

correct text on the screen and then print the text via the printer. All shifted keys are made available unshifted (via software), thus allowing one-finger or stick input. This program is intended for use by individuals who can type with fingers or the head/hand-stick. It allows them to write, proofread, and

correct prior to printing. It was written for Insta-Speak users who wish to print as well as speak.

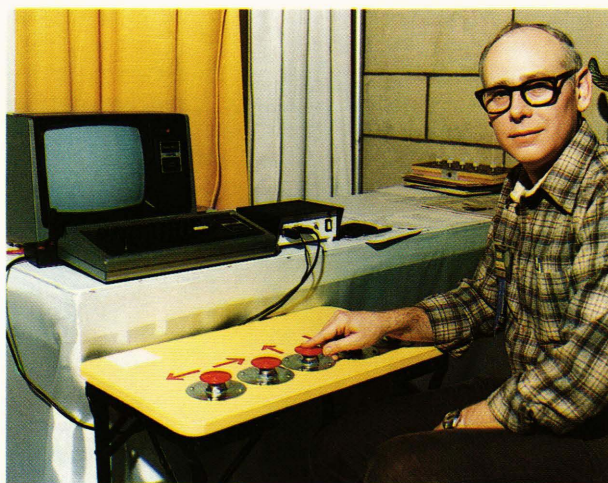
#### NOTE

<sup>1</sup>The initial clinical research is described in the article "CD: A Micro-computer-Based Communication Prosthesis for the Profoundly Handicapped," *Fam. Med. Rev.* 1(3), 67-75 (Winter 1982).

## A LOW-COST COMMUNICATION SYSTEM FOR THE NONVOCAL SEVERELY PHYSICALLY HANDICAPPED

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*A low-cost system (under \$1000, including computer) permits one or two nonvocal, severely physically handicapped persons to interact, write letters, communicate with others, and control external devices. It also provides a means of evaluating individual language and mathematical abilities and permits tutoring in these areas.*

### Objective

The system described in this article has been operational since December 1980 and was developed for Lois, who has very severe cerebral palsy and has been completely nonvocal since birth, more than 50 years ago. Although her motor coordination is very poor, Lois does have limited control of her right arm with a minimum positional resolution of 5 to 6 inches. She cannot use a joystick, nor can she grasp a pencil or wand. Her computer system was designed to satisfy the following requirements:

1. She should be able to control all system functions and operations with the fewest number of physical motions and keyboard controls.

2. The hardware and software should be easily adaptable to other home computers and should be readily available.
3. Software should perform the majority of decisions to minimize user activity and maintain keyboard simplicity.
4. The system must be very reliable and affordable by an individual.

### Background

Cerebral palsy is normally caused by damage to the motor coordination part of the brain at birth but usually does not affect the person's innate intelligence. The distinction between intelligence and knowledge is quite important here: simply put, intelligence is a measure of a person's ability to learn, and knowledge is a measure of what or how much has been learned. In severe cases of cerebral palsy, such as with Lois, it has been extremely difficult to assess either intelligence or knowledge, primarily due to the person's lack of physical ability to communicate complex thoughts and abstractions. However, with an appropriate interface to a home computer, Lois has shown that not only is she quite intelligent, but also that she has a very well-developed ability to clearly express her thoughts, feelings, and needs.

### System Description and Operation

Lois' system consists of an unmodified, low-cost personal computer (Radio Shack TRS-80), a simple interface device that accommodates two users, two custom-designed keyboards, each with only five keys, and a software program that controls the functions of the entire system from either keyboard.

