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A Technical Note

Computer as a group teaching aid for persons who are blind

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Abstract—A concept has been formulated whereby a teacher in a classroom for students who are blind can communicate line diagrams and text directly to the students. This approach is based upon a single computer placed on the teacher's desk, with monitors on the students' desks. Access to the information displayed on the monitors is obtained by means of an optoelectronic sensor and vibrotactile output. Two versions of the sensor have been made—one for sensing line diagrams, and the other for Braille text. A simple, low-cost arrangement has also been designed by which students who are blind can prepare a hard copy of the diagrams from the monitor display. The special feature of the system is that it allows the teacher to convey information directly to the students, that is, diagrams and text that have been entered into the computer while the students are in the classroom. Information previously stored on floppy disks may also be communicated in this way. This methodology will overcome the current limitation where the teacher is able to hand out only embossed diagrams and text that have been previously prepared. Learning to use the new system can be accomplished in a short time, with the added advantage that the system is relatively inexpensive.

Key words: *Braille, computer sensors, line diagrams, optoelectronic sensors, teaching aid, vibrotactile output.*

INTRODUCTION

In a classroom for the sighted, the teacher communicates by speaking, writing and drawing on a blackboard, and/or using some other visual media for presentation. However, while teaching persons who are blind, the teacher is limited to using only voice communication. No doubt, handouts of text in Braille and embossed diagrams may be given, but the flexibility of conveying thoughts conceived in the classroom does not exist—the handouts must always be prepared in advance. Clearly the quality of training could be improved if a better means of communication between teacher and student could be provided.

Reading equipment for persons who are blind, such as the Optacon, which provides a tactile output, and the Kurzweil Reading Machine which scans printed material and provides a synthesized voice output of the text, are commonly used as personal aids (1-3). However, these devices are not suitable as teaching aids in the classroom. All material must be in standard printed formats and the teacher cannot type information into the machines. Also, there is no provision for presenting diagrams to the students. Moreover, the equipment is too expensive to be provided for each student. Therefore, alternative schemes are necessary.

One method which could be worked out (at least theoretically) with currently manufactured equipment, is to have computer-controlled embossing machines at each student's desk, with the computer being on the teacher's desk. The teacher could then enter a diagram or text into the computer, and the embossing machines would output

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NOTE: At the present time, our objective is to communicate a concept. However, we would be pleased to answer queries from any investigators who are considering trying out this system in their own laboratories. *The authors.*

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the material to the students in embossed form on paper or plastic sheets. Besides the high cost of procurement of embossing machines for each student desk, there are serious limitations to this form of communication itself. Each change in the text would require a different embossed output sheet; the teacher could not readily point out a specific location on a diagram without going through the process of generating a new output sheet. Also, embossing machines are somewhat noisy, and if there were a number of these in a classroom, the overall sound level would be unacceptable.

Another concept, also based upon using a personal computer (as in the scheme mentioned earlier), has been reported where the computer output is presented in tactile form (4). There is a scope for connecting multiple tactile output devices to one computer. This system may serve well as a means of access to the printed text for individuals, but it is ineffective for graphics. In teaching, the communication of diagrams entails considerable difficulties. By and large, embossed diagrams on paper or plastic sheets is still the only means of communicating graphic text in schools. Consequently, a teacher is not able to convey even two-dimensional line diagrams drawn in the classroom. Clearly, the quality of training could be improved if a more versatile means of communication could be provided. Although a number of schemes can be conceived to overcome the limitation of current teaching aids, only those which are of low overall cost can become practically acceptable. The issue was therefore studied in its total perspective, and a new concept of teaching has been formulated wherein a single personal computer could be used for classroom instruction.

