THE DEVELOPMENT OF A READING MACHINE FOR THE BLIND[a]

SUMMARY REPORT

Glendon C. Smith, Sr. Project Engineer
Hans A. Mauch, Principal Investigator

Mauch Laboratories, Inc.
3035 Dryden Road
Dayton, Ohio 45439

ABSTRACT

This report discusses progress from July 1, 1965 through June 30, 1966 on the development of a personal-type reading machine for the blind sponsored by the Veterans Administration, Prosthetic and Sensory Aids Service.

The most advanced personal-type reading machine being developed by Mauch Laboratories provides the blind user with a "spelled-speech" equivalent for each upper- and lower-case letter or ligature scanned by a hand-held optical probe. The character recognition technique recognizes most popular type fonts with moderate accuracy (90-95 percent) and speed (80-90 wpm) by using a special arrangement of photoconductors to gather information on letter features. The development of the hand-held probe for this machine has resulted in a family of direct translation reading aids which are pocket sized and battery operated and may be used independently for low speed reading. These are Visotactor A which may be used for recognition also, the Visotactor B and Multicolumn Visotactor which are "tactile optophones" with one or more columns of photocells and associated stimulators, and the Visotoner which is a line-tone self-contained optophone. One or more operating prototypes of each device were completed and tested.

The complete character recognition reading machine, consisting of the *Visotactor A,* the *Colineator* tracking aid, the *Recognition Prototype,* and the electromechanical *Word Synthesizer,* was assembled and tested for the first time during this reporting period. Reading performance was excellent on more than nine different type fonts. Plans were made to reduce the effects of vertical mistracking by redesigning the photocell array and the recognition logic. Frequency compensation circuits were added to improve

[a]Based on work performed under VA Contract V1005M–1943.

recognition accuracy at high reading speeds (90 wpm). Improved photocell materials were investigated which will permit 90 wpm operation without degrading recognition accuracy. The Recognition Prototype uses conventional discrete component construction and a large number of indicator lamps, whereas the production version will use about 100 low cost integrated circuits and no visual indicators. The production model of the Recognition Prototype and the photoelectric Word Synthesizer will occupy a total volume of about one-quarter cubic foot.

A blind volunteer, Miss Reinicke, has used a Visotactor B (tactile optophone) and Colineator tracking aid in her home for over one year. Maximum reading speeds of 15 wpm for a 2-minute period and 10 wpm for a 10-minute period were observed.

Mr. Harvey L. Lauer, a blind braille instructor at Hines VA Hospital, Hines, Illinois, has used the Visotoner prototype and a Colineator since January 1966. Mr. Lauer reported that he can read as well with the Visotoner as with the Battelle optophone.

A *Multicolumn Visotactor,* which uses 24 photocells and associated piezoelectric stimulators in three columns of eight each, was designed and constructed during this reporting period. Miss Reinicke began using the Multicolumn Visotactor on June 10, 1966. After 10 hours practice, she read at an average rate of 4.0 wpm using only one column of the three available in the Multicolumn Visotactor prototype. Later, when her reading performance has reached a plateau, the second column will be turned on, and still later, the third column will be activated.

The electromechanical Word Synthesizer was improved by recording new magnetic tape segments along the same arc used in playback. A special turntable apparatus to permit recording in an arc was designed and built. The new spelled-speech letters have greatly increased sibilance, and letters which sounded almost alike before are now more distinctive.

At the request of the Veterans Administration, Mauch Laboratories made preparations to build six Visotoners, four Visotactors B, ten Colineators and accessories. The procurement of commercial and manufactured component parts is nearly complete and the assembly will be carried out by personnel of this laboratory during the first part of the coming fiscal year.

Future work to design and build a pre-production model of the Recognition Prototype, to evaluate a photoelectric drum-type Word Synthesizer, and to build additional Visotactor-Visotoner prototypes is outlined at the end of the report. Improvement of the photocell construction techniques and further testing of the Visotoner, Visotactors A and B, and Multicolumn Visotactor are planned. The development of a *Digitactor,* a type of Multicolumn Visotactor which stimulates the underside of only one finger with a large number of vibrators, is also discussed in the *Future Work* section.

PERSONNEL

Persons engaged in the work reported herein during the period covered by this report are as follows:

Hans A. Mauch — Principal Investigator
Glendon C. Smith — Sr. Project Engineer
Albert C. Abnett — Project Engineer
Gervais E. Murray — Design Engineer
Kenneth C. Liest — Sr. Engineering Technician
Jack C. Kuntz — Sr. Engineering Technician
Mrs. Jeanne Manley — Office Manager

The assistance of Miss Bonnie Reinicke, Dayton, Ohio, and Mr. Harvey Lauer, Hines, Illinois, who gave their time to act as volunteer subjects for this project is gratefully acknowledged.

INTRODUCTION

Interest in providing a useful reading machine for the blind has been gradually increasing since the end of World War I. Most of the emphasis has been placed on simple *direct translation machines* (*optophone types*) which commonly use a vertical row of narrow photocells to scan letters sequentially and generate a different audio frequency for each photocell while it is "seeing" black. While such machines are simple and thus relatively inexpensive, they have the shortcomings of requiring extensive training and yielding low maximum reading speeds (10 to 25 wpm).

The work reported here is part of a continuous effort carried out by this laboratory, since 1957, toward the development of a personal-type reading machine for the blind. The most advanced system now being evaluated and improved will permit satisfying reading speeds (up to 80-90 wpm). It will be portable and will be reasonably priced when manufactured in moderate quantities.

In early studies we found that a speech-like aural output is necessary in order to achieve satisfying reading rates. Consequently, an electromechanical *Word Synthesizer* was designed and constructed which would play back tape recordings of individual phonemes stored in the Word Synthesizer and electromechanically selected for playback, in accordance with photoelectric scanning signals derived from the printed text. Full recognition of the entire alphabet was not intended at that time.

Somewhat later, a relatively economical scanning method was developed whereby a letter is seen simultaneously, as in a "snapshot," by a number of photocells in a two-dimensional array (rather than by a single line of photocells which must progressively scan over a letter to establish its identity). This "single snapshot" recognition technique was incorporated in a

prototype scanner which recognized all the lower case letters of the IBM Executive typewriter alphabet. In order to recognize upper- and lower-case letters of a wide variety of type styles, a more versatile recognition scheme which utilizes "multiple snapshots" to collect information on letter features was devised; and a *Recognition Prototype* which uses the "multiple snapshot" technique was designed and built. This Recognition Prototype was tested with 498 letters from 9 widely used type styles.

When it was realized that full recognition would be possible, the Word Synthesizer was equipped with tape recordings of "spelled-speech" letters, developed by Professor Milton Metfessel, University of Southern California, instead of phonemes. The "spelled-speech" output can be understood at 80-90 wpm with little training and is much more suitable for an inexpensive reading machine for the blind than attempting to synthesize English words.

