AUTHOR: Foulke, Emerson PH.D.

TITLE: Investigative Approaches to the Study of Braille Reading

CATEGORY: Braille Research, Braille Reading

PUBLICATION: Journal of Visual Impairment and Blindness, American Foundation for the Blind; Vol. 73, No. 8, October 1979, 298-308

ABSTRACT: Three approaches to the study of Braille reading can be identified. They are (a) the observation of Braille reading behavior, for the purpose of drawing inferences concerning the perceptual and cognitive processes upon which Braille reading depends, or to discover the behavioral patterns that characterize fast and slow readers; (b) the determination of the legibility of Braille characters; and (c) the demonstration of Braille reading performance as a function of variables relating to the manner in which Braille is displayed. Experiments exemplifying these approaches are described, and some suggestions for future research are made.

Investigative Approaches to the Study of Braille Reading

EMERSON FOULKE, PH.D.

Dr. Foulke is a professor of psychology and the director of the Perceptual Alternatives Laboratory at the University of Louisville, Kentucky.

A review of the research so far conducted discloses three general approaches toward the understanding of Braille reading. In one of these approaches, an effort is made to obtain a more careful and detailed description of the reading behavior of Braille readers, and to compare the behavior of good and poor readers. The second approach is concerned, not with the behavior of readers, but with the legibility of Braille characters and the readability of words composed of Braille characters. The third approach calls for the manipulation of variables relating to the manner in which Braille characters are displayed in order to observe their effects on reading behavior. Studies in this category frequently ascertain the effects of the same variables on the visual reading of print in order to acquire comparative data.

Braille Reading Behavior

A study reported by Eatman (1942) is a good example of the first approach. She made motion pictures of the hands of Braille readers as they read. Observation of these motion pictures revealed that her subjects read Braille with only their index fingers, and that those who employed two index fingers usually read faster than those who employed only one. When two index fingers were employed, best results were usually obtained by those who divided the reading task between the two fingers by searching for the beginning of the next line with the left index finger while reading to the end of the current line with the right index finger. This strategy permits the reader to eliminate those intervals during which no information is acquired that would be present if the reader read to the end of the current line with both index fingers and then searched for the beginning of the next line.

It could be hypothesized that those Braille readers who use two index fingers read faster because they have learned to involve the two index fingers cooperatively in the same perceptual process. For instance, the function of the information acquired by the trailing index finger might be to clarify and evaluate information acquired by the leading index finger. However, Eatman's findings suggest that faster reading is possible when two index fingers are employed independently, because the reader can utilize the time spent in reading more efficiently.

Eatman's camera also recorded the ineffective behavior of poor Braille readers. These readers often engaged in scrubbing motions. They retraced frequently, and frequently strayed from the line they were reading.

Eatman's technique provided a good molar description of what Braille readers do, but her camera viewed the hands of Braille readers from above, and since their hands were interposed between the camera and the Braille they were reading, it could not look where the action is. This shortcoming might be overcome by requiring readers to read Braille written on a transparent sheet of plastic mounted on a plateglass reading surface. Their hands could then be photographed from beneath, and a clock could be placed in the camera's field of view. The film thus produced could be shown on a motion analysis projector in slow motion, or a frame at a time. Each frame of this film would contain a record of the character or characters being observed, the fingertip or fingertips used for observation, and the exact time of observation. With these data, in addition to the observations afforded by Eatman's technique, it would be possible to observe the time spent in reading each character, the time spent in reading each word, momentary variations in the speed of finger movement, the skipping of characters, syllables, and words that do not have to be read because they can be predicted, and so forth. With the detailed description of Braille reading behavior obtained by this technique, it should be possible to compare good and poor Braille readers in order to find out what good readers do that poor readers might be taught to do.