The computer video display presents a list of letters, numbers, and preprogrammed words that can be selected and "printed" in a workspace area at the bottom of the screen (see Fig. 1). Although this basic system concept has been implemented with computers before, the approach described here is novel in its simplicity, low cost, flexibility, and lack of required additional expensive peripherals such as disk drives or large amounts of memory. The 16-line, 32-charac-



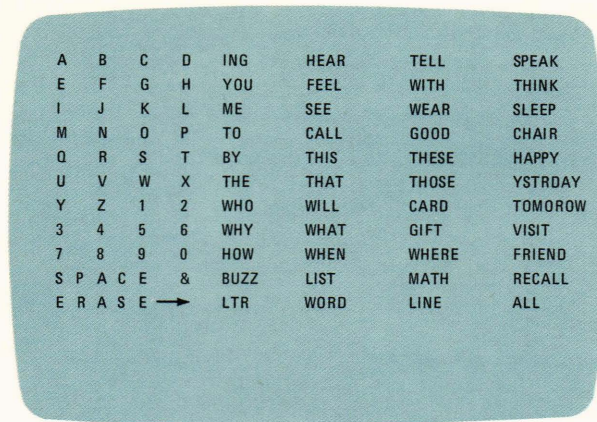


Figure 1 — Word construction video display 1.

ters-per-line video format was selected to permit good visual discrimination of displayed characters and maximum transferability to other computers. Any displayed letter or word in the top nine rows can be selected by pressing the keyboard buttons labeled ←, →, ↑, ↓, and + (corresponding to LEFT, RIGHT, UP, DOWN, and PRINT). The selected element is added to the text constructed in the bottom four lines of the screen. Holding the PRINT button down repeats the selected character or word. Automatic word spacing and line scrolling are accomplished by the software.

*User Keyboard.* Selection and arrangement of the five keyboard switches are determined by the physical abilities of the intended user. Working with Lois established her potential for deliberate movement and coordination of her arms, her reach and span within which she could make distinguishable movements, and her ability to control her head and visually discriminate words on the screen. In Lois' case, sturdy industrial "panic button" switches were used on the keyboard; they have about a 0.5-inch travel for the 2-inch diameter plunger tops. The mushroom shape allows her to place her fingers firmly around the back of the plunger head and depress the plunger with the palm of her hand. The switches are mounted on a small table made from sturdy composition board; folding legs were added to allow convenient storage.

Other switch arrangements and types are possible; for example, a quadriplegic with motor control of only the head, or perhaps only the jaw, could use an appropriately designed custom harness with more sensitive microswitches. The only requirement is that five distinct motions or movements be distinguishable and that these motions close a simple switch. Since there is virtually no power applied to the switches, the keyboard is completely safe electrically.

Provisions are made on the interface printed circuit board to accommodate two five-button keyboards. This permits two nonvocal handicapped users to "talk to each other" or allows a tutor to in-

struct a single handicapped user in language or arithmetic lessons. Switch-type joysticks are also directly usable instead of a five-button keyboard without modification to the interface.

*Word Construction.* By operating the five switches, the user is able not only to construct words and phrases but also to command the computer to jump to an arithmetic subroutine or to control external devices. Each of these functions will be described in turn.

The top nine lines of the display include the complete alphabet, all digits, and 36 preprogrammed words, which can be printed as displayed with a single action. Punctuation is not necessary for communicating ideas. If required, additional spaces can be inserted to indicate the end of a sentence or thought.

To keep to an absolute minimum the number of physical motions required, both horizontal and vertical wraparound is included: HEAR is one unit left from A. This is done by dimensioning a string array into which the alphabet and menu items are stored; the 86 different array elements are then arranged visually into a nominal  $8 \times 11$  matrix but still treated by software as an  $88 \times 1$  array with sequentially numbered indices.

If a mistake is made in the printed text, it can be corrected by locating the appropriate command on the ERASE → line. If only the last printed letter is to be erased, LTR is selected and printed; selection and printing of WORD removes the last printed word from the display workspace, and LINE does the same for the last printed line. Printing ALL clears the entire text workspace. In order to distinguish properly between words that are printable and commands that are not, the blinking rate of the items on the lower two lines of the menu is approximately double that of the printable menu elements.

The words on the right part of the menu, with the exception of ING, automatically insert a space between themselves and the last letter in the constructed text. Printing ING can be used to build quickly many words such as GOING, DOING, etc.

When you come to the end of the fourth displayed line of text in the workspace area at the bottom of the screen and print another word or letter, the displayed text is automatically scrolled up one line so that at least the last three complete printed lines are always displayed. The top line is scrolled off into a text buffer capable of storing 32 lines of text. This scrolled-off text in the buffer can be recalled by selecting RECALL on the menu and pressing the PRINT button on the user keyboard. The text workspace is then cleared, and the first four lines of text that were previously displayed on the screen are recalled and displayed. Each depression of the PRINT button while RECALL is selected prints out the next four lines of text stored in the buffer.