The character recognition reading machine being developed by Mauch Laboratories consists of several components. The *Visotactor A* is the hand-held and guided optical scanner which at present contains eight tactile stimulators (two per finger) and operates as a type of tactile optophone to enable the user to adjust probe magnification for size of type (7 to 36 point), to locate the line of print, to scan along the line of print, and to decipher numerals and characters outside the spelled-speech "vocabulary." In addition to the eight photoconductive cells in the optophone-type array, the Visotactor A contains a two-line array of photoconductive cells which provide sequential signals necessary for the "multiple snapshot" character recognition technique. Logic circuitry located in the *Recognition Prototype* operates from the photoelectric signals to determine the presence or absence of letter features independent, in large measure, of the letter width and type font. A bench model of this recognition machine recognizes the most popular type fonts (9 have been tested to date) with excellent accuracy (90-95 percent). As soon as the letter (upper- or lower-case or ligature) has been determined, the logic circuitry translates its information into the 5-bit Baudot code which causes the *Word Synthesizer* to reproduce one of 32 pre-recorded outputs through a loudspeaker or earphone(s). A mechanical tracking aid, the *Colineator,* is an optional accessory which may be used for easier tracking over extended periods of reading (Fig. 1 and 2).

The *Visotactor B* consists of the same hand-held probe, tactile stimulators, and self-contained electronics to operate the stimulators as the Visotactor A but without the complex photocell array, logic circuitry, and Word Synthesizer needed for recognition operation. The Visotactors A or B and a rechargeable battery may be carried in a coat pocket and may be used as a portable tactile optophone in those cases in which small size and porta-

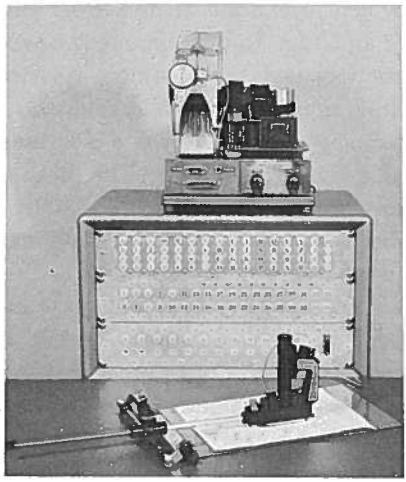

FIGURE 1. — The laboratory bench model of the recognition machine presently consists of the Visotactor A, Colineator, Recognition Prototype, and electromechanical Word Synthesizer. (Additional illustrations and descriptions of these units may be found in previous Summary Reports prepared by Mauch Laboratories.) The production model of the Recognition Prototype and the photoelectric Word Synthesizer will occupy a total volume of about ¼ cu. ft.

bility are more important than the speed and performance of the complete recognition system.

The *Multicolumn Visotactor* is an advanced version of the Visotactor B which contains three adjacent columns of photocells and associated tactile stimulators which are sensed by the "braille area" of the finger tips. The potential performance regarding reading speed places it between the single column Visotoners or Visotactors and the character recognition machine.

The *Visotoner* is the laboratory name for a compact, battery operated, optophone which uses the frame, illumination, and optics developed for the Visotactors A and B. The Visotoner frame contains nine transistorized audio oscillators which produce the optophone code. The Visotoner and its battery are also pocket sized.

One or more operating devices of each type described have been built and tested. The Visotactor B, Visotoner, and Colineator prototypes have been used by blind subjects in their homes for periods of 6 to 18 months. The Visotactor A, Recognition Prototype, and Word Synthesizer have been operated in the laboratory during many hours of testing. The first Multicolumn Visotactor prototype is now being used regularly by a blind subject.

aaaaaaaaa AAAAAAAAA fififfffi
bbbbbbbbb BBBBBBBBB flflflflfl
ccccccccc CCCCCCCCC ffffffffff
ddddddddd DDDDDDDDD ffiffiffiffiffi
eeeeeeeee EEEEEEEEE ffffffffffff
fffffffff FFFFFFFFF
ggggggggg GGGGGGGGG
hhhhhhhhh HHHHHHHHH
iiiiiiiii IIIIIIIII
jjjjjjjjj JJJJJJJJJ
kkkkkkkkk KKKKKKKKK
lllllllll LLLLLLLLL
mmmmmmmmm MMMMMMMMM
nnnnnnnnn NNNNNNNNN
ooooooooo OOOOOOOOO
ppppppppp PPPPPPPPP
qqqqqqqqq QQQQQQQQQ
rrrrrrrrr RRRRRRRRR
sssssssss SSSSSSSSS
ttttttttt TTTTTTTTT
uuuuuuuuu UUUUUUUUU
vvvvvvvvv VVVVVVVVV
wwwwwwwww WWWWWWWWW
xxxxxxxxx XXXXXXXXX
yyyyyyyyy YYYYYYYYY
zzzzzzzzz ZZZZZZZZZ

FIGURE 2. — Almost 500 characters were photographed and arranged on transparencies as shown to aid in the design of the photocell array and recognition matrix. The nine type styles illustrated here are estimated to make up about 75 percent of the printed and typewritten material used in the U.S.A.

PROGRESS DURING CONTRACT PERIOD

1. Development of the Recognition Prototype

The miniature recognition array which was encapsulated during June 1965 was mounted in a Visotactor probe and used to scan letters attached to a rotating drum obtained from Battelle Memorial Institute. The drum may be driven at variable speeds from 10 to 90 wpm. Photographic reproductions of the nine type fonts (Caledonia, Baskerville, Janson, Corona, Imperial, Regal, Elite, Pica, and IBM Executive) were attached to the drum. For very low speed checking of the recognition array, a friction drive added by this laboratory may be engaged and a small knob rotated by hand. Initial tests were very encouraging but revealed some problems in the Recognition Prototype and Word Synthesizer. In the Recognition Prototype a high resistance short circuit from the case of a power transistor to the chassis was caused by a small metal burr which scratched the anodized aluminum washer used to mount the transistor. When the Word Synthesizer release mechanism operated, electrical noise from a pair of relay contacts apparently activated the ring counter and caused spurious pulses to enter certain memory units. A capacitor shunting the contacts greatly reduced the noise.

After these faults were corrected, the Visotactor A probe (containing the first miniature recognition array) was adjusted to the proper magnification and used to scan the upper- and lower-case letters of several type styles on the drum. For two of the type styles, Imperial and Regal, all the lower-case letters were recognized at 20-30 wpm, and approximately 80-90 percent of the letters in the remaining type styles were correctly recognized at this speed. As the speed was increased, the accuracy of recognition decreased, due mainly to the poor response of the photoconductor material to rapidly changing light levels.

An illumination standard was needed for checking the light-dark ratios and response times of photoconductive cells constructed at Mauch Laboratories for the various reading machines. If such a standard could be modulated by sine or harmonic waveforms, it would be useful for measuring the sensitivity and speed of response of photocell arrays before attaching leads and encapsulating.

The range of modulating frequencies (d.c. to 400 c.p.s.) and the desired light output (0 to 10 ft. candles) in the red end of the visible spectrum (6500-7500 angstroms wavelength) suggested the use of a small neon lamp such as the Ne–51H. The neon lamp, a 90-volt battery, and a transistor modulator circuit using a 2N719A silicon transistor were assembled in a small aluminum box. The lamp illuminates a .750-in. diameter opening in the box. A clear plastic plate covers the opening and the rest of the top of the box.

To measure the sensitivity of a photocell, leads from an ohmmeter are clipped to the cell terminals and the cell is placed face down on the plastic plate over the opening illuminated by the neon lamp. A calibrated control which adjusts the steady current through the lamp, thereby adjusting the light output, can be turned to several settings while resistance readings on the ohmmeter are recorded. Measurement of response speeds requires the addition of an oscilloscope and waveform generator.