In 1974, the American Foundation for the Blind published Kusajima's account of research be had conducted over a number of years concerning the perception of Braille. To obtain a record of the reading behavior of blind children, he devised an apparatus which produced a tracing on the smoked paper chart of a kymograph when the finger or fingers used in reading moved. In general, his results were similar to those reported by Eatman (1942).

In 1932, the American Foundation for the Blind published F. K. Merry's translation of a book by Karl Bürklen in which he reviewed the research and observations of others, and reported a number of experiments of his own concerning Braille reading. Although his research was conducted during the early years of the present century, at a time when there was not much instrumentation for the quantitative measurement of behavior, be was quite ingenious in devising ways of obtaining records of behavior that could be subjected to quantitative analysis subsequently. A good example of his ingenuity is the Tastschreiber, or touch writer. This was a simple clamp, one end of which was attached to the reading finger of a subject. A pencil, attached to the other end of this clamp, rested on the paper some distance above the line being read by the subject, and as the subject's reading finger moved, the pencil moved. Thus, it traced a record of the subject's finger movements. When Bürklen wished to study the finger movements of subjects who read with both index fingers, be placed Tastschriebers on both index fingers, and used differently colored pencils so that he could distinguish the tracings produced by these readers. In general, the results obtained by Burklen are in close agreement with those reported by Eatman and by Kusajima.

The Legibility of Braille Characters

The second approach is directly concerned with the legibility of Braille characters and the readability of words formed with them. In studying the legibility of dot patterns, one may obtain evidence regarding the speed and accuracy with which subjects can identify them absolutely, discriminate them one from another, or replicate them from memory.

The absolute identification of dot patterns. The speed and accuracy with which Braille characters can be identified absolutely would appear to be a satisfactory test of their legibility. An early attempt to assess the legibility of Braille characters in this way was reported by the Uniform Type Committee in 1913 (AAWB Annual Report, 1913). The procedure they devised required the subject to read aloud, as rapidly as possible, a list of 160 Braille letters. The list included four instances of each of the 25 letters not under test, and 60 instances of the letter under test. Letters were presented in a random order which was changed from trial to trial. The time spent by subjects in reading the list was measured on the assumption that reading time would be a function of the time needed to identify the letter under test. By comparing reading times of lists with different test letters, the letters of the Braille alphabet were arranged along what would probably qualify as an interval scale of legibility.

The experiment conducted by the Uniform Type Committee lacked the sophistication of subsequent experiments, in which instruments were used for the controlled presentation of letters and the precise measurement of identification times. Nevertheless, their findings concerning the legibility of Braille letters and their inferences concerning the characteristics of a dot pattern that make it more or less legible than other dot patterns have, in general, received corroboration from better controlled experiments conducted in recent years, and the experiments of the Uniform Type Committee should remind us that it is often possible to conduct useful research in the absence of elaborate instrumentation.

Nolan and Kederis (1969, Study 1) initiated their investigation of the perceptual basis for Braille word recognition by determining the legibilities of 55 of the 63 characters in the Braille code. They employed an experimental task in which subjects were required to make absolute identifications of those 55 characters. In order to qualify for an experiment in which absolute identification of Braille characters is required, subjects must have learned the dot patterns used as stimuli, must have learned the names assigned to those dot patterns, and must have learned the associations between names and dot patterns. The subjects tested by Nolan and Kederis were blind children in Grades 4 through 12 at residential schools for the blind. Although these subjects exhibited considerable variability in Braille reading experience, their least experienced subjects, those in the fourth grade, had four years of experience in reading Braille. Nolan and Kederis could safely assume that all subjects had extensive over learning, and given this assumption, they judged that the minimum time of exposure required for the identification of a dot pattern would serve as a valid index of legibility.

