A Scanning Computer Access System for Children With Severe Physical Disabilities

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This article discusses scan access to microcomputers and describes a scanning keyboard designed to allow children who are severely physically disabled to access microcomputers for writing, playing, and engaging in educational activities. Two case examples are presented to illustrate potential applications of this keyboard.

One of the primary intervention goals in occupational therapy is to develop or restore a person’s highest level of functioning possible in activities essential to productive living (Hopkins & Smith, 1978). In some situations, function cannot be developed without the aid of adaptive devices. Many children who are severely physically disabled have few opportunities to independently engage in play or to actively control learning activities and have no access to traditional writing modes (Goldenberg, 1979). The microcomputer can potentially serve these children as an adaptive means of access to these important activities. Because some physically disabled children do not have sufficient voluntary movement to point directly to items or keys on standard or adapted keyboards (e.g., enlarged keyboards, keyboards controlled by optical head-pointers), these children must rely on a scanning keyboard to enter information into a computer (Vanderheiden, 1982).

A scanning keyboard consists of a screen or display across which a cursor or indicator travels in a preset pattern. The cursor highlights each item or group of items arranged on the display and presents them one at a time to the user for selection. The user activates a switch to stop the cursor at the desired item, and the selection is sent to the computer. Any volitional movement that the individual can control reliably (e.g., head movement, puffing, or sipping) may be used to activate the appropriate switch. In directed scanning, the ability to control more than one movement enables the individual to use additional switches to actively guide the cursor or indicator to the desired item (e.g., one switch to guide the cursor to the left, another to guide it down, etc.), thus providing a potentially increased rate of selection. A range of scanning methods exist (e.g., automatic, row-column, or directed) that differ in speed and in the cognitive, perceptual, and physical abilities required of the user (Vanderheiden & Grilley, 1975).

To determine the optimal means of accessing the computer, the occupational therapist must carefully assess both the skills of the individual and the skills required to control the access means.

Specifications for Scanning Keyboards

A variety of scanning systems exist that enable persons with severe physical disabilities to use standard computer software (i.e., provide transparent access). These systems include cards that are installed into the computer and display the selection set on a portion of

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1 In this paper the term switch is used to refer to a device that translates volitional movement into an electronic signal understandable by the computer.
ties of the preschool or primary school-age child. A scanning keyboard must be suited to the skills of the child with physical disabilities so that he or she can make optimal use of standard children's software. A list of specifications for such a scanning keyboard follows.

- There must be a clear simple presentation of choices. A large, bold, uncluttered presentation of selections is simplest for the young child. As the child matures the size of the choices can often be reduced and the number increased.
- The choices should be represented in a way that is meaningful to the child. This may mean that the items are represented by pictures, symbols, letters, or sight words known to the child or a combination of these. The child who is developing literacy needs to be able to move from one representational set to another (pictures or symbols to letters and words).
- The choices should directly relate to the task. The set of choices should therefore be changeable (preferably by the disabled child) as the task is changed or as the school exercise is changed.
- Because scanning is considerably slower than writing or typing, these children will require the fastest scanning method that is commensurate with their physical and cognitive ability; thus, a system that provides a range of scanning methods is required.
- Since this keyboard should be adapted on an ongoing basis by teachers, teacher's aides, or parents all of whom have little if any computer experience, setup and modification of selection sets should be simple and quick.

Thus, to meet the needs and abilities of these children, a highly flexible scanning keyboard is required which (a) allows numerous display sets to be created that are completely programmable in terms of the layout, quantity, size, and representation of items available for selection and (b) offers a range of scanning methods.

Limitations of Existing Scanning Systems

Existing approaches do not have the flexibility to accommodate such a large number of options. Some provide only one unmodifiable display of items or they provide a modifiable but very small display so that the size and number of items visible at one time is restricted (e.g., Adaptive Firmware Card). Most allow only an alphabetic and numeric representation of items with limited or no capacity to modify the size and format of each item. Similar systems that allow the use of pictures or symbols (e.g., Light Talker) do not provide transient displays (i.e., displays that can be changed by the user): Codes must be used to represent and retrieve additional items. The process of creating and modifying display sets is often complex and time-consuming; thus, frequent modifications to accommodate the changing needs and abilities of young children by people unfamiliar with computers are not feasible. Many systems can only accept input from one or two switches, precluding faster scanning methods that require more than two switches.