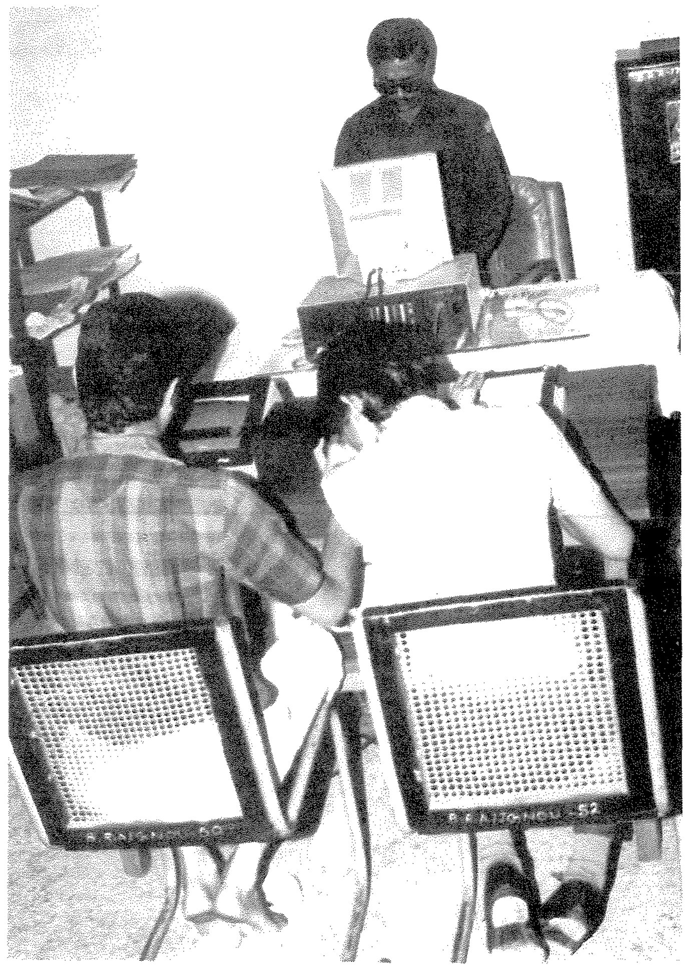

Figure 1.
An arrangement showing a main computer on the teacher's desk with a "mouse" to draw diagrams on the monitor screen. There is one desk for every two students. Each student is provided with a monitor.

THE APPROACH

A computer provides a convenient means of drawing and storing diagrams and can also be programmed to convert text into Braille. Hence the system that has been developed is based on the use of an IBM-compatible personal computer. Only one computer, placed on the teacher's desk, is necessary for the entire classroom. A number of monitors are connected to the main computer, and each student desk has a monitor (**Figure 1**). A diagram drawn by the teacher using a "mouse," or a diagram stored on a floppy disk may be displayed on the monitor of the teacher's computer as well as on the students' monitors. A special part of the system is a sensor with an output device by means of which the persons who are blind can trace a line diagram on the monitor and also get a hard copy output on a plastic sheet. When tracing alone is done (without hard copying), the perception of the overall diagram can be improved by sticking small globules of modeling clay on the monitor screen at places where the illumination is sensed. To meet the cost-containment objective, expensive embossing machines have been eliminated from the system. A second type of sensor is also provided so that the text displayed on the monitor in Braille code can be perceived by the students who are blind. Text may be entered on the computer keyboard in standard alphanumeric form.

Computer software converts the text into Braille code which is displayed in the form of illuminated dots in the standard 2 × 3 matrix form on each student monitor. This helps the teacher to communicate, at will, diagrams drawn in the classroom, as well as text entered while teaching. In this manner, three provisions are incorporated, enabling the student to:

1. Trace line diagrams without obtaining a hard copy.
2. Trace a diagram point by point and obtain a hard copy.
3. Read text converted into Braille by the software.

These facilities aid the voice communication in classroom teaching.

THE SYSTEM

General

Figure 1 shows the system with a computer and monitor on the teacher's desk and a two-student desk with one monitor for each student. The student on the right side of the figure is holding the hard copy-making device in his right hand. When a hard copy is not required, the student will have a compact sensor with vibrator output which will be moved directly on the monitor screen. The student on the left is holding the sensor for reading Braille on the monitor screen, and his right hand is feeling the pins on the output device. Although only two student monitors are shown, any number of monitors may be connected by means of a proper buffer interface in order to serve a larger group of students.