Figure 1

Nolan and Kederis used a specially designed instrument, called the tachistotactometer, for their studies of legibility. This instrument is shown in Figure 1. The tachistotactometer provides control of the time during which dot patterns are available fo tactual observation. Up to a full line of dot patterns may be presented at one time. This sheet is placed on a platform that can be elevated by solenoids. A tightly stretched metal membrane with holes in it corresponding to the dot position in all of the cells in a line of Braille writing is held just above the platform. When the platform is elevated, the dots on the sheet that is mounted on it protrude through the holes in the membrane to the height of the standard Braille dot. They remain available for observation during a predetermined interval, and then, as the platform falls to its resting position, recede beneath the surface of the membrane again.

Figure 2 is a close up view of the display surface of the tachistotactometer with its platform elevated and a dot pattern on display.

Figure 2

The tachistotactometer made it possible for Nolan and Kederis to determine thresholds of legibility for most of the characters in the Braille code, but like most instruments, the tachistotactometer had its problems. Because they were asking their subjects to report not just the detection but the identification of stimuli, Nolan and Kederis were not free to use a standard psychophysical method in which threshold value for a stimulus is determined by presenting several values of that stimulus that span the region in which the threshold is believed to lie. If such a method had been used, after the first exposure that was long enough to allow a subject to identify the test character, knowledge that the test character had been presented would permit a correct inference concerning its identity on subsequent exposures, and this knowledge would be provided by the operating noise of the instrument, alone.

One solution to this problem would be to present random permutations of all of the characters under test, but this would have meant changing the sheet on which characters are embossed after each presentation of a stimulus, and the time that would be consumed by changing sheets made this procedure impractical. The solution adopted by Nolan and Kederis was to emboss eight characters on a single sheet, and to determine thresholds for these characters before replacing the sheet with another sheet containing eight new characters. With only eight characters under test at any given time, subjects could easily remember characters they had already identified, and as testing proceeded, they would soon be able to guess the identities of characters with an unacceptably high probability of success. They solved this problem by dispensing with the descending series of stimulus values called for by the method of limits, but in so doing, they increased the likelihood of systematic errors, such as errors of habituation.

Another problem with the tachistotactometer was the time required for one cycle of its operation. Because of the mass of its platform and the distance through which the platform must travel as it is elevated to the display position and dropped to the resting position again, it was not possible to adjust the instrument for times of exposure that were brief enough to determine thresholds for a few of the characters, and the minimum time of exposure of which the instrument was capable was used as the threshold value for these characters.

In spite of these difficulties, the experiments made possible by the tachistotactometer have produced the best measures of the legibility of Braille characters to date. Examples of these measures are shown in the third column of Table 1. The entries in the fourth and fifth columns will be explained later on. The characters in Column 3 are ranked according to their thresholds of legibility. As the threshold value increases, legibility decreases. Raving determined the relative legibilities of the characters in the braille code, Nolan and Kederis could search for those characteristics of a dot pattern that make it more or less legible than other dot patterns. They found that patterns with large numbers of dots and patterns with dots in the lowest third of the cell tended to be relatively illegible.

Table 1 (Part 1)

Table 1 (Part 2)

Table 1 (Part 3)

A theory that accounts adequately for the performance of braille readers must be stated in quantitative terms, and to the extent that such a theory considers the legibilities of braille characters, legibility must he measured with accuracy and precision. An attempt to realize this objective was made in the Perceptual Alternatives Laboratory at the University of Louisville by building an improved tachistotactometer. Unlike the instrument used by Nolan and Kederis (1969), this instrument is limited by the ability to display only one dot pattern at a time, and hence it cannot be used in studies of the time required for the identification of words. Dot patterns are formed by metal pins that rise above its display suffにおける to the height of a standard braille dot. Each pin is controlled by its own solenoid.

Figure 3

Figure 3 is an overall view of the instrument with a subject observing its display. The small box with switches mounted on it is used by the experimenter to set up the dot pattern that is to be presented. The presence of the microphone and the timer will be accounted for later on. Figure 4 is a closeup view of the display surface with a Braille character on display.

