THE DEVELOPMENT OF PERSONAL READING MACHINES FOR THE BLIND

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INTRODUCTION

Mauch Laboratories research and development work on reading machines for the blind has resulted in several promising machines. The Stereotoner, which is based, in part, on the earlier Visotoner, is a new aural direct-translation reading aid. It is now being evaluated in a study using about 50 subjects. The improved Cognodictor will recognize print characters from many type styles and provide the user with the "spelled speech" sound for each letter. It uses new recognition procedures to achieve very significant performance advantages over earlier Cognodictors. A breadboard version of the Cognodictor is being built and tested. Useful accessories for the reading machines, such as the Reflex Viewer and several devices to aid tracking the lines of print have been developed.

STEREOTONER FEATURES

The Stereotoner is noteworthy for its stereophonic output code, its 10:1 zooming range which accepts letters up to 3/4 in. high, its capability for normal operation on reversed (light on dark) letters, its very small optical probe, and a compact, lightweight control box which is suspended in front of the user's chest from an adjustable neckstrap. The Stereotoner can be used for reading printed and typewritten materials including computer (and calculator) printouts. Many other tasks may be performed with the Stereotoner such as identifying paper currency denominations, reading labels on cans and boxes, determining the lightness or darkness of clothing or other objects, and locating light sources. As compared with the Optacon, the Stereotoner is one-third as
heavy, one-third as bulky, and less than one-third as expensive, yet training times and reading rates are comparable. With these and other advantages, including its wider range of letter sizes (the Optacon's magnification range is only 2.5:1) and its one hand operation, the Stereotoner will be the best choice for many people, though obviously there are needs for devices with tactile and audible outputs.

**STEREOTONER DEVELOPMENT**

A number of new ideas and several years of successful experience with the Visotoner were combined during 1971-1972 in the design of the Stereotoner. The Visotoner had been produced by modifying a tactile probe (Visotactor) by adding tone generating circuitry. Thus, a number of design features of the Visotoner were not well suited for an aural aid.

In 1970, Dr. Sanford Fidell demonstrated his use of computer generated pulses applied to each of a pair of earphones to produce the sensation of signals localized at various points inside the listener's head. This demonstration increased interest in a multicolumn Visotoner intended to produce stereophonic tone patterns representative of the portions of letter images seen by two or more columns of photocells.

Several experiments were conducted with a two-column Visotoner. These results were not promising. Later tests with a stereophonic code, produced by diverting into left and right earphones different amounts of each tone generated by a single column Visotoner, were successful. Worthwhile increases in speed and "legibility" were reported.

The design and construction of the first Stereotoner prototype was conducted during the last quarter of 1971 and the first quarter of 1972. The Stereotoner illumination system, consisting of a single lamp in a unique "clamshell" reflector, consumes only one-sixth of the power required by the Visotoner. Part of this reduction comes from the design of the reflector, part comes from illuminating a narrower vertical strip, and part comes from reducing the size of the photocells so that the image needs to be magnified less. The Stereotoner probe has a novel system of tubes containing complementary helical slots which produce its wide zooming range.

The complete Stereotoner, containing a battery which can operate it for 8 or 9 hours, weighs just 19.5 oz. The handheld optical probe which is attached to the chest box by a shielded cable contains the most frequently used adjustments for sensitivity (illumination intensity), letter size (magnification), and italic slants. It weighs only 1.5 oz. The remaining controls (switches for off-on, monaural or stereophonic output, normal or reversed print, and two volume controls (one for each ear) are located in the chest box.

With these features the first prototype was well accepted and work was
started on three additional prototypes, each one incorporating additional improvements desired in the production models of the Stereotoner. These prototypes were built and tested during the last half of 1972 and the first quarter of 1973.