Optical sensor

A sensor for illuminated dots and line segments on the screen is a requirement for all three modes of operation. Basic sensor configuration is the same for all three operating modes, but the external mounting of the sensor parts differs to suit the individual requirements of the three modes of use. The key elements are a collimating aperture, a lens assembly, and a cadmium sulfide light-dependent resistor (LDR) (**Figure 2**). The lower face of the assembly is kept in contact with the monitor screen. Since the phosphor of the monitor is at a distance from the outer surface of the screen, with a layer of glass intervening, the phenomenon of light scatter has to

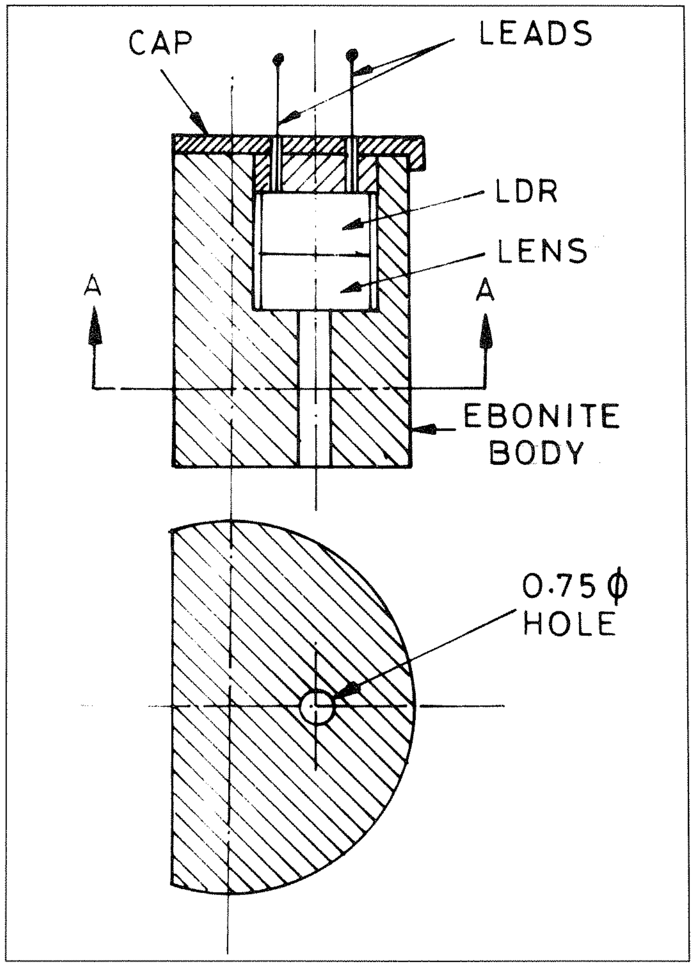

Figure 2.
Optoelectronic illumination sensor. The lower face of the unit is placed in contact with the monitor screen.

be taken into account. Furthermore, when a line on the monitor is viewed from a distance, the light rays from the illuminated region reach the eye in a small angle cone. Hence, a sharp image is seen. When a light sensor is brought close to the monitor screen, rays from a larger cone angle reach the sensor. Therefore, the illumination from neighboring line segments and dots overlap, and it becomes difficult to distinguish two separate neighboring illuminated zones. Good spatial resolution has been obtained by incorporating a 0.75 mm diameter aperture, and a lens in the sensor at the end which is in contact with the monitor. Another miniature lens is housed in the sensor so that the illumination from the phosphor surface of the monitor suitably illuminates the entire exposed area of the light sensor. This lens also helps to reduce the overall length of the sensor.