Figure 5

It is a tape transport that is similar in operation to the transport of a conventional tape recorder. Paper tape, 1 inch in width and of a weight that is suitable for embossing braille characters, is transferred from a supply reel across a display suffface and onto a take-up reel. Tape speed is controlled by a capstan, driven by a well-regulated DC motor, the speed of which can be varied continuously through a wide range. Figure 6 is acloseup view of the top of the machine. Notice the word written in braille that is about to pass beneath the reading finger of the subject.

Figure 6

Kilpatrick (cited in Foulke, 1974) (Note 1) used this machine to conduct a preliminary study of the legibility of some of the characters in the Braille code. In his study, each subject experienced random permutations of the characters under test. Initially, the transport was adjusted for a tape speed that was too fast to permit identification of any of the characters. As testing proceeded, tape speed was gradually reduced. When a subject had made three consecutive correct identifications of a character, the tape speed during the first of those three presentations was taken as the index of the character's legibility. Tape speeds were transformed to exposure times by computing, at each of the tape speeds employed in the experiment, the time required for .25 of an inch of tape, the width of a letter space in a line of braille writing, to pass any point on the surface of the fingertip that was in contact with the moving tape. The averaged results for 10 subjects are shown in Table 1, Column 4, along with the thresholds of legibility measured by Nolan and Kederis (1969) and the identification times measured by Challman (1978) for the same characters.

The thresholds of legibility measured by Kilpatrick appear to be lower than the thresholds measured by Nolan and Kederis. This may, in fact, be the case. Nolan and Kederis' subjects were children, while Kilpatrick's subjects were experienced adult braille readers. On the other hand, Kilpatrick's lower threshold values may simply be a consequence of the way in which tape speeds were transformed into exposure times. If exposure time had been defined as the total time a character was in contact with the portion of the sufface of the fingertip used for sensing braille characters, Kilpatrick would probably have computed higher threshold values. In spite of these problems, Table 1 affords a comparison of relative legihilities as determined by the three methods. The rank order correlation between the entries in Columns 3 and 4, Columns 3 and 5, and Columns 4 and 5 are: .54, .30, and .73, respectively. The distributions of values produced by the three methods have some variance in common, but there are many disagreements in rank, and the choice among these measures will depend on the ability of the measures yielded by each method to predict significant aspects of Braille reading performance.

The discrimination of dot patterns. If the legibility of braille characters is to be assessed by the methods already discussed, subjects must have had enough prior experience with those characters to learn both their dot patterns and the meanings associated with those dot patterns. However, it may sometimes be worthwhile to gather information about dot patterns with which subjects have had no prior experience. For example, the over-learning of characters that are examined in studies of legibility may mask differences in their discriminability and ease of learning that could be taken into account in arranging the initial learning experiences of new Braille readers. If the existing Braille code were to be expanded, or if a new code of the same type were to be constructed, the selection of new dot patterns and new meanings could not be guided by the learned performance of subjects who already knew the code. Of course, subjects could be required to prepare themselves for service in a legibility experiment by first learning the code, but it would not be practical to provide the overlearning that characterizes subjects in a typical legibility experiment. In the absence of such overlearning, the outcomes of legibility experiments of the type conducted by Nolan and Kederis (1969) would be ambiguous. Slow and/or incorrect identification of stimulus patterns might be due to incomplete learning of those patterns or of the names assigned to them, or to incomplete learning of the associations between names and dot patterns, or to some unspecifiable mixture of all three, and there would be no way to decide among these alternatives.

One solution to this problem is to relieve the subject of the necessity of learning a response alphabet by changing the task to one in which only discrimination is required. The discrimination task, in its simplest form, requires the subject to decide whether two dot patterns, made available for observation at the same time, are the same or different. The difficulty of this task may be increased by requiring the subject to compare a present pattern with a memorial representation of a previously experienced pattern. Difficulty may be increased again by increasing the number of present patterns that must be compared with a remembered pattern, or by increasing the number of remembered patterns that must be compared with a present pattern.

