5; of whom 2 had spasticity and 2 had athetosis) performed best using the inverse scanning mode.

Discussion

Inspection of the graphic evidence suggests that subjects with spastic cerebral palsy performed poorly using the automatic scanning mode, whereas those with athetoid cerebral palsy had most difficulty with the step scanning mode.

Subject 6 had the most difficulty with switch pressing. He was also the most seriously impaired person in the study and the most difficult to position. Lack of proper positioning could be partially responsible for his ability to perform using only the slow cursor speed. A new seating system, which may improve his performance, is being developed for him; however, such seating was not available at the time of this study. With the wheelchair and equipment that he used at the time of this study, it was possible only to minimally adjust his positioning. Despite these limitations, he was determined to continue and perform to the best of his ability, using his head to press the switch. All of the other subjects used their right or left hand or forearm satisfactorily, and adequate positioning was achieved.

There are two possible explanations for the finding of no significance between the modes. The first is that the sample size was too small. The second is that grouped data are of greater consequence. The heterogeneity of this sample makes it difficult to produce differences that are statistically significant with traditional quantitative methods. Nonsignificant grouped results were found not only with the present study but also with a previous study (Bravo, LeGare, Cook, & Hussey, 1990). Pooled analysis of the cerebral palsy data in this study was not significant, even though there were large differences in performance. However, when the results were examined with a single-subject approach, useful information was revealed, thus indicating that motor performance capacity is a good predictor of upper limb motor abilities.

The use of grouped data may not be the best way to interpret scanning modes or data when persons with cerebral palsy make up the group under investigation. When data are grouped, important indicators are hidden due to performance variations. Single-subject design may be a more appropriate method in the interpretation of these data.

To counter these study limitations, future studies might increase the number of subjects and pool the data. Grouped data will only be useful if all the subjects have the same type of cerebral palsy and have similar functional abilities. However, the grouped-data method is likely to overlook important information concerning individual performance due to the extreme variability, both within and between subjects.

Conclusion

The results of this study suggest that it is important that clients try each scanning mode — automatic, inverse, and step — and that their performances on each be compared in order to ensure the most appropriate recommendation for an interface method. Single-subject designs, which focus on individual performance in natural settings, are ideally suited for achievement of this determination.

The study results also suggest that for the subjects in this study with spastic cerebral palsy, the automatic scanning mode should be avoided. For persons with athetoid cerebral palsy, the step scanning mode should be avoided. Replication of these findings is required before these recommendations can be generalized. Replication is also needed to provide the clinician with additional information that may be used in making the best therapeutic judgment concerning how technological devices can be incorporated as part of occupational therapy service.

The present study has provided information on scanning modes with several influencing factors eliminated. These influencing factors include expression, correction of errors, and choosing from several symbols. Elimination of these factors allowed for examination of the performance of persons with cerebral palsy with the use of three scanning modes. Of course, in the environment, these other factors will influence voluntary motor control with the use of the scanning modes. They should be introduced one at a time during therapy to consider their effect on the user's ability to continue using different scanning modes. ▲

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