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Output device

A vibrator is the output device in all three operation modes. The key element of the vibrator is an electromagnetic relay of the single-pole single-throw (SPST) type. The electrical relay connections and the link to the LDR are shown in **Figure 3**. When the light sensor is over an illuminated region, the LDR resistance drops, the transistor base bias becomes more positive, and the transistor is switched on. The relay coil current flows through the normally closed contact. The relay armature is attracted, and the relay contact breaks. The armature then returns to the normal position, closing the contact. The sequence repeats at a rate that is characteristic for the relay. A pin is soldered to the armature plate: a vibration can be felt at the tip of that pin by lightly touching it with a finger. When the sensor is near an illuminated line or a dot, a certain amplitude of vibration is sensed by the finger, and is interpreted as the sensor being over a dot or a line. Lower amplitudes of vibration are interpreted as being in the vicinity of a dot or a line.

System to trace line diagrams without obtaining a hard copy

Figure 4 shows the sensor and actuator in use for tracing a diagram without making a hard copy. Affixing the sensor to the side of the vibrator provides convenience in handling. The aperture of the sensor is almost at the extreme right surface of the sensor housing. The user moves the assembly over the screen, and at a place where a vibration is sensed, a small globule of modeling clay is pressed onto the monitor screen at the right margin of the sensor. Since the sensor aperture is almost at the right margin of the sensor, the difference in position between the illuminated point and the location of the globule is small. The user then continues to trace the line and fix the globules. It has been observed that a small zig-zag movement helps to identify the points, especially when there are junctions and bends. After tracing the diagram, the overall diagram can be felt by lightly passing the hand over the array of modeling clay globules. With a little practice, this scan can be done without displacing the globules. Since the optical sensor part of the hand-held module is affixed to the extreme right of the sensor housing, and the user is holding the device with his left hand, it is recommended that the scanning is started from the right upper corner of the screen and moved leftward (right to left). For more complex diagrams, scanning can be done first from top to bottom, followed by bottom to top, at a slight angle in a raster fashion, until the whole screen is covered. After the scan, the globules can be removed with the fingers, and the residual modeling clay on the screen can be wiped off easily using a cotton cloth. In the case of simple diagrams (like triangles and circles), fixation of the modeling clay globules is not necessary.

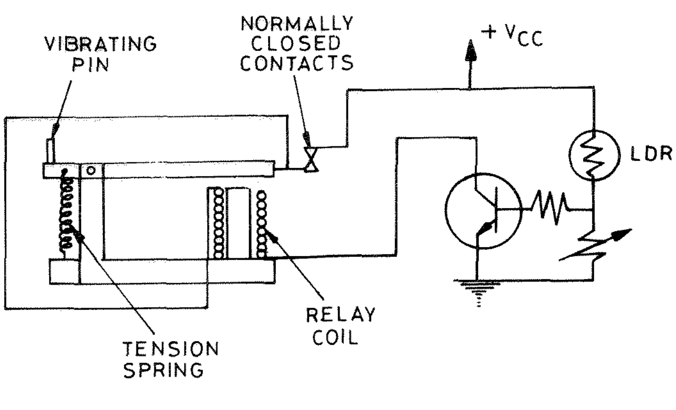

Figure 3.
Schematic of the vibrating actuator with LDR and switching circuit.

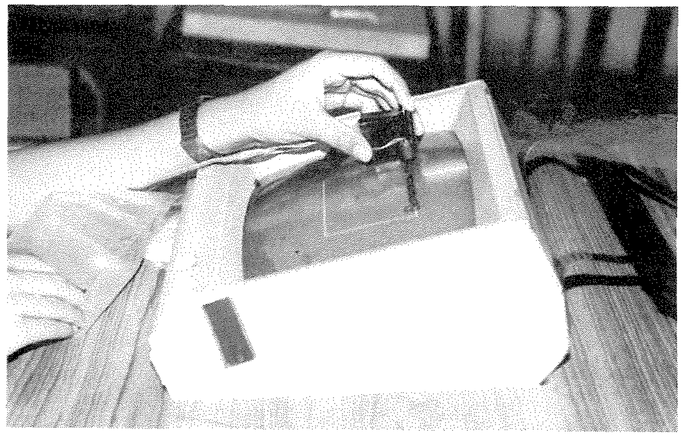

Figure 4.
Diagram tracing sensor and actuator being held in the subject's left hand. With the right hand, small pieces of modeling clay are fixed near the illuminated points.