A task of this sort was employed in a series of experiments conducted by Foulke and Warm (1967; 1968, Note 2), Warm and Foulke (1968, 1970), and Warm, Clark, and Foulke (1970). The purpose of these experiments was to determine the effects of variables such as complexity and redundancy on the speed and accuracy with which dot patterns resembling histograms can be discriminated.

The apparatus used to present the experimental task is shown in Figure 7.

Figure 7

The subject's side of the apparatus has a curtained opening through which subjects put their hands in order to examine dot patterns. There is a response keyboard to the left of this opening, and another one to the right. With two response keyboards, the subject is free to use either hand for observing dot patterns and the other for operating the response keyboard.

Figure 8

Figure 8 shows the experimenter's side of the apparatus. There is an electric stopclock that measures response latency and a display with three light bulbs that informs the experimenter of the subject's response. The hand of a subject is attempting the discrimination task on a dot pattern of the sort that might be presented during a trial. These patterns were formed in a cell with more positions for dots than the braille cell, and they were used to investigate the feasibility of expanding the braille code by adding characters formed in cells with more than six dot positions. An elevated runway on the floor of the compartment in which dot patterns are displayed guides the subject's finger to the dot pattern that serves as the standard stimulus. Touching the dot pattern interrupts a beam of light that is focused on a photocell, and this event initiates a timed interval. At the end of this interval, the sound of a buzzer informs the subject that the time allowed for observation is over. Another elevated runway guides the subject's finger to the two dot patterns that serve as comparison stimuli. Touching either of these patterns interrupts the beam of light, which starts the stopclock running. The subject's task is to decide which if either of the two dot patterns being observed is like the dot pattern observed earlier. The choice made by the subject is indicated by pressing the appropriate one of three keys labeled "left," "right," and "neither." This response stops the clock and turns on the light that informs the experimenter of the response made by the subject.

Though the results of discrimination experiments may guide the selection of dot patterns for such uses as the expansion of the present braille code, or the construction of a new code, care must be taken in the design of these experiments to exclude alternative explanations of the performance that is observed.

The reproduction experiment. The remaining type of experiment that can be used to predict the legibility of characters not yet learned is the reproduction experiment.

In this experiment, the experimenter presents a dot pattern for observation by the subject, and then requires the subject to reproduce the dot pattern just observed from memory. Like the discrimination experiment, the reproduction experiment avoids the ambiguities of an identification experiment in which dot patterns, their meanings, or the associations between dot patterns and meanings are not completely learned.

The implementation of such an experiment requires an apparatus which allows the experimenter to produce, on a display surface, the dot patterns to be observed, and which allows the subject to reproduce observed dot patterns by placing dots at any of the positions in the cell in which dot patterns are formed. The subject must be able to remove and add dots until the pattern appears to be a faithful reproduction of the pattern just observed. This apparatus must have simple controls the operation of which can be learned quickly and easily, so that skill in operating the apparatus will not be a significant factor in determining the subject's ability to reproduce dot patterns. Furthermore, it is probably important for the reproduced pattern to be of the same type as the original pattern, and not just an analog. For instance, if the original pattern is formed with tangible dots, the reproduced pattern should not be formed by placing pencil marks in the appropriate squares in a printed grid. This problem is avoided if the same apparatus is used to form the original pattern and the reproduced pattern.

Figure 4 is the top view of the apparatus shown in Figure 3. In addition to the display area, there is a small grid of squares arranged in three rows and two columns, like the dot positions in a braille cell, and a seventh square just beyond the grid. This grid is the keyboard used by a subject to reproduce patterns. When the subject places a fingertip in a square and presses, a dot appears in the corresponding position in the braille cell on the display surface.

If the same square is pressed again, the dot disappears. Thus, a dot can be added to a pattern, its effect on the pattern can be observed, and if the subject wishes, it can be removed again. If at some point in the reproduction of the pattern, the subject wishes to clear the display and start over again, this can be accomplished by finger pressure in the seventh square.