Experiments indicated that a simple resistance-capacitance frequency compensation network for each photocell used in the recognition prototype could partially compensate for recognition errors caused by slow photocell response. To select the amount of compensation needed, the frequency response characteristics of individual photocells were measured. This was done using the above described light source modulated by sine waves from 10 to 400 c.p.s. The resulting response curve indicates a loss of about 3 db at 20 c.p.s. and slopes downward of almost 6 db/octave. An amplifier circuit which compensates for the photocell response was designed and bread-boarded.

During October 1965, 14 frequency compensation amplifiers were built and mounted in the Recognition Prototype. Each amplifier has a compensation capacitor (initially 0.1 mfd.) which may be connected or disconnected by inserting or removing a single plug. With the capacitor disconnected the amplifier has unity voltage gain at all frequencies of interest. With the present capacitor connected the amplifier gain is unity at zero frequency, + 3 db at 20 c.p.s. and increases at about 6 db per octave to a maximum of + 28 db. The signal generated by the photocell first passes through an emitter follower, then through the compensation amplifier, and next to the Schmitt trigger circuit.

When the compensation amplifiers were first tested, a spurious oscillation of about 65 kc. frequently appeared at the output of the compensation amplifiers and consequently, at the output of the Schmitt trigger circuits. The common impedance responsible for the feedback was an electrolytic capacitor in the power supply. The internal impedance of this capacitor increased with frequency so that in combination with the + 28 db of gain present in the compensation amplifier sustained oscillation was possible under certain conditions. Two changes were incorporated in the Recognition Prototype which completely eliminated this condition.

The two changes involved shunting the electrolytic capacitor with a large paper capacitor which has a better high frequency characteristic than the electrolytic and adding another capacitor to each compensation amplifier to reduce its gain at all frequencies above 1 kc.

Another problem noted was a transient oscillation or "ringing" which occurred in the compensation amplifier used for the #1 photocell (the "key" cell which initiates the taking of each snapshot and which also par-

ticipates in determining whether the letter is past). Whenever photocell #1 was the last cell to sense white and thus initiate the "end-of-letter" sequence the sudden demand on the negative 12-volt supply (caused by switching a large number of lamps simultaneously) produced a pulse which entered the photocell common circuit and caused the Schmitt circuit connected to #1 photocell to again begin the "end-of-letter" sequence. A filter in the photocell common circuit consisting of a resistor, zener diode, and capacitor completely eliminated this problem.

The effects of the frequency compensation circuits were tested as follows: Each lower-case letter of the IBM Prestige Elite type style was typed 91 times in a line. Thus, there was a line of a's, b's, c's, etc. for a total of 2366 letters. This sheet of paper was mounted on a rotating drum and scanned by the Visotactor A probe at 90 wpm (450 characters per minute). Tracking was adjusted once at slow speeds for best performance across each line. A pen recorder was attached to the lamp terminal corresponding to the letter being scanned to record the number of times the letter was correctly recognized. Each line was scanned at 90 wpm with all the compensation capacitors connected and then the scan was repeated with the capacitors disconnected. Although no other changes were made between the scan with compensation and the scan without compensation the sequence of testing was alternated. The test results indicated a very definite improvement using compensation although additional work will be needed to determine the optimum compensation. In the test material 15 letters showed considerable improvement and 11 letters were unchanged largely because recognition accuracy was near 100 percent without compensation. Of the 15 letters which showed improvement, the average number of mistakes in recognition without compensation was 52 of a possible 91; with compensation this decreased to 30 of a possible 91. Overall average accuracy at 90 wpm for the lower-case letters of this type style was 79 percent. The lower-case "m" is recognized poorly because its last serif at the baseline and the first serif of the next letter may overlap and prevent detection of a white space between the letters about 50 percent of the time. It is worth noting that this type style (IBM Prestige Elite) was *not* one of the nine most popular fonts studied during the development of the Recognition Prototype. The low speed recognition accuracy of IBM Prestige Elite is about 90 percent; thus the top speed of 90 wpm still results in some degradation.

Further tests of the high reading speed performance of the Recognition Prototype using the procedure described above are planned. To reduce the labor involved in counting the thousands of correct responses recorded as "blips" on the pen recorder chart, an electromechanical counter was purchased and modified to count correct responses. The four digit counter can count up to 10 counts per second provided the coil is energized .06 second

and de-energized .04 second for each count. The circuitry needed to match the output of the Recognition Prototype to the counter was designed and built in an aluminum case which also contains the counter. The low voltage signal pulse from the Recognition Prototype is applied to an adjustable threshold Schmitt trigger circuit which drives a monostable multivibrator, which in turn produces the required .06 second duration output. This output is amplified by one transistor to operate a reed relay which switches the 110-volt supply required by the counter. The extra circuitry serves to "stretch" and amplify the short pulse from the Recognition Prototype so that an electromechanical counter can be used to count correct responses up to 10 characters per second.

The addition of frequency compensation amplifiers to the Recognition Prototype produced another problem in addition to those described above. When the tactile stimulators were made operative by connecting the eight optophone-type photocells in the combined Visotactor-Recognition photocell array to the Visotactor circuit, recognition errors increased slightly. It was found that the stimulator frequency (150 c.p.s.) and its harmonics were being coupled into the recognition circuits and amplified greatly by the compensation amplifiers. The interference caused the Schmitt trigger circuits to switch earlier or later than they should and sometimes caused #1 Schmitt trigger to signal for extra "snapshots." A simple cure for this interference has not been found yet. Providing separate ground (common) leads for the Viscotactor photocells and the recognition photocells seems to be a certain cure but one which requires redesigning the photocell masks and making a new photocell array.

Tests to determine the amount of tracking error (distance above or below the baseline) which would result in the Recognition Prototype missing more than 20-25 percent of the letters in a typical test were begun in November 1965. A 12-point size alphabet of the lower-case letters of the Imperial type style was attached to the drum apparatus previously described. The Visotactor scanned the alphabet at slow speeds. Beginning at a point below the letter baseline successive scans were made spaced .0016 in. apart. Four scans near the optimum height resulted in recognition accuracy of 90 percent or better. Two additional scans, one on each side of this group of four, resulted in recognition accuracy of about 80 percent. The six scans which produce a useful recognition accuracy enclose five spaces each .0016 in. for a total of .008 in. Since the lower case main body height (x height) of this type style and size is .080 in. the useful tracking band is 10 percent of this figure.

The accuracy figures used above are based on the frequency of letters in common English rather than giving each letter equal weight. For example, at the upper tracking limit (above the baseline) the Recognition Prototype fails to recognize only three letters (a,e,b) out of the 26. Considering

only the alphabet, this could be expressed as an 11.5 percent error; but considering that "a" and "e" are very frequently used, the error rate in reading text would be about 22 percent.

It was noted that the magnification adjustment of the Visotactor A used with the Recognition Prototype affected the sensitivity of the recognition photocells. This effect was caused by the non-uniform illumination pattern produced by the lens end lamps presently used. Our experience with the Recognition Prototype on various type sizes has not yet assessed the degree the recognition accuracy is affected by the non-uniform illumination.

Although the lens end lamps CM8–426 were carefully selected for good illumination patterns, only the central area of the combined pattern of two lamps seems to be uniform enough for a recognition machine. The lamp which has the same filament as the CM8–426 but lacks the lens is the 1784L. Two of these were assembled in a reflector and compared with the lens end lamps. The illumination patterns produced by the 1784L lamps is uniform for letter sizes up to the largest type size accommodated (36 point). As expected, the light intensity measured about 20 percent less than that obtained with the lens end lamps. Experiments to obtain a higher intensity uniform pattern will continue.