The Elementary MOD Keyboard

The Elementary Mod Keyboard (EMK)\textsuperscript{2}, which provides a range of options not presently available in one device, is a dual computer scanning keyboard that allows persons who are severely physically disabled to use commercially available software programs that run on one of the commonly used personal microcomputers (e.g., Apple IIe, IBM-PC, Commodore 64). As shown in Figure I, the EMK consists of a VIC 20 microcomputer with monitor, a VIC 20 cartridge containing the special software, and the appropriate interface to connect it to a second microcomputer called the host computer which runs the standard software (Lee, et al., 1985). The monitor of the VIC 20 serves as a visual keyboard on which the selectable items are displayed. A large, red, box-shaped cursor clearly highlights each of the items or group of items as it scans across the screen. Items selected from this screen display are sent to and received by the host computer as if they were inputted from its own standard keyboard (which remains active throughout the process). The EMK can accept input from one to five switches, permitting a range of scanning methods.

Each item may comprise 1 to 20 characters, the size of which may be changed from standard VIC 20 characters to large, bold characters. Information sent to the host computer may differ from the item displayed on the keyboard. For example, if the software program demands an arbitrary command string to cause an animated figure to move upwards, the command can be represented on the MOD keyboard by the word up or by an arrow. This labeling feature allows clinicians to easily circumvent a current limita-

\textsuperscript{2}The Elementary MOD keyboard was developed by the National Research Council Canada together with the Microcomputer Applications Programme at the Hugh MacMillan Medical Centre.
tion of the EMK, namely, the inability to create graphic or symbolic items on the display set. Blank spaces of varied dimensions on the MOD screen may be redefined with words, phrases, or other items, as demanded by the software program. Pictures or symbols representing the items may be mounted on an acetate sheet directly over these blank spaces. The sheet can then be placed over the MOD screen. The large cursor, which is still visible through the acetate, moves across the screen and outlines each picture or symbol for selection.

The EMK allows numerous display sets to be created; separate displays may thus be created and stored in memory for each software program or task. Each of the stored screen displays may be called up and viewed, giving the user independent access to an extensive vocabulary without the cognitive demand of recalling or referring to codes. The creation and modification of display sets are relatively simple processes; a step-by-step tutorial designed for people who are unfamiliar with computers is available.

Applications of the Elementary MOD Keyboard

The following case examples of two children who were severely physically disabled and unable to speak and who were seen by a multidisciplinary team consisting of professionals with backgrounds in occupational therapy, speech pathology, and special education and specializing in augmentative communication at the Augmentative Communication Service (ACS) of the Hugh MacMillan Medical Centre in Toronto, Canada, illustrate potential uses of a scanning keyboard such as the Elementary MOD keyboard.

Case Example 1

At the time of assessment, Andrew was a 7-year-old boy with severe athetoid cerebral palsy who was unable to speak. He had no functional voluntary control over his upper extremities. He was bright, but had very few means to successfully affect or control his environment. No significant sensory or perceptual deficits were noted.

Andrew communicated using a communication display on which Blissymbols (McNaughton, 1985), pictures, and words were organized into groups. He directed his listener to the desired group using a fixed intent look. The listener was then expected to call out the symbols within that group until Andrew indicated a selection by looking up or vocalizing.

Needs to be addressed. Andrew required an outlet for creative expression, humor, and imaginative play. He also needed the means to explore language and experiment with the organization of output so that it could be understood by other people; the means to correct his mistakes so that he could repair frustrating situations himself; and the means to develop the skills to control technical, written, and face-to-face communication systems in the future. Andrew required opportunities to interact with peers and family members in common, age-appropriate activities. These needs could be partially met through access to children's software programs.