To form a pattern, the experimenter sets the appropriate toggle switches on a remote keyboard. The pattern is presented for observation by the subject when the circuit is completed by an interval timer connected in the common return of the toggle switches. When the time allowed for observation has passed, the interval timer opens the circuit again, and the pattern disappears from the display. The disappearance of the pattern starts an electric stopclock, and serves as a signal for the subject to start reproducing the pattern. When a reproduction has been achieved that the subject is willing to submit for inspection by the experimenter, a vocal signal generates a microphone signal that is used to stop the clock. The subject is scored for speed and accuracy of reproduction, and if desired, incorrect reproductions can be examined for errors of various kinds.

An experiment requiring reproduction should directly reveal what a subject knows about the original pattern at the time of its reproduction. However, its outcome will be ambiguous in one respect. It will not always be possible to decide whether an error is due to misperception of the original pattern or to forgetting. Nevertheless, such experiments may provide information that will prove useful in the evaluation of novel dot patterns.

The Manipulation of Display Variables

The third approach taken by researchers in their investigation of the factors upon which the reading of Braille depends is the manipulation of variables relating to the manner in which Braille characters are displayed. Similar research on the display of print characters has also been conducted, and the comparisons thus afforded have provided useful clues to our understanding of the reading of Braille. Print readers can observe more of their display at one time than Braille readers, and in general, print readers can read print much faster than Braille readers can read Braille. That the difference in favor of print readers is a consequence of the difference in the amount that can be observed at one time by print and braille readers is an obvious hypothesis, and a number of experiments which have varied the manner in which print and Braille characters are displayed have produced results that are relevant to this hypothesis.

In 1886, Cattell reported an experiment in which he demonstrated that the time of exposure needed by his subjects to identify several characters displayed at the same time was no greater than the time of exposure needed for identification when only a single character was displayed. Since Cattell's time, there has been considerable improvement of the instruments used to control and vary the exposure of visual stimuli but his findings have generally been confirmed by experiments employing modern tachistoscopes.

Use of Tachistoscopes

Foulke and Wirth (Foulke, 1973, Chapter 8, Note 3) used a tachistoscope manufactured by Scientific Prototypes (Model GB) that provides for variation of the time of exposure in steps of approximately 1 msec. The minimum time of exposure is approximately 5 msec. With this instrument, they determined the minimum time of exposure required for the identification of single letters, and words with 2, 3, 4, and 5 letters, using the staircase method of limits described by Cornsweet (1962). They determined the medians of the times needed by each subject to identify the stimulus items in each category, and computed the means of these medians as follows: single letters, 35 msec; words with 2 letters, 35 msec; words with 3 letters, 36 msec; words with 4 letters, 37 msec; words with 5 letters, 39 msec. The differences among these means are small, and analysis of the variance of identification thresholds did not find significance.

The frequency of occurrence of a word is a factor that may influence the time required for its identification. To control for this factor, Foulke and Wirth used only frequently occurring words as stimulus items on the assumption that such words were likely to have been stored in the lexical memories of their subjects.

The experiments just reviewed urge the conclusion that the time needed by visual readers to identify most of the words they encounter is not a function of the number of characters in those words. If this is true, the information available to visual readers at any given instant greatly exceeds the information a single character can provide.

This is clearly not the case for Braille readers. Nolan and Kederis (1969, Study 2) reported an experiment in which they found that the time needed by Braille readers to identify a word is a function of its length. This is true for both familiar and unfamiliar words and for both slow and fast readers. Furthermore, they found that, in many instances, the time spent by a subject in identifying a word exceeded the sum of that subject's identification times for the characters of which the word was composed. Of course, the subjects tested by Nolan and Kederis were occasionally able to take advantage of their knowledge of orthography and to identify words without having to identify all of the characters in them, but their results strongly imply that at any given time, the Braille reader is acquiring only the information that can be provided by a single character. If this is true, the Braille reader must have to identify and remember each of the letters in a word, and then integrate them in order to identify that word. The inevitable consequence of such a process would have to be a Braille reading rate that is much slower than the visual reading rate.