2. Evaluation of the Visotactor B

During most of the current fiscal year, Miss Bonnie Reinicke, a young blind woman, used a Visotactor B prototype and Colineator to read the lesson material, supplementary material, and tests contained in the 200-lesson Battelle Training Program prepared by the Battelle Memorial Institute for students of the Battelle optophone (Fig. 3).

During July 1965, Miss Reinicke read tests #7, 8 and 9 at average speeds of 3.3, 4.5, and 4.2 wpm, respectively. The drop from 4.8 wpm on test #6 to 3.3 wpm on test #7 seems to be caused by the test material. According to Miss Reinicke, test #7 has a curved baseline for most of the lines.

During July 1965, Miss Reinicke read tests #7, 8, and 9 at average speeds speeds including line change time of 5.0 and 7.1 words per minute, respectively. The considerable speed increase on test #11 also appeared in the speeds of the Battelle optophone class of 1963 and seems to be caused by the test material which contains a more meaningful story than the tests immediately preceding or following #11.

During September 1965, Miss Reinicke read tests #12 and #13 at average speeds of 5.1 and 5.0 wpm, respectively. She noted that the performance of the Visotactor B which she has been using since September 1964 seemed to change after two hours of continuous use. The performance change seemed to make sensing the lower portion of certain lower-case letters such as "r" more difficult. When Miss Reinicke was given another

FIGURE 3. — Miss Bonnie Reinicke is shown using the Visotactor B and Colineator to read a book. She has used this equipment in her home since September 1964. Miss Reinicke has read the Battelle 200-lesson training material, a 200-page book, and several magazine articles with the Visotactor B.

Visotactor B to use, she reported that the difficulty did not appear. The difficulty was corrected when the photocell array in the first Visotactor B was replaced with a more sensitive array made at Mauch Laboratories using techniques described below. The faulty array was one of the "rejects" left over from the production of Battelle optophones.

During October 1965, Miss Reinicke read tests #14 and #15 of the Battelle lessons with the Visotactor B and Colineator at average speeds, including line change time, of 6.9 and 7.2 wpm, respectively. Line change time averaged 15 seconds per line, and tracking corrections while reading the line were rarely required.

In November 1965, Miss Reinicke read tests #16, #17, and #18 with the Visotactor B and Colineator at average reading speeds, including line change time, of 5.7, 7.0, and 6.6 wpm, respectively.

During December 1965, Miss Reinicke read the last two tests, #19 and #20, of the Battelle 200-lesson training material at average speeds of 7.2 and 7.7 wpm, respectively (Fig. 4).

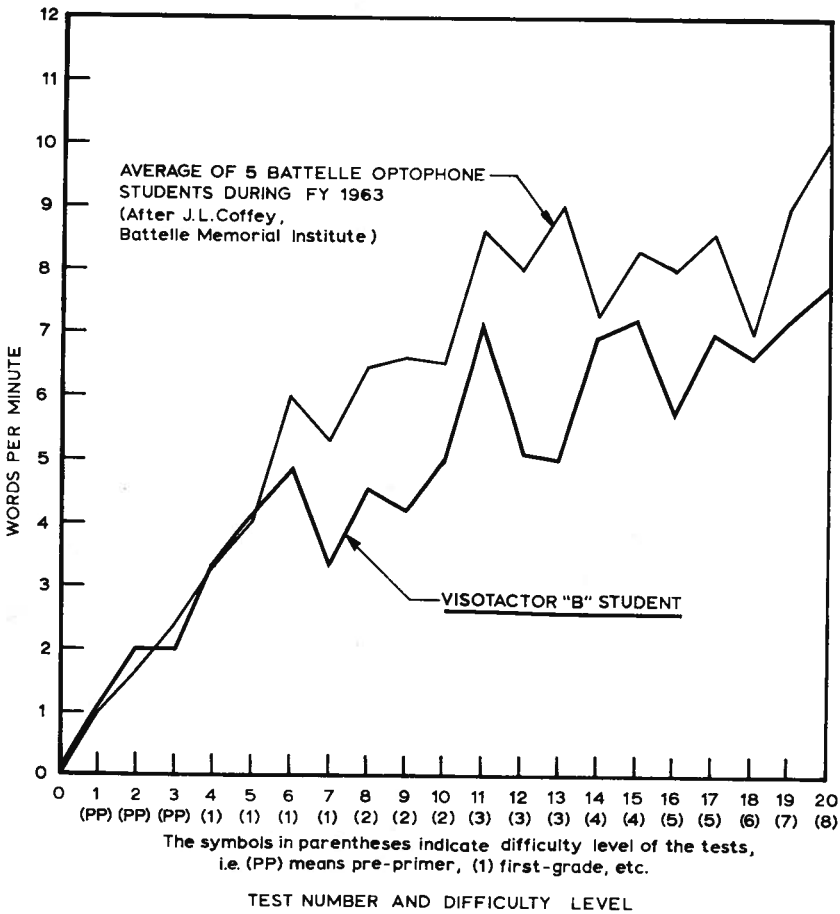

FIGURE 4. — The learning curve for the first Visotactor B student closely follows a curve well established for students of an optophone. Training procedures for the Visotactor B student were very informal, since Miss Reinicke read most of the Battelle lesson material at home, without guidance, and lacked the tape recorded practice material used by optophone students. Both curves include line change time. Each test score is for 10 minutes of continuous reading. Word identification errors, mainly substitutions, are only about 1 percent.

During January 1966, Miss Reinicke began reading a book of mystery stories, *Alfred Hitchcock's Ghostly Gallery,* with the Visotactor B and Colineator. After several hours practice, she became accustomed to the new type style and the techniques involved in reading a book. The first test was taken from page 13. Miss Reinicke read for 20 minutes at an average speed, including line change time, of 7.0 wpm.

On February 3, 1966, Miss Reinicke read page 33 of the Hitchcock book

at an average rate of 8.0 wpm and on February 15, 1966, she read page 47 at an average rate of 8.0 wpm. On February 18th, the Visotactor B used by Miss Reinicke was modified to produce less energetic tactile stimuli. The voltage applied to the stimulator coils was reduced from 6.0 volts to 5.0 volts. Miss Reinicke reported that the reduced stimulator voltage in the Visotactor B seems to allow reading for longer periods without fatigue. In addition to investigating the relationship between stimulator intensity and fatigue effects, the Visotactor B modifications served to prepare Miss Reinicke for using the Multicolumn Visotactor which has a weak tactile stimulator.

On March 1, 1966 and March 22, 1966, Miss Reinicke read from her book at average rates, including line change time, of 6.9 and 6.4 wpm, respectively. On April 5 and April 19, 1966, her reading speeds were 5.3 and 7.7 wpm. The stimulator voltage was again reduced, this time to 4.0 volts. Reading speed appeared to be unaffected by the change in stimulator voltage. Miss Reinicke read at rates of 7.5 and 7.6 wpm including line change time on May 2 and June 2, 1966, respectively. From January 1966 when she began reading test and practice material from her book, to June 1966, the average line change time has decreased to about 3 seconds. Maximum reading speeds of 15 wpm for a 2-minute period and 10 wpm for 10 minutes were observed.