System to trace a diagram point by point and obtain a hard copy

When a diagram has to be examined very carefully and maintained for future reference, a

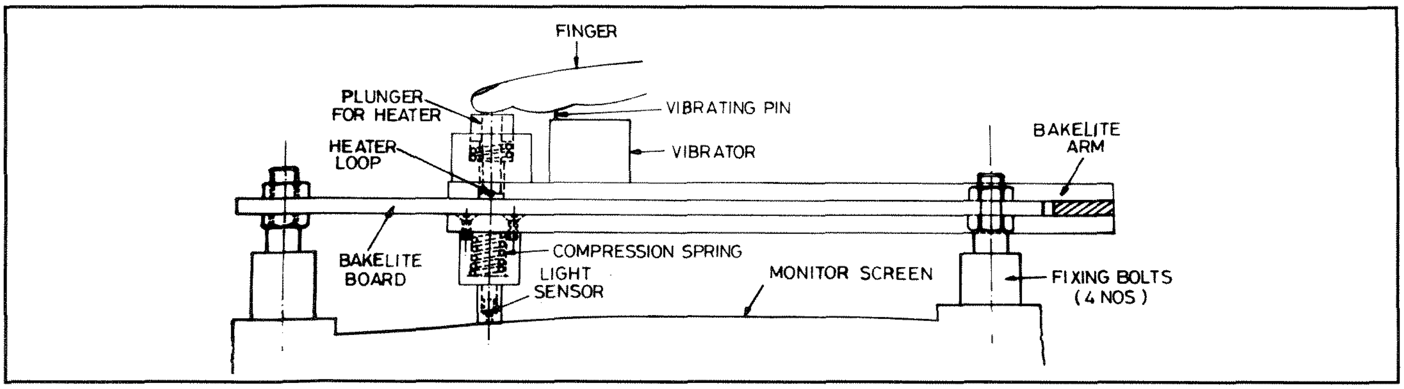

Figure 5.
Diagram showing relative placement of the sensor, heating element, and arm of the hard copy–making device in relation to the monitor screen.

hard copy is needed. A very simple low-cost technique for obtaining a copy on a plastic Braille duplication sheet has been formulated. The gadget is shown attached to the monitor on the right-hand side of **Figure 1**. The main principle underlying the system is as follows: if a loop of heated wire is briefly pressed onto a standard plastic Braille duplication sheet and then lifted up, the adhesion forces between the wire loop and the molten plastic leads to an upward flow of plastic over a small area. By making the loop have a sharp bend at the tip, the region of polymer flow can be made to be about half the size of a standard Braille dot when produced for duplication. Since the contours are very sharp (unlike the Braille duplication dots), the elevations are readily perceived, though being of small size. The small size also allows for higher resolution in tracing the diagrams. Wire of a highly specific resistant material such as manganin is used so that controlled heating can be obtained simply by passing a regulated electrical current through it.

The system (shown in **Figure 5**) is arranged so that the wire loop tip is in line with a light sensor. This line is perpendicular to the monitor screen. A flat board is placed above the screen, and a plastic Braille duplication sheet is attached to the upper side of the board. An electrical vibrator linked to the sensor (as in the earlier system) is also provided. The person who is blind can sense that the light detector is over an illuminated spot. When such a position is recognized, the subject presses down on the plunger with the finger tip, and the heated wire comes in contact with the plastic sheet. The plunger has a recoil spring that rises up when released. When moving upward, the heater tip forms the dot on the plastic sheet. (The heater tip needs only a very short period of contact with the plastic sheet.) Thus a diagram may be traced, and the corresponding dots obtained quite rapidly. For example, a blind 16-year-old male student was introduced to the system and allowed one hour of practice for Braille, as well as for making diagrams. The next day he was given one more hour of practice with diagrams of various forms. Then the figure of a hut (**Figure 6a**) was presented; the result of the first trial is shown in **Figure 6b**, and that of the second trial in **Figure 6c**. Studies also show that if some indication of the nature of the diagram is given by voice communication in advance, the speed of tracing is even faster. Regarding accuracy, it seems that the recognition is very good if the overall size of the diagram is larger than 50 mm, and there are few small-sized details. Error in locating points, except at junction points, does not generally exceed ± 1.25 mm. Even corners are suitably mapped.