If the visual reading rate is, in large measure, a consequence of the number of characters that can be observed at one time, then the visual reading rate should be reduced by restricting the number of characters that can be observed at one time. In an experiment conducted by Foulke and Smith (Foulke, 1973, Chapter 9, Note 3), visual readers were required to read text a letter at a time with freedom to manage their access to the display. To accomplish this, they were required to look at the printed page with one eye, through a tube mounted on a pair of goggles. The lens in front of the eye not used for reading was painted to make it opaque. The material to be read was typed on vellum with a bulletin typewriter, and backlighted. An aperture at the end of the tube was adjusted so that when one character was completely in view, the edges of adjacent characters could also be seen. Subjects were prevented from varying the distance between their eyes and the printed page by an aluminum tube, 4 feet in length, attached at one end by a ball-and-socket joint to the wall behind the chair in which subjects sat, and at the other end by a ball-and-socket joint attached to a headband worn by the subjects. Thus, they could explore the page they were reading by moving their heads up and down, and from side to side, but they could not vary the amount they could see at one time by moving their heads closer to or farther from the page. Under this condition of observation, visual readers were forced to read the printed page in the manner in which a Braille page is read by tactual readers. The college students who served as subjects found the experimental task quite irritating, and only a few subjects could be persuaded to endure enough training to reach a stable reading rate. However, the few subjects who persisted achieved reading rates ranging from 65 to 75 wpm. These rates are in the vicinity of the reading rates reported for Braille readers in junior-high school (Nolan & Kederis, 1969).
These results suggest that when visual readers of print are required to read under conditions which limit the number of characters that can be observed at one time to the number that can be observed at one time by tactual readers of Braille, their reading rates resemble Braille reading rates.

In an experiment reported by Troxel] (1967), visual readers read text displayed on an oscilloscope under two conditions. Under one condition, text was displayed a character at a time. Under the other condition, it was displayed a word at a time. Under both conditions, Troxell varied the rate at which items were presented, and determined the maximum reading rate of each subject in words per minute. When text was displayed a letter at a time, his subjects achieved a mean reading rate of 19.5 wpm; and when it was displayed a word at a time, they achieved a mean reading rate of 108.5 wpm.

In another condition of Troxell's experiment, experienced Braille readers read text presented a character at a time by sensing patterns of pins pressed against the tips of the fingers used to operate the keys on a braillewriter. Each of the six keys on a braillewriter produces one of the dots in the Braille cell, and the dot patterns in the Braille code are formed by pressing the appropriate combinations of keys. For example, pressing Keys 2 and 3 with the middle finger and ring finger of the left hand, and Keys 4 and 5 with the index finger and middle finger of the right hand, would produce dots 2, 3, 4, and 5, the dot pattern to which the meaning "t" is assigned in the Braille code. To present "t," Troxell would stimulate simultaneously the fingertips just mentioned. Thus, his subjects were reading not Braille characters, but analogues of Braille characters. Nevertheless, after only brief practice, they achieved a mean reading rate of 18 wpm, which was the maximum rate at which the instrument used by Troxell to display characters could be operated. It can be argued that if characters had been presented at a faster rate, his subjects might have learned to identify them at a faster rate, and that they might have been able to identify Braille characters at a faster rate than the analogues they experienced. However, the rate at which they identified characters closely matched the rate at which Troxell's visual readers identified characters, and in the absence of evidence to the contrary, there is no reason to suppose that tactual readers of Braille can identify characters presented one at a time at a faster rate than can visual readers of print.