3. Evaluation of the Visotoner Prototype

Because the American Center for Research in Blindness and Rehabilitation had difficulties in obtaining suitable blind subjects to evaluate the Battelle optophone and the Visotoner, the Visotoner prototype was returned to Mauch Laboratories on December 17, 1965. Mr. H. Freiberger, Electronics Engineer, Research and Development Division, Prosthetic and Sensory Aids Service, Veterans Administration, New York, suggested that Mr. Harvey L. Lauer, a blind braille instructor at Hines VA Hospital, Hines, Illinois, would be interested in using the Visotoner and Colineator. Mr. Lauer has used the Battelle optophone and tracking board for about two years. On January 11, 1966, Mr. G. C. Smith took the Visotoner prototype and a Colineator to Mr. Lauer at Hines and instructed him in the proper use of these devices. At the Sixth Technical Session on Reading Machines for the Blind held in Washington, D.C. on January 27th and 28th, 1966, Mr. Lauer demonstrated the Battelle optophone and the Visotoner and indicated that he was already using the Visotoner to read labels on cans and boxes in addition to letters, signatures, paper money, bank statements, etc. He had even carried the Visotoner and its battery in the leather case to a supermarket where he scanned the labels of possible purchases. Mr. Lauer also stated that rotating the optical barrel to correct for italics did in fact make italics readable.

On March 20, 1966, Mr. Lauer provided us with a copy of his first report to the Veterans Administration on the Battelle optophone and the Mauch Laboratories Visotoner. Mr. Lauer has used the Visotoner for about 30 hours between January 11, 1966 and February 14, 1966. He used the Colineator for about 10 hours out of the 30. Mr. Lauer commented on the fact that tone #4 (880 c.p.s.) turned on before the others. He also requested an adapter which would permit using earphones with different plugs and which would permit using a second earphone for monitoring a student's performance, and indicated that he would like a hard case for the Colineator.

The Visotoner photocell series resistor for tone #4 was changed to reduce the sensitivity of that channel. The thirteen hard attaché cases which were ordered for the three existing Colineators and the ten Colineators being built arrived by the end of March and one case was sent to Mr. Lauer when the Visotoner and Colineator were returned on March 25, 1966. A special headphone adapter with five output jacks was assembled for use with the Visotoner. A patch cord which can connect from this adapter to the input of a tape recorder or public address system was also included in the return shipment to Mr. Lauer.

4. Design and Construction of a Multicolumn Visotactor

A photocell array which contains 24 photoconductor cells in three columns of eight cells each was completed during September 1965. Unlike earlier designs, this array for the Multicolumn Visotactor is composed of circular cells which respond equally well to horizontal, vertical, or sloping lines. Each cell consists of a common indium electrode completely surrounding a circle of photoconductor material .050 in. in diameter. The other electrode is an indium dot as small as practical (.025 in. in diameter, in this array) located in the center of the photoconductor circle. In an ideal array this center electrode would be located over a small hole in the substrate and the wire lead to the photocell electrode would exit through this hole. Since the production of an alumina substrate with the required holes (24) is an expensive, time consuming operation it was not undertaken at this time. The first array of circular cells uses fine wires (.005 in. diameter) attached to the center electrode and suspended in the space above the array. The shadow cast by this wire is small and a constant factor which does not seem to affect adversely the performance of the cell.

The design of a Multicolumn Visotactor base which can accommodate 24 bimorph stimulators each 1.00-in. long was completed during early October. The base closely resembles existing Visotactors and can be substituted for a Visotactor B base which contains eight electromechanical stimulators. An increase in height of .340 in. was necessary to accommodate the longer bimorph stimulators.

The Multicolumn Visotactor base which was designed during October 1965 was built during November 1965. Twenty-four bimorph stimulators were mounted in the base and checked for proper operation. Two of the 24 stimulators required replacement when they short circuited due to application of excessive voltage.

During January 1966, the first Multicolumn Visotactor prototype was completed. Most of the final design and construction work involved the circuitry required to apply a high voltage to each stimulator through a series charging resistor and to discharge the stimulator approximately 150 times per second when the corresponding photocell senses black. The switching circuit had to meet several criteria. Each photocell-stimulator amplifier should be simple and small and should permit switching voltages on the order of 150–175 volts d.c. with an input voltage change of less than 0.3 volts (10 percent of the voltage applied to each photocell). A search for a transistor in a small case (TO–18), with this type of voltage rating revealed that none are available commercially. However, a suitable solid state switching device, the TSW–200C, is made by Transitron Electronic Corporation, Wakefield, Mass. The TSW–200C is a PNPN bistable device similar to a silicon controlled rectifier (SCR) with an anode to cathode voltage rating of 200 volts which will conduct when about 20 microamperes gate current is applied.

The same multivibrator circuit used in the Visotactor B proved suitable for the Multicolumn Visotactor. A spare circuit board originally prepared for the Visotactor B which uses 26 transistors was used in the Multicolumn device by etching off all the copper circuit except that needed for the multivibrator and installing 24 SCR's and 2 transistors. Since the piezoelectric stimulator behaves electrically like a capacitor of about 0.005 mfd., a separate series resistor is needed for each stimulator to provide a charging path. (The discharging path is through the SCR when it is conducting.) The series resistors are each 470,000 ohms, which results in a charge time constant of 2.5 msec. An active stimulator will thus charge to 74 percent of the supply voltage during one-half cycle of the multivibrator (150 cycles per second) and discharge to about zero volts during the next half cycle. A suitable inverter transformer to increase the 6 volts from the rechargeable battery to 140 volts was not available "off the shelf." A design which is optimum for small size and efficiency would require a special transformer core. To save time, a miniature laminated iron transformer was redesigned and rewound to operate as a saturating inverter driven by two germanium transistors. Since the space in the Multicolumn Visotactor handle was nearly filled, the inverter circuit and transformer were molded into the battery plug. If suitable integrated circuits are available in the future, the space saved will permit building an inverter to fit into the handle.

The completed Multicolumn Visotactor was first tested on January 26, 1966 and performed satisfactorily. The tactile display is somewhat confusing at first for a person accustomed to a single column device. In a short time, however, the user begins to recognize letters and shapes.

Further experiments with the Multicolumn Visotactor prototype indicated that the circular cells first used in the photocell array result in a tactile pattern sufficiently different from that produced by narrow, tall cells to confuse a person accustomed to the narrow, tall cells. To eliminate this effect as a variable in later testing, the array of circular cells first used in the Multicolumn Visotactor was later replaced with an array of 24 rectangular cells each .010 in. wide and .050 in. high. Drawings and mask negatives for such an array were made during February 1966. Copper masks were etched and several arrays were made during March 1966. One of these photocell arrays was encapsulated and installed in the Multicolumn Visotactor prototype during April 1966.

Changing the photocell array from one composed of circular cells to one of rectangular cells revealed some problems associated with the switching circuits. The new array has cells which have higher resistances than the old array. About one-third of the TSW–200C switches have characteristics which do not permit proper operation with the higher resistance photocells. These units (TSW–200C's) are low cost industrial types which have wide tolerances on a number of parameters. Future prototypes may use a more expensive, higher quality SCR or the industrial type can be tested and about one-third of them rejected. For the present prototype, the TSW–200C's that did not operate properly were replaced with selected devices of the same type. During May 1966, new TSW–200C switches were purchased, selected for suitable characteristics, and installed in the Multicolumn Visotactor. A high voltage zener diode was added to regulate the inverter output. With these changes, the switching circuitry operated very well.