Accessing and previous computer experience. Andrew's most reliable voluntary movements were head rotation to both right and left. His previous experience with the computer was not positive or reward-
ing. He was introduced to a program called BlissApple, which allows message creation with Blissymbols. This program required symbols to be chosen by entering the appropriate number code. He selected these numbers by activating a head switch when the correct number was highlighted on a scan line. Up to four selections were necessary to enter a single symbol if no mistakes were made. This proved too tedious for Andrew, with too many opportunities for error. The cognitive demands involved (i.e., number matching, sequencing, and scan selection of the appropriate numbers) distracted from the actual task of written expression. It was felt that the EMK was the system that could eliminate these problems.

Considerations in selecting scanning keyboard. In considering Andrew's needs and skills the following system requirements were identified:

- The process of entering selections needed to be quick, simple, and as direct as possible to allow Andrew to concentrate on the actual task.
- Both the input method and the activities needed to be easily adapted to Andrew’s skill level to ensure a reasonable level of success while challenging him.
- Correction of mistakes needed to be under his control.
- The system needed to provide access to a full range of motivating software (“software worth the effort”).
- Both the standard keyboard as well as Andrew’s input method needed to be active at the same time to allow peers and family members to play with him.

Application. At the time of reassessment Andrew had used an Apple IIe system controlled by a EMK with synthetic voice feedback at home for approximately 5 months (a duplicate system had been recently made available at school). Andrew controlled the EMK using two switches activated by left and right head rotation. Vocabulary was represented using Blissymbols, pictures, words Andrew recognized, and letters when appropriate to the task. Andrew selected the desired item by activating his head switch first when the row containing the item was highlighted and again when the item itself was highlighted. Vocabulary items were updated regularly to accommodate current interests (e.g., Darth Vader, Hulk Hogan).

Andrew was observed to have taken responsibility for correcting his mistakes. He used the second head switch to escape from a row inadvertently selected when scanning. He used delete commands to erase unwanted selections. Andrew was able to use scanning skills developed through use of the EMK to control a portable voice output system for face-to-face communication.

To encourage Andrew to develop a sense of mastery over the computer he was introduced to motivating software programs that provided quick rewards for actions. Because of the flexible selection sets, the response required of Andrew could be adapted to his skills. As his skills increased, the demands made of him were gradually increased. By creating the appropriate labels on the EMK, a single standard software program can be adapted to a large continuum of skill levels (e.g., the sentence “The boy jumps” can be entered by simply selecting pictures representing boy and jump with the appropriate label definitions or by spelling the entire sentence out letter by letter, which requires far more advanced skills).

In working with Andrew, exploration and experimentation were encouraged while test situations were initially avoided. Andrew used the synthetic voice to explore and play with language (i.e., repeating a funny sounding word, finding the longest word). He used the available vocabulary creatively to exercise his sense of humor (i.e., stating that staff and teachers were in the toilet). Later, he used the computer to write stories and relate events. Written utterances lengthened over time. Andrew’s writing became more coherent to readers unfamiliar with him. Andrew’s parents reported that he also played games on the computer with his twin brother and neighborhood friends.

Future developments. Because his selectable items were attached to an acetate sheet mounted on the screen of the monitor, Andrew could not flip to additional display sets independently. He was, therefore, limited to the vocabulary that could be represented on one screen unless an assistant changed the acetate sheet. It was clear that Andrew would require independent access to several display sets as his vocabulary needs increased. Currently, independent access to an extensive vocabulary is available on the EMK only when an alphanumeric representation of selectable items is used since these can be displayed directly on the screen. A scanning keyboard is needed that would allow graphic characters to be created directly on the screen. This option would give preliterate children like Andrew independent access to a large vocabulary and would reduce the time needed to create display sets.

Case Example 2
At the time of assessment, Casey was an 8-year-old boy with severe cerebral palsy who was attending an integrated Grade 3 class. He was unable to speak and communicated through gesture, gaze, vocalization, and head nod and shake to signal yes and no. In addi-
tion, he used an extensive vocabulary of Blissymbols, printed words, and pictures. He accessed these items by grossly list pointing toward the one he wanted. His partner scanned through the selected area, pointing to each item until Casey confirmed his selection by vocalization or nodding. No significant sensory or perceptual deficits were noted.