After tracing the diagram, the flat board may be easily removed, so that the monitor may be used in other modes. **Figure 7** gives a picture of the entire assembly.

System to read text converted into Braille by software

Software has been developed by which text entered through the computer keyboard can be converted into Braille. Computer monitors at each student desk display the Braille code for the typed text in the form of illuminated dots. In order to sense the dots, six light sensors of the type described

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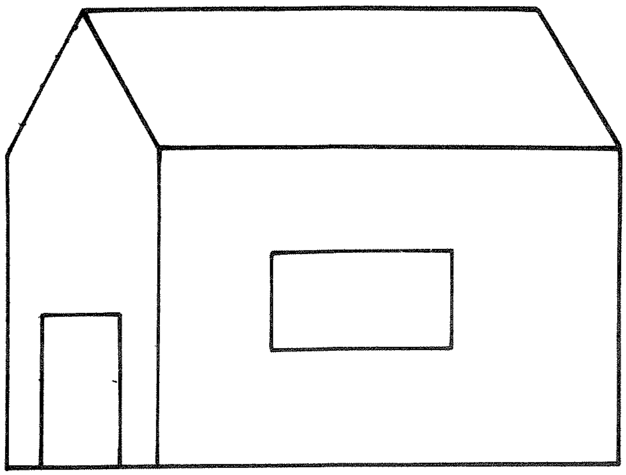

Figure 6a.
Figure of a hut presented for a practice diagram.

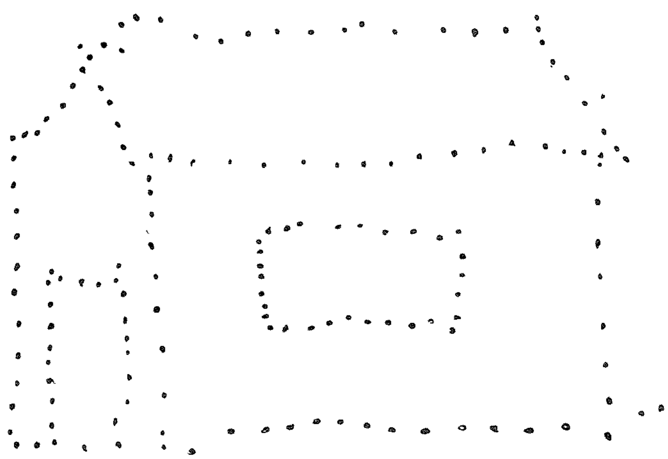

Figure 6b.
Result of the first trial of the practice diagram.

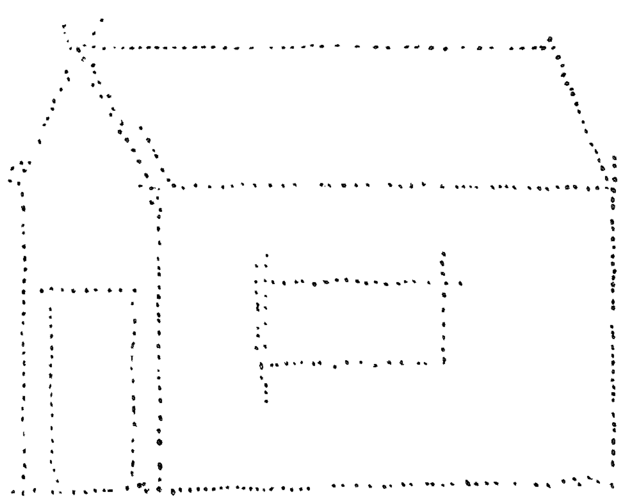

Figure 6c.
Result of the second trial of the practice diagram.