Miss Reinicke was given the Multicolumn Visotactor prototype on June 10, 1966. Only the center column of eight stimulators was turned on. One of the stimulators was adjusted to make better contact with her finger. Miss Reinicke's reading speed after several hours was less than one word per minute. After about 10 hours practice she had become accustomed to the weak tactile stimuli produced by the piezoelectric stimulators in the Multicolumn Visotactor and she read from page 188 at an average rate of 4.0 wpm using only one column of the three available in the Multicolumn Visotactor. Later, when her reading performance has reached a plateau, the second column will be turned on, and still later, the third column will be activated (Fig. 5).

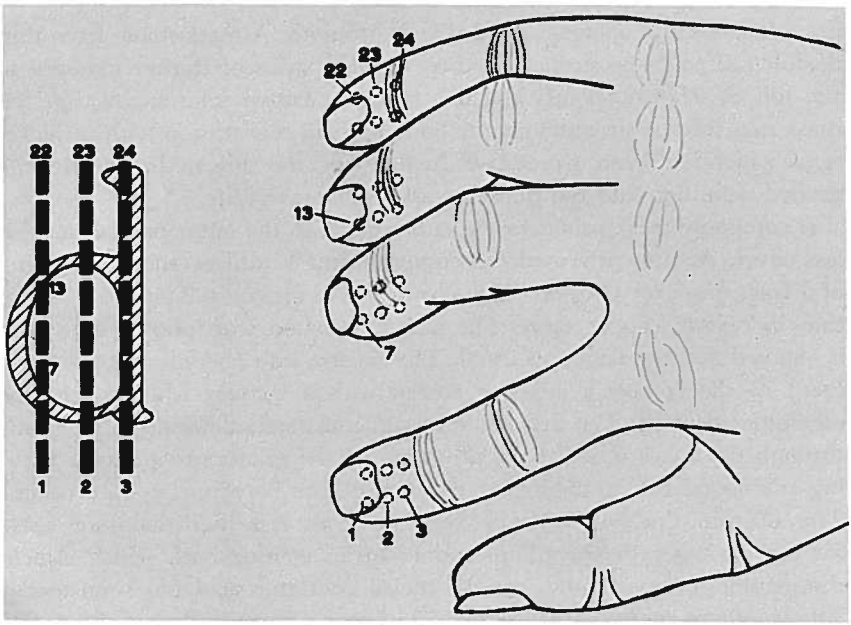

FIGURE 5. — This schematic shows the image of the letter "d" projected on the photocells of the Multicolumn Visotactor prototype and the location of the stimulator controlled by each photocell. The optical barrel occupies the space between the index and middle finger. The first Multicolumn Visotactor prototype is being used by a blind subject.

5. Photocell Construction Techniques

The difficulties of obtaining small numbers of the specialized photocell arrays for reading machines for the blind have, in the past, handicapped developers in this field. To meet the needs of this research project, Mauch Laboratories has developed techniques for making arrays as complex as the combined recognition-optophone array which has 20 or more photoconductive cells of varying sizes and shapes in a ½-in. diameter circle. The techniques developed have been improved during the past year.

The evaporation masks previously made of .001-in.-thick molybdenum with a conversion coating still had some shortcomings. The strong acids required to etch molybdenum attacked the photoresist, frequently causing it to separate from the metal surface. The principal product of the etching process is a gas and the gas bubbles forming at a pinhole in the photoresist can also cause the resist to be lifted off the molybdenum. Gas bubbles interfered with the circulation of the etching acid in fine details of the mask and caused rough edges around openings.

Beryllium copper masks may be etched in ferric chloride to avoid the above problems, but beryllium copper foil thin enough (.001 in.) to retain

the fine lands and openings needed lacks strength. A mask made from thin flexible foil could be strengthened by welding strips of thicker material to the foil at strategic points but this is an expensive solution. A thin foil mask may also be strengthened by bonding it in registration with a thicker mask which had been overetched. In this way, the thin mask provides the needed definition and the thicker mask provides rigidity.

A composite mask produces the same results as the latter procedure with less effort. As presently used the composite mask utilizes selective etching of a layer of nickel .0005-in. thick electroplated on one side only of .005-in. thick beryllium copper sheet. The nickel is coated with photoresist which is exposed and developed as usual. The reverse side (berylliumcopper surface) of the composite mask is coated with a lacquer which resists the etching acids used. The first etching bath uses ferric chloride to etch only through the areas of nickel not protected by the photoresist pattern. Etching is stopped before significant removal of the beryllium copper occurs. The .0005-in.-thick nickel layer can then serve as a high definition mask for etching away the beryllium copper in an etching bath which attacks the beryllium copper only, not the nickel (chromic acid has been used). The beryllium copper, because of its thickness, will be undercut about .005 in. beneath the edge of the nickel pattern. In this fashion, we have made masks which retain the accuracy of a thin foil mask, but also have sufficient rigidity.

Since the nickel which determines the accuracy of the mask is only .0005 in. thick it seemed doubtful that it could be used as a mechanical mask for the Airbrasive unit to define the areas which high speed abrasive particles could strike to remove photoconductor material. Experiments with composite masks and the Airbrasive unit indicate that each mask may be used at least twice. If greater life is needed the mask may be protected by a very thin coating of polyurethane rubber.

6. Word Synthesizer Improvements

Construction of an apparatus to record the "spelled-speech" letters on the magnetic tape elements of the Word Synthesizer along the same arc used in playback was started during July 1965. By locating the tapes to be recorded on the face of a 12-in. diameter disk rotating at about 12.7 r.p.m. and attaching the original straight line recordings of the spelled-speech letters to the rim, it was possible to record from one track to the other without problems of synchronization. Because an undercut on the rim permits locating both tracks at the same 5.610-in. radius, the original letter recording may be cut to the same length as the corresponding flag and positioned to occupy the same angular space. A half-track playback head is spring loaded to press against the straight line recordings on the rim and a full track recording head contacts the flags on the face. A Viking model

RA–72 recording amplifier receives the signal from the playback head and supplies the audio frequency recording current and high frequency (65 kc) voltage bias to the record head.

The center spindle, bearing, and 4-pole motor from a phonograph turntable were used to speed construction of the above apparatus. The original photograph used a rubber idler wheel driving a 4-in.-diameter hub to operate at 33½ r.p.m. By driving on a 10.3-in. diameter, the proper speed results without changing pulleys or belts in the existing motor drive. Although the speed need not be exact for this tape-to-tape recording, a large error would affect the playback equalization which is designed for a linear tape speed of 7.5 in. per second. A new turntable was made from ¾-in.-thick aluminum and the bearing and motor assembly were mounted on a steel chassis (17 in. x 13 in. x 4 in.).

The above described apparatus was completed and tested during August 1965. Obtaining uniform contact between the magnetic record and playback heads and the magnetic tape was a more difficult problem than anticipated. Because the plastic flags used in the Word Synthesizer are not sufficiently flat, it was necessary to make the arc recordings on magnetic tape before attaching the spelled-speech letters to the flags. A number of materials were tried as backing pads between the magnetic tape and the aluminum turntable. Pure gum rubber .062 in. thick in combination with a spring load of 50 grams for each head produced uniform head to tape contact without causing skipping or unusual speed variations as the turntable rotated the tape under the heads.