**Needs addressed.** In addition to the assessment of his total communication needs, Casey was referred to ACS to determine the most appropriate system to meet his written communication needs in the classroom. In order to participate in his Grade 3 class curriculum, Casey required an independent writing system as well as a tool with which he could experience class lessons from which he was otherwise restricted by his disability (e.g., cutting and pasting, painting).

**Accessing and previous computer experience.** Casey was able to directly activate or point to only a very small number of large targets (with arm and head mounted pointer) and only with great effort. He had previously used single-switch scanning to control the BlissApple program. He entered Blissymbols by selecting the corresponding number code using a scanning number line and a switch activated by left head rotation. However, this program did not give him access to standard software, nor did it accommodate his developing literacy.

Casey's most reliable movements were head rotation to both left and right as well as slight head extension. He was able to make these movements quickly and reliably in sequence. Initial investigation using the EMK as an assessment tool indicated that he performed well using directed scanning, achieving faster rates of entry than with single-switch scanning after a short period of familiarization. He made fewer errors because this method gave him more direct control of the cursor. He used head rotation to the right to move the cursor in that direction, head extension to move the cursor down, and rotation to the left to enter the vocabulary item. The cursor “wrapped around” the screen when right or lower boundaries of the screen were reached.

**Considerations made in selecting a scanning keyboard.** In considering Casey's needs and skills, the following system requirements were identified.

- As the pace within the classroom could not be drastically altered to accommodate one child, Casey required the fastest access method to writing possible given his physical limitations. At the time Casey performed best using directed scanning.
- It was important that the cognitive demands made by his system be minimized, allowing him to concentrate on his academic curriculum. Casey required independent access to a large, flexible vocabulary without relying on a coding system. It was important that the selection set be directly related to the task he was working on.
- Casey's scanning keyboard needed to be easily adapted to the class curriculum on an ongoing basis by assistants who were not familiar with computers.

**Application.** At the time of reassessment, Casey had an Apple IIE computer system with EMK in school for 1 academic year. He had a duplicate system at home for homework, for other written communication such as letter writing, and for recreation. He had become a proficient scanner. In addition to using a number of educational software programs, Casey had accessed a talking word processor that echoes letters and words entered as well as the entire message. Since Casey could not sound out words he was writing or reading, a Votrax Personal Speech System attached to the Apple was used for voice feedback. The voice was turned off during tests to prevent other students from copying his work. At the time of reassessment, he was using an ABC arrangement of the alphabet when spelling. It was expected that as his literacy skills became better established, he would exchange the ABC arrangement for a frequency of use array where letters that occur most often are close to each other, thereby increasing the rate of entry. When the task involved choosing the correct word from a list of words the selectable words were used to create the selection set. Because of his large Blissymbol vocabulary and because of the proficiency he had reached over several years of use, Casey used number coding to enter Blissymbols in creative writing.

Both Casey's mother and teacher's aide had attended a 2-day computer workshop that focused on applications of the computer at home and school and strategies for creating display sets for Casey and taught them how to set up and maintain his system. With support and encouragement, both had become comfortable in adapting Casey's display sets on an ongoing basis.

**Future developments.** Casey's written communication needs had been well met by the described system. However, as academic demands increase it will become more difficult for him to keep pace with his classmates. It is not possible to achieve a normal, adult writing speed with scan entry. A possible method of entry to increase Casey's writing speed might be a keyboard that would accommodate a combination of direct selection with scanning: Casey would select a larger group of vocabulary items di-

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rectly using a head-mounted indicator. The items within that group would then be scanned until he indicated with a head movement that the correct item had been reached. Such a method is not yet available.

Summary

The EMK is a scanning keyboard that provides a range of options not presently available in a single device. As a result, it has been possible to enable a group of children who are severely physically disabled to use standard software with several commonly used microcomputers while meeting their complex needs and limited capabilities. The ability to create numerous large and clear display sets that are easily modifiable in terms of layout, quantity, size and type of items make the EMK particularly well suited to the needs of the young child.

Possible future developments of the scanning keyboards include a graphic character set to allow pictures and symbols to be created directly on the screen displays, and an input method which combines direct selection and scanning to provide a faster access method for individuals whose limited pointing abilities make direct selection a possible but insufficient method of selection.

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