When the word LIST is selected and PRINT is pressed, the 36 words that are preprogrammed in the listing appear (see Fig. 2). These new words can then



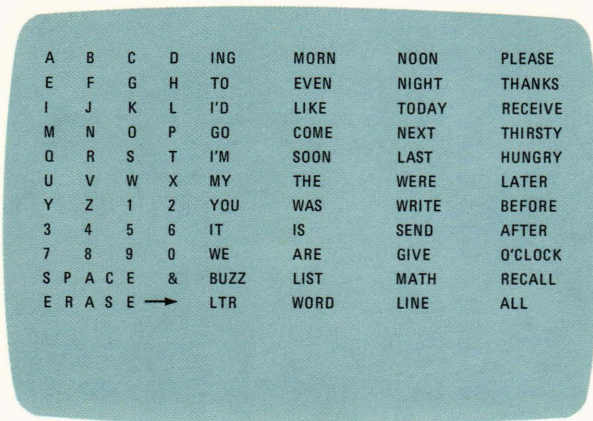


Figure 2 — Word construction video display 2.

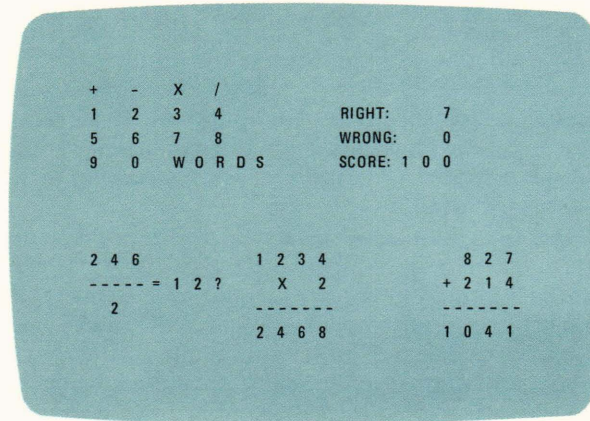


Figure 3 — Arithmetic video display.

be selected, printed, or edited in the screen workspace just as the words from the first list were. Pressing PRINT a second time while LIST is selected restores the original list to the screen. The number of separate lists that can be displayed is a function only of the amount of memory space available.

Selecting BUZZ and pressing the PRINT button activates a remote buzzer to summon the nurse. Two buzzers or other external devices can be activated independently, one from each keyboard. Suggested circuits for external control are available.

**Math Subroutine.** MATH is the entry point to the arithmetic subroutine. When MATH is selected and blinking, and the PRINT button is pressed, we go to the arithmetic subroutine. First, any text that was displayed on the screen is saved in the text buffers. The screen is then cleared, and the math display of Fig. 3 is displayed. A series of prompts is then provided that establishes what kind of problem you want (addition, subtraction, multiplication, or division) and the level of difficulty (number of digits in the longest number). All prompts can be answered with the direction buttons on the keyboard.

If addition or subtraction has been selected, you may specify from 1 to 4 digits for both operands. If subtraction is selected, the top number will always be greater than the bottom number; i.e., the answer will always be positive or zero. A mixed number of digits is also possible (e.g., 127 + 63, 4102 - 386, etc.).

For multiplication and division, the multiplier or divisor will always be only one digit (e.g., 136/8, 427 × 7, etc.). Additionally, division problems will always come out evenly with no remainder because this program is aimed at teaching the basic skills and methods of the times tables and simple division, usually with supervision. If multipliers or divisors of more than one digit were allowed, or if division problems included remainders, too much mental arithmetic would be required.

After the computer is given the problem parameters, the first problem is printed on the bottom left of the screen and we can now move right, left, up, or

down in the numbers menu to select the digit we want to print where the question mark appears in the displayed problem. Right-left and up-down wraparound is also featured. Digits of the answer are printed just as you would normally proceed, adding up the right column first and then proceeding left until the answer is complete. Subtraction and multiplication work the same way.