Frequency response of the complete system was checked and found to be within ±3 db of the industry standard (NAB) from 100 c.p.s. to 10,000 c.p.s.

Several "spelled-speech" letters recorded on this equipment were mounted on flags in the Word Synthesizer and compared with the older straight line recordings. The new recordings have greatly increased sibilance and letters which sounded almost alike before are now more distinctive.

During September 1965, all the "spelled-speech" letters were recorded in an arc and mounted on flags in the Word Synthesizer. Scotch brand magnetic recording tape number 282 was used on the Word Synthesizer flags. This "sandwich" tape has a very thin plastic coating over the iron oxide particles to reduce wear of the tape and playback head.

Although the present Word Synthesizer permits the use of various letter lengths and has inherent buffering capability, its size and magnetic tape wear caused us to consider several alternate Word Synthesizer designs. An optical read-out method seems to have several advantages over the magnetic tape presently used. The design of such an optical Word Syn-

thesizer could take several forms depending on what compromises are to be made in the output. If the "spelled-speech" letters could be recorded to have one fixed length (or two lengths in the ratio 2:1) a rotating drum system would be the most suitable. A drum system sold commercially by the Cognitronics Corp., Briarcliff Manor, New York was investigated. More complex systems are required to reproduce letters of varying length without switching noises or pauses between letters. One such system could use a mirror galvanometer (or two in an XY arrangement) to scan one track out of 32 on a photographic negative. If the pause during retrace and letter selection is excessively long, two galvanometer assemblies could alternate, one producing a letter while the other retraces and selects the next letter.

7. Construction of Additional Visotactor, Visotoner, and Colineator Prototypes

Much of November and December 1965 was used to prepare production drawings of the Visotactor, Visotoner, and Colineator. About thirty drawings were made for the Colineator parts, and sixty were made for the mechanical parts in the Visotactor and Visotoner. Drawings #0302-01001 to #0302–01030 cover Colineator parts and assembly, and #0303–01001 to #0303–01050 and #0303–0120 to #0303–0129 cover Visotactor-Visotoner parts. Two sets of prints of these drawings were sent to the Veterans Administration. Four manufacturers were asked to bid on parts needed to build four Visotactor B probes, six Visotoners, and ten Colineator tracking devices. These manufacturers also bid on the tooling needed for producing the parts. Plans called for all parts to be completed by the end of the current fiscal year (June 30, 1966) so that assembly and testing can be done during the following fiscal year.

Because parts manufacturers are not usually interested in very small production lots, it was helpful to demonstrate the reading machines to the management of the four companies and thus arouse their interest in blind rehabilitation. On December 16th and 17th, 1965, Mr. Frank Witteck, Technical Assistant to the Director of the VA Prosthetics Center, New York, and Mr. Howard Freiberger, Electronics Engineer with the PSAS, Veterans Administration, New York, and H. A. Mauch, G. C. Smith, and K. C. Liest of Mauch Laboratories visited the prospective suppliers and made the demonstrations. As a result, all four companies submitted bids on the parts.

The special manufactured parts were ordered during January 1966. The gages needed for manufacturing and inspection were ordered also. Many of the temporary assembly tools used at Mauch Laboratories were improved and several new tools were made.

The photocell arrays used in earlier prototypes were made by cutting standard photocell substrates with a diamond wheel to fit the array barrel. Considerable savings in labor would result by having an alumina substrate manufactured in the final shape needed. Three manufacturers of high alumina ceramics were requested to bid on making the photocell substrate to our specifications.

During March 1966, the electronic parts for the Visotactor and Visotoner prototypes were ordered. Most of the manufacturing and inspection gages were received and accepted by Mauch Laboratories. The aluminum castings for the Visotactor-Visotoner handles and bases and the Colineator cross slides were completed during March and given to the parts manufacturer for the required machining.

During April and May 1966, most of the electronic parts were received, inspected, and accepted by Mauch Laboratories. By the end of June 1966, most of the mechanical parts were completed, with only a few parts and tools behind schedule.

8. Miscellaneous

On July 22, 1965, H. A. Mauch was interviewed by Mr. Joe Early at the Franklin Institute, Philadelphia, Penn. The tape recorded interview was divided into two 15-minute programs which were broadcast in the Franklin Institute Science Report over a number of domestic and overseas radio stations. Mr. Mauch presented a description of the Visotactor, Recognition Prototypes and Word Synthesizer which can be readily understood by the average listener.

A third Colineator protoype, built over a period of several months, on a low priority basis, was completed. This Colineator was needed for use here at Mauch Laboratories with the Visotactor A and Recognition Prototype. One of the other two existing Colineators is being used by Miss Reinicke with the Visotactor B, and the other is being used with the Visotoner by Mr. Harvey L. Lauer at Hines Veterans Hospital, Hines, Illinois.

On November 15th, 1965, representatives of the National Academy of Sciences-National Research Council visited Mauch Laboratories. Members of the CPRD Subcommittee on Sensory Aids present were Professor Robert W. Mann, Chairman, Dr. Frank Geldard, Dr. Patrick W. Nye, and Dr. Leon Harmon. Also present were Mr. A. Bennett Wilson, Jr., Executive Director of the CPRD, and Mr. James Kingham, CPRD Staff Editor.

A review of the reading machine program at Mauch Laboratories was presented along with demonstrations of existing devices and an outline of future plans. The Visotactor B, Colineator, and Multicolumn Visotactor breadboard were examined and operated by each individual. The Visotactor A, Recognition Prototype, and Word Synthesizer were demonstrated by reading at high speed phrases typewritten in IBM Executive and IBM

Prestige Elite type styles. The vacuum evaporator, Airbrasive unit, pantograph, and several photoetched masks were shown during an explanation of the photocell construction techniques used to produce miniature photocell arrays. The demonstrations were well received. The Visotoner, then located at ACRIBAR, was seen at a later date.

On January 27th and 28th, 1966, H. A. Mauch and G. C. Smith attended the Sixth Technical Session on Reading Machines for the Blind held in Washington, D.C. and sponsored by the Prosthetic and Sensory Aids Service, Veterans Administration. A tape recording of the Word Synthesizer was played and twenty color slides illustrating the Visotoner, Colineator, Visotactor A and B, Multicolumn Visotactor, Recognition Prototype, and Word Synthesizer were shown. Mr. Harvey Lauer demonstrated the Visotoner with considerable enthusiasm. The Visotactor B, the Colineator, and the newly completed Multicolumn Visotactor prototype were also shown at the meeting. Interest in the availability of the reading machines was expressed by a number of participants and the talks and demonstrations were well received.

A Science News Service reporter, Miss Patricia McBroom, attended the Sixth Technical Session and wrote a popular article on the Visotactor B and the Recognition Prototype. The article with a photograph of the Visotactor B was published in the February 12th, 1966 issue of "Science News Letter." The text also appeared in a number of newspapers which subscribe to the Science News Service.

On March 16th, 1966, G. C. Smith presented a paper, "A Family of Portable Reading Machines for the Blind" at the 50th Anniversary Meeting of the Optical Society of America in Washington, D.C. The presentation was well received and the Visotactor B, Visotoner, and Colineator prototypes were examined by a number of interested persons at the end of the meeting.

At the request of CBS Television, and with the approval of the Veterans Administration, H. A. Mauch appeared on the program "I've Got a Secret" which was shown on the evening of March 21st, 1966. Mr. Mauch demonstrated the Visotactor B and explained that it is an experimental reading machine for the blind developed for the Prosthetic and Sensory Aids Service, Veterans Administration, and that commercial production is several years away.