**STEREOTONER EVALUATION**

Stereotoner production models were available in the second quarter of 1973 and a VA-NAS sponsored evaluation study, conducted by American Institutes for Research in cooperation with The Hadley School for the Blind and three VA hospitals, was started several months later. At this time all four schools are processing students and about half of the planned 48 subjects have been started in the training program. Many of the Stereotoners purchased for the study have been placed in service. Records of the required repairs indicate that making some minor design changes will result in a long interval between repairs.

Stereotoner repairs thus far have chiefly involved contact failures. A few are due to faulty solder joints; each Stereotoner contains about 500 soldered connections. More than half of the remaining contact failures were caused by a spring finger contact, which is being replaced by a soldered joint wherever possible, and the remainder were due to a bond failure of silver-filled epoxy between the battery’s positive contact (a disk containing a raised post like that on a flashlight cell) and the battery’s positive end. Existing batteries are being improved by removing the contact, removing the nickel plating from the bonding area, and rebonding the contact to the battery. In the future this area will not be plated.

Two repairs have involved semiconductor failures, and two probe cables have been replaced on Stereotoners which had heavy daily usage by teachers in the evaluation program. Five batteries became faulty; two of these evidently deteriorated while on the shelf for 18 months. In the future, batteries will be purchased in smaller lots to reduce the storage time.

As the Stereotoners age and receive more use, the number of battery and cable replacements probably will increase. Modifications in the cable design which may provide longer life will be tested. The number of contact failures probably will decrease as the Stereotoners are updated to remove the sources of such failures.

Mauch Laboratories will continue to service the Stereotoners used in the evaluation. The repair records and the experiences of teachers and subjects will be used to further improve the function and reliability of the Stereotoner.

**COGNODICTOR FEATURES**

A personal reading machine which recognizes each letter of a dozen
or more common type styles will make reading far easier and faster than possible before. To be readily available it should be compact and easily portable. It should be easy to set up and use, tolerating substantial mistracking. Such a machine should cost no more than an automobile and it should be much more reliable and maintenance free. Its usual output should be easy to learn, short, spoken letters (“spelled speech”) at rates up to 100 words per minute, but provision should be made for alternate outputs such as moving braille belt displays or machine speech produced by a remote computer.

These are difficult and sometimes conflicting requirements for the Cognodictor to meet. To meet the cost requirement one must use the abilities of the operator as far as possible without placing undue burdens on him. For instance, with the addition of either an aural or tactile version of what the photocells in a hand-held probe see, the user can scan the line of print and adjust for letter size, tracking, and italic slant. With additional training the user can use these direct translation signals to recognize numerals, punctuation marks, and symbols so that the machine does not have to be made larger to accommodate these things. Even among the upper- and lower-case letters and ligatures, the user can tolerate some recognition errors so that the machine recognition system can be modestly priced as compared with commerical optical character readers.

COGNODICTOR BREADBOARD DEVELOPMENT

Although the first Cognodictor design operated well for a variety of type styles, the main problem, a requirement for tracking the line of print with deviations held to less than ±10 percent of the lower case “x” height, slowed many readers excessively. At times very rapid line scan caused both recognition errors, due to the slow response of the photoconductive cells, and loss of letters due to the limited storage capacity of the Word Storage Unit. The fastest reader, Mr. Harvey Lauer, reported 50 words per minute; the maximum rate of the spelled-speech alphabet was 75 w.p.m.

To eliminate the tracking problem, the recognition logic and the photocell array were redesigned to use our newly invented “Two-Dimensional Multiple Snapshot Process.” This process and the photocell array allow a mistracking tolerance of ±50 percent of the “x” height. Except for designing the Recognition Matrix, a breadboard version of the improved Cognodictor logic has been completed. At first, the breadboard received its input from an array of 52 photoconductive photocells pending the design and manufacture of a special array of self-scanned silicon photodiodes. In the meantime this work has been completed and one of these arrays has been installed in a Stereotoner probe for initial testing.
In the coming year a Cognodictor probe will be designed. It will probably use the base and "clamshell" reflector of the Stereotoner probe design but everything else will be redesigned for new optical reduction ratios, a new lens (two Stereotoner lenses, back-to-back), and the new photocell array of the Cognodictor probe. Also, during the coming year, a Word Storage Unit with a capacity of up to 64 characters will be designed and added to the breadboard.