When the number of digits printed equals the actual number of digits in the correct answer, the printed and actual answers are compared and the score printed. The entire problem and answer are then shifted right to the bottom middle of the screen, and, if correctly answered, a new problem of the same type is displayed. However, if the displayed answer is incorrect, the prompt TRY AGAIN will appear, and the missed problem will be reprinted in the lower left screen area, giving a second chance to answer that problem while examining the previous wrong answer. If answered incorrectly again, there will be a third chance, but after that, a new problem of the same type will be presented, as well as the prompt LET'S TRY A NEW ONE.

For division problems, the format is changed somewhat to the form of a fraction to ease display requirements. Initially, the ? would be just to the right of the equal sign, the position of the first digit printed in the normal division process. When the first digit of the answer is printed, the question mark moves to the right one space, and the second digit is selected and printed.

The process above has been described in fairly great detail to illustrate that the manner in which arithmetic problems are visually displayed is quite important. To be useful in a teaching/learning situation, the computer must present the problem in the normal flow of steps you and I have taken for granted since the third grade. Still, until the handicapped student has mastered the arithmetic processes, some tutoring or personal assistance will be required to get across the concepts of carrying and borrowing, which must be done mentally with this program.



*Returning to Words.* If the menu item WORDS is selected and printed, the screen is cleared, the original menu of words is automatically reprinted, and all previously stored text is recalled to the workspace area in increments of four lines of text. By pressing any direction key, additional text can now be added to the displayed text; you can always pick up again where you left off.

One final note on the displayed menu: Phrases that have a space in them (such as I AM or I WANT) cannot be included in the preprogrammed menu. Only single words can be used for the menu items, and they are limited to four letters for the first two columns, five letters for the third column, and seven letters for the far right-hand column, plus a leading space for each item except ING.

*Interface Description.* Complexity and cost of the dual keyboard interface are drastically reduced if we use only those computer signal lines we really need and which are commonly available on most home computers. The circuit was also designed to meet the requirement to keep program statements simple. For example, the input data are called from the left keyboard with INP(1) and from the right keyboard with INP(2). OUT1,X (X is any integer from 0 to 255) sends an unambiguous output signal for the left user, and OUT2,X does the same for the right user. OUT0,X (or manually depressing the front panel RESET pushbutton) resets the output latches for both users to their normal logic state. These commands were purposely chosen so the programmer can easily remember what commands affect which port, while avoiding any possible interaction with the TRS-80 cassette input and output port 255. Either of the two output signals can then activate an external device such as the buzzer to summon a nurse.

Since the circuit is all CMOS, except for the voltage regulator, power drain is very low, on the order of about 10 milliamperes. The entire interface can be powered by an inexpensive AC adaptor for games and calculators or by other voltage sources that have outputs of 8 to 15 volts. The entire circuit is assembled on a 3 × 4 inch double-sided printed circuit board. A few extra dollars for a good-looking cabinet for cosmetic purposes is well worth the investment.

The printed circuit board is easily assembled from readily available components and is adaptable to other personal computers besides the TRS-80. The circuit was also purposely designed to accept directly two standard Atari joysticks so that, with the proper software program, the many TRS-80 owners could use the same interface for the very popular interactive arcade games. This much larger potential market for the interface ensures a minimum cost to the handicapped user through production in much larger quantities.

*Software.* The complete, well-documented software program is written in BASIC to facilitate a transfer of the program to a different computer. Dif-

ferent user reaction times can be accommodated by changing a single program statement. The preprogrammed word lists can also be modified easily to suit the user's individual needs. The words shown in Figs. 1 and 2 were selected by Lois. The software program includes extensive prompts that can be answered by pressing the appropriate keyboard button. Cassette tape is used for low-cost storage. The program for this project is placed in the public domain.

*“To be useful in a teaching/learning situation, the computer must present the problem in the normal flow of steps you and I have taken for granted since the third grade.”*

*Battery Backup.* During this project, it was found that provision for battery backup for the computer was essential. Several nursing homes and most schools have emergency lighting for use when the commercial 115-volt power fails, and these are tested regularly. The weekly exercising of this capability at Lois' nursing home resulted in the additional design of a battery backup to the TRS-80; technical and construction details will soon appear in *80 Microcomputing* magazine. In addition, a power line transient suppressor is highly recommended.