On May 24, 1966, Prof. Eugene Lawler and Mr. Dave Wood of the University of Michigan visited Mauch Laboratories. Prof. Lawler and Mr. Wood plan to develop a character recognition machine using a shared central computer facility connected to blind subscribers via the telephone.

From June 13, 1966 to June 17, 1966, G. C. Smith attended St. Dunstan's International Conference on "Sensory Devices for the Blind" held in

London.[b] A paper "The Development of Recognition and Direct Translation Reading Machines for the Blind" was prepared and presented to the conference. The paper will be published in the conference proceedings with illustrations of the reading machines developed at Mauch Laboratories. The Visotactor B, Visotoner, and Colineator were examined and operated by many of the conference participants and delegates. The presentation and demonstrations were well received.

On June 1, 1966, Mr. Albert C. Abnett, Electronics Engineer, joined Mauch Laboratories. Mr. Abnett's experience includes several years with the Speech Science Laboratory of Ohio State University, Columbus, Ohio.

FUTURE WORK

1. Construction of Additional Visotactor B, Visotoner, and Colineator Field Test Models

Research personnel on this project will use a substantial portion of their time to assemble and test four Visotactors B, six Visotoners, ten Colineators, ten battery chargers, twenty rechargeable batteries, ten spare lamp assemblies, and five spare optical barrel assemblies.

Mechanical parts for these reading machines and accessories have been built to our drawing specifications by local manufacturers during the past fiscal year. The assembly and critical machining operations on a number of parts must be done by Mauch Laboratories shop personnel. Production engineering tasks which remain involve developing efficient inspection, assembly, and testing procedures for the mechanical and electronic subassemblies and the completed devices. In particular, since only one Visotoner has been built, additional experience will be needed to determine allowable tolerances of the various transistors, resistors, and capacitors used in the circuit. An electronic counter will be used to adjust the frequencies of the Visotoner oscillators and to record frequency shifts under various conditions.

2. Recognition Prototype

Our experience with the "multiple snapshot" recognition technique and the first *Recognition Prototype* indicates that its performance may be improved in certain respects. It seems likely that the tracking tolerance may be increased from 10 percent to 20 or 25 percent by redesigning the photocell array and recognition matrix. This improvement would make tracking the line of print with the Visotactor A (recognition machine probe) just

[b]A summary of this Conference appears elsewhere in this issue.

as easy as tracking correctly with a Visotactor B or Visotoner (direct translation probes). Experience with a blind subject using the Visotactor B and Colineator indicates that tracking within one photocell height is relatively easy after some practice. The changes which must be incorporated in the new recognition matrix and photocell array will be determined during the coming year by using the same photographic slides used during the design of the present Recognition Prototype.

A relatively simple change to be made in the ring counter will permit recording in selected memory units the fact whether a photocell sensed "white" or "black" between any two "snapshots." This feature will help the Recognition Prototype to discriminate between certain letters with greater reliability. The bulk of the letter feature information will still be taken at the instants of the "snapshots." One of the planned changes which will improve tracking tolerance involves the photocell which senses descenders below the line. Originally, this cell was placed very close to the baseline to register the "tail" of the capital "Q." Moving the descender cell further below the line will permit lengthening two cells which cross the baseline. Since the "Q" occurs in combination with the "u" and is very infrequent in text, missing this letter will not affect the overall performance of the Recognition Prototype.

When the redesigned photocell array and recognition matrix for the Recognition Prototype have been tested, the recognition circuitry will be designed for inexpensive integrated circuits and a preproduction version will be built into the same enclosure containing the drum memory system of paragraph 7 below. In line with our earlier expectations, prices of integrated circuits have decreased to the point that the recognition logic can be built with about 100 integrated circuits within our cost limitations. This *pre-production Recognition Prototype* and the essential parts of the drum-type *Word-Synthesizer* will occupy a total volume of about ¼ cu. ft.

3. Evaluation of the Visotactor B Prototype

The many hours Miss Reinicke has used the Visotactor B and Colineator have been noteworthy for the low incidence of equipment malfunctions and the steady improvement in reading ability. Similar long duration studies interspersed with short trials in the laboratory will probably become the pattern for future preliminary evaluations of reading aids developed at Mauch Laboratories.

Most of Miss Reinicke's time during the coming year will be used to compare the Visotactor B with the Multicolumn Visotactor. Both Visotactors will be used in a range of reading tasks. Some time will be spent using the Visotactor A in recognition operation at Mauch Laboratories. It is expected that the Veterans Administration will select subjects to use the four new Visotactor B prototypes to be built during the next fiscal year.

4. Evaluation of the Visotoner Prototype

The availability of six additional Visotoner prototypes, Colineators, and accessories which will be built during the coming year will make it possible to gather opinions and data from more than one user. Mr. Harvey Lauer probably will continue to use the first Visotoner prototype while the new Visotoners are being built. Mr. Lauer has expressed considerable interest in training other blind persons to read with the Visotoner.

5. Development of Multicolumn Visotactors

Exactly what modifications are made in the Multicolumn Visotactor design depend on the evaluation of the present prototype. The possibility exists that a future version of the Multicolumn Visotactor may stimulate the underside of only one finger with a large number of vibrators.

This direct translation reading aid which will fit on the finger doing the scanning has been given the name "Digitactor." The Digitactor will not incorporate the lens and the variable magnification mechanism used in the Visotactor and the Visotoner. Instead, the Digitactor will have a number of light pipes which conduct light to the printed page or object being examined and other light pipes to guide reflected light to the array of photocells. By having 16 stimulators per column, the Digitactor can be used to read letters which may vary over a size range of slightly more than 2 to 1 (7 to 16 point size, for example). The resolution at the smallest type size will be as good as that in the Visotactors-Visotoners (eight photocells per column) and much better at the larger, more frequent type sizes. Many factors must be studied before the first Digitactor prototype can be built. These studies will be started during the next contract year.

6. Photocell Construction Techniques

The techniques presently used to make arrays of photoconductive cells will probably remain unchanged in principle but they will be improved in practice. The photo-etched masks can be improved by using a spray etching machine instead of hand agitation in a tray. The photocell material undergoes some changes in the vacuum processing which reduce sensitivity. Greater cleanliness in the processing of masks and photocells would probably improve the uniformity of the photocell arrays.

A new process for depositing CdSe photoconductive layers was developed by the Physical Research Department of the National Cash Register Company in Dayton, Ohio. The chemical technique used involves spraying an aqueous solution of cadmium chloride and thiourea onto heated photocell substrates for very thin films of cadmium sulfide. For CdSe photoconductors the selenium can be obtained from a substituted selenourea such as N,N, dimethyl selenourea. Cells made with this process are somewhat

more sensitive and respond better to rapidly changing light signals than photocells made by other processes. This photoconductor material probably can be used with Mauch Laboratories photocell construction techniques. A notable improvement in all the reading machines would result.

7. Word Synthesizer Improvements

During the coming year, we plan to purchase a 32-channel photographic drum memory system which can be equipped with the "spelled-speech" letters and evaluated as a possible replacement for the magnetic system used in the present Word Synthesizer. Experiments performed by splicing together magnetic tape fragments containing "spelled-speech" letters yielded the result that a constant letter length of .150 seconds each would be suitable for a drum system, and would still provide good intelligibility.