The major Cognodictor development of the next year will be the design of the patterns to be used in the Recognition Matrix. These fixed patterns will be stored in integrated circuit memories and compared in sequence with each pattern produced by the Cognodictor circuitry. The latter pattern appears in the second register of the Cognodictor and it varies according to the letter last scanned.

To determine the best stored patterns, i.e., those which will achieve the highest recognition accuracy over a wide selection of frequently used type styles, a large number of second register patterns will be collected on punched paper tape. These patterns will be the results of scanning 12–15 different printed alphabets under several different conditions of tracking position and optical probe adjustment. The tape contents will be transmitted to a remote computer in a time-sharing system where a program will be used along with considerable operator input to develop the stored patterns. It is expected that three to five stored patterns will eventually be required for each character. As the development of the stored patterns progresses, the computer will be able to calculate probable recognition accuracy for each type style.

The computer will also be used to prepare a second punched paper tape which will be used to load the stored patterns into the integrated circuit memories. Sixteen integrated circuits on the breadboard can contain up to 256 such patterns, about five patterns per character. If more are needed to increase the recognition accuracy or the number of styles recognized, they can be added later.

At this time, a computer terminal with a tape punch and reader has been requested for the above uses, the writing of the computer program has been started, the circuitry to transfer the second register contents to the tape punch has been completed, and the Recognition Matrix circuitry is being wired.

For the first prototype of the Improved Cognodictor, its direct translation portion (needed for adjusting magnification, italic slant, and for line tracking) will use an acoustic optophone-like code. Two arrangements appear to be useful in reducing interference between it and the spelled-speech output. First, each ear will receive only one of the two codes through its earphone. Second, the loudness of the optophone-like code can be reduced with increasing scanning speed. Various relationships between the loudness of each code are possible and experiments in
this respect can easily be done when the first prototype is operational. If it still appears that the direct translation portion of the Cognodictor should have a tactile output instead of the aural output (either in all cases or for those people who are more tactually oriented), an array of miniature stimulators will be designed to fit one finger and stimulate its underside.

**READING MACHINE ACCESSORIES**

Many users of the above reading machines will prefer moving their probes freehand, especially for short periods of reading. For beginners and for extended periods of reading, a device to aid tracking the lines of print is very helpful.

For the Stereotoner, a Tracking Aid was developed. It consists of a rectangular plate, 8¼ in. long × 1 in. wide × ⅛ in. thick, with a lengthwise cutout in which an 8-in. long, ¼-in. diameter roller is mounted. Such a device can be rolled from line to line parallel to itself. During the past year, the Tracking Aid was improved by the addition of a narrow strip of magnetic material to its underside. With a steel surface, such as the dictation slide found in metal desks, the Tracking Aid will hold itself on the line while a thin, flexible paper-holding magnet which is also provided can be used along the upper edge of a single sheet of paper to hold it in place.

In order to allow a sighted teacher to see the letter “seen” by the reading machine probe, the Reflex Viewer was developed. It consists of a transparent reading surface located about 4 in. above a flat metal mirror. The illumination from the Stereotoner probe passes through the paper along with the reversed image of the letter in the lighted area. Looking from either side into the mirror, the letter can be seen in its normal orientation. The Reflex Viewer is available as a part of a Teaching Kit which also includes two Tracking Aid Clips to hold the Tracking Aid to the upper reading surface, two Secondary Earphones, and a Teaching Manual.

A new improved Colineator is also being developed. The new design will be much more compact and lower in cost while retaining the margin stops, skew adjustments, and book-handling capabilities of its predecessor.