Figure 7.
One student holding the 6-sensor assembly with the left hand and moving the unit along the guide. The thumb of the left hand is near the touchplate used for return and scrolling. Illuminated dots corresponding to the text in Braille are seen on the monitor screen. The right hand of the subject is placed over the vibrating 6-pin assembly. The left hand of a second student is seen over another monitor in the foreground.

earlier are fixed in a 2 × 3 matrix array form in one module. These sensors are linked to six vibrators. In use, the subject moves the sensor module over the monitor screen with the left hand, and feels the vibrations with a finger of the right hand (**Figure 7**). A guide fixed to the monitor helps in scanning the screen from left to right.

The software allows a change in the spacing of the dots, as well as inter-letter spacing on the monitor. A display of five letters in one line has been found to give good results. There is adequate spacing between letters so that no vibrations are felt while scanning in the inter-letter space. Thus, the user would not confuse a vertical column of one letter with that of a next letter. Several lines can be accommodated on the screen. Shifting the guide was not found to be convenient. Instead, a touch switch is provided at the extreme right of the guide. As soon as the user touches this touch switch, the software scrolls to bring in the display of the next line. This line can then be scanned from left to right, and the process is repeated.

At present, the system is new and users are not very familiar with its use. At a later stage, with widespread use, the present large spacing of dots and letters will not be necessary. With a simple change in the software, more letters will be displayed in a line, and reading speed will improve. Spacing in the sensor module will have to be changed. A sensor module can be designed so that the user can adjust the spacing in the sensor to suit his own requirements, and accordingly, dot spacing adjustment can be made through the software. For the output module, it has been found convenient to use spacing about two times that of the standard Braille display. All of the subjects were skilled in Braille reading, yet they found the increased spacing convenient. Probably the fact that they were exposed to vibrotactile display for the first time, and that perception was still achieved with only the distal segment of one finger, made the transition acceptable. With further experience in vibrotactile perception, the users will possibly ask for the standard Braille spacing. If so, the output module pins will be brought closer to each other simply by repositioning the six relays.

SUMMARY

A concept has been formulated which brings the computer within the realm of classroom teaching for persons who are blind. During the course of the development, a number of blindfolded sighted volunteers, and blind subjects with varying levels of intelligence and academic preparation have tested the system. The learning time is quite short, being accomplished in a day or so. The degree of proficiency acquired in short-term trials depends upon the age and intelligence level of the student. While all persons can learn to trace the diagrams, the relationship between complexity and recognition varies widely. Also, the speed of tracing differs from person to person. Reading speed for the Braille text was over 60 percent of the speed with the standard paper Braille within 3 days of practice. Errors in recognition were infrequent.

During the study it became clear that the learning time and the acquisition of speed is markedly dependent on the initial psychological attitude toward the trial of the new systems. Students in the age group of 14 to 17 years were very receptive and learned very fast. This group did not express any difficulty in adapting to the vibrating mode of perception. The adult group, especially blind teachers, expressed the opinion that rising pins are preferable to vibrators. A detailed study with trials over an extended period can clarify the actual basis of the difference in perceptions.

A number of improvements are possible. For diagrams, the sensor and actuator may be placed on more than one finger, so that finger tips may be placed at appropriate locations at the same time, giving clearer spatial relations. Logic functions may be incorporated so that shades of gray may also be judged by sensing frequency variations in the actuator in addition to the amplitude changes. Also, some subjects may find an audio output more suitable than a vibrotactile output. There is no doubt that investigations on these aspects will ultimately lead to a very powerful classroom teaching aid. Furthermore, the system can be modified to serve as a means of following diagrams drawn on a blackboard.

ACKNOWLEDGMENTS

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