An interesting observation during this project was the evident reluctance of the residents at Lois' nursing home to have anything to do with a computer. Therefore, the computer keyboard, interface, power supply, backup battery, tape recorder, and all power cords were placed in a small cabinet with doors on the front. The video display “TV” was placed on top of the cabinet slightly below Lois' seated eye level. The only obvious cords were a single power cord to the wall socket, the TV (TV's are harmless and quite acceptable) video cable, and the small cable leading to her five-button keyboard. The computer was left on continuously, as before, and turned off at its front panel only when Lois was through for the day. Rather suddenly, other guests started visiting to see what Lois had to say. Use of a secure cabinet should also be considered in a school or classroom situation to prevent accidental damage to or tampering with the computer.

## Conclusions

Lois' complete system is extremely reliable, very easy to use, requires a minimum number of physical movements, and yet is very sophisticated in its ability to construct and edit messages, control external devices, tutor elementary arithmetic, and permit two users to interact on the system. The custom-designed hardware interface is inexpensive and very flexible in its application, and can easily be constructed by a person with only a modest amount of experience. The sophisticated software program accommodates



two users of different abilities and reaction times, permits tailoring the word menus to meet individual needs, and allows the user keyboards to remain small and simple. The keyboards are rugged, reliable, and electrically safe and can be designed to meet individual motor skill and coordination abilities. But the real value of the system was apparent when, after only ten minutes of verbal instruction, she printed out MY NAME IS LOIS and immediately followed her first words with the repeated message, THANKS THANKS THANKS. . . .

## LEARNING DISABILITY

### WE HELP MORE

Sandra Jackson, Judy Maples Simmons,  
and Tony Wedig  
*Robert E. Lee High School, San Antonio, Tex.*



*Judy Maples Simmons*

*Tony Wedig*

*Sandra Jackson*

*The Radio Shack TRS-80 microcomputer system has proven to be a beneficial remedial and diagnostic aid for the students in academic areas at Robert E. Lee High School, San Antonio, Texas.*

### Introduction

The program has been implemented, tested, and evaluated since October 1979. It was designed to accomplish the following goals:

1. Aid students with minimal cerebral damage arising from congenital anomalies or chemical or accidental injuries to adjust to the mainstream of school campus life;
2. Help students compensate for learning disabilities in order to lead normal, productive lives;
3. Stimulate underachievers to learn, thus helping them adjust to a regular classroom setting;
4. Aid in constructive as well as continual com-

For information on the availability of the hardware and software designs developed during this project, a self-addressed stamped envelope to the author will ensure a prompt response.

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ACKNOWLEDGMENTS—I would like to acknowledge Lois' enthusiasm, patience, perseverance, and, indeed, her many suggestions made along the way to refine the operation of this system. The constant support of her family has also been invaluable. Without it, this project could not have come to fruition. I would also like to express my appreciation to Richard O. Savoye for his helpful suggestions, particularly in the area of human/machine interfacing.

munication for deaf students so that they may join in the mainstream of education;

5. Eliminate frustration for emotionally disturbed children, thus helping them gain the ability to cope with the normal classroom setting;
6. Improve basic skills in reading and mathematics, thus allowing students with minimal learning difficulties to mainstream;
7. Teach students with minor muscular coordination problems to compensate and adapt so that they may be mainstreamed into regular classroom settings.

### Needs Assessment, Program Testing, and Evaluation

Public Law 94-142, passed by the Congress in 1975, amended the Education of the Handicapped Act and has become known as the Education for All Handicapped Children Act. It is designed to provide free and appropriate public education to all handicapped persons aged 3 to 21 years, regardless of the severity of the handicapping condition. In addition to several other categories of handicaps, PL 94-142 defines those children who are evaluated as having specific learning disabilities as handicapped. A learning disability is a disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written language; it may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning problems that are primarily the result of visual, hearing, or motor handicaps, mental retardation, or of environmental, cultural, or economic disadvantage.