In spite of its limitations, Troxell's experiment has important implications for the reading of Braille. First, when the conditions of observation for the visual reader of print and the tactual reader of Braille are equated by displaying only one character at a time, it appears that sequences of characters can be identified as rapidly by touch as by vision. The finding that visual readers were able to increase their reading rate from 19.5 wpm to 108.5 wpm when they were given the opportunity to experience all of the characters in a word at the same time, suggests that they were able to treat whole words as single patterns. They did not read faster because they identified the same units at a faster rate, but because they identified larger units that provided more information at approximately the same rate.

It is unfortunate that Troxell's experiment did not include a condition in which braille readers were presented text in braille, a word at a time. If, because Braille readers cannot observe as much at a time as visual readers, they must read words a character at a time, they should not be able to take much advantage of the additional information that is made available to visual readers of print by displaying text a word at a time, and their reading rates should not be affected much by changing from the display of text a character at a time to the display of text a word at a time.

Atypically Low Reading Rates

Troxell's experiment is interesting because of the comparisons it suggests, but the reading rates he found under all experimental conditions seem atypically low. The reading rates he observed may have been a consequence of the novelty of the manner in which text was displayed, and of the reduced ability of his readers, visual or tactual, to manage their access to the display. Under normal reading conditions, the entire page is available, and the reader is free to vary the strategy for acquiring information from it in accordance with the continuously changing requirements imposed by the text being read. As already stated, when text was presented a character at a time, Troxell's subjects read it visually at a rate of 19.5 wpm. When it was presented in a manner that allowed them to take advantage of their ability to observe several characters at a time, their reading rate increased to 108.5 wpm. When text is displayed on the printed page in the conventional manner, and when access to it is managed by the reader, there is another dramatic increase in reading rate. The average silent visual reading rate for high-school students is in the neighborhood of 250 wpm (Harris, 1947; Taylor, 1966), and if the average silent reading rate had been determined for Troxell's subjects, who were students at Massachusetts Institute of Technology, it probably would have been higher still.

When text was displayed to Troxell's Braille reading subjects a character at a time, they read 18 wpm. When text is displayed in Braille on a page, and read in the normal manner, there is an improvement in reading rate, but it is more modest than the corresponding improvement when text is displayed in print on a page, and read normally. Though the rate at which braille is read by adult braille readers has not been adequately measured, their average reading rate is probably in the vicinity of 104 wpm (Foulke, 1964), and in the absence of better information, 104 wpm will serve as an estimate of the average reading rate of Troxell's Braille reading subjects. Because of the way in which characters were presented to these subjects, text could not be displayed a word at a time. However, if they had read text displayed in Braille a word at a time, they doubtless would have read faster than when text was displayed a character at a time, because their familiarity with orthographic and linguistic conventions, and their awareness of the context of meanings in which the text was embedded would occasionally enable them to predict words and parts of words successfully without the necessity of identifying all of the characters of which they were composed. However, since their perceptual limitations would not allow them to take advantage of the increased number of characters on display, they should receive less benefit than visual readers from a display that presents several characters at a time.

The experimental evidence reviewed in this section points to the conclusion that the difference in reading rate between visual readers of print and tactual readers of Braille is a consequence of the difference in the number of characters that can be observed at one time by touch and by vision. However, in order to reach this conclusion, it has been necessary to make a number of assumptions, particularly in regard to the performance of Braille readers. If, in a single experiment, visual readers of print and tactual readers of Braille read text displayed a character at a time, a word at a time, and on a page in their normal manner, the comparisons afforded by the resulting data should permit an adequate evaluation of the hypothesis that the difference in reading rate between visual readers of print and tactual readers of Braille is accounted for by the difference in the number of characters that can be observed at one time.

The inclusion of another condition, in which text was displayed as a continuous line of characters embossed on a tape that moved beneath the fingertip or tips normally used for reading might provide some indication of the ability of Braille readers to identify temporally extended patterns consisting of several characters. If tactual readers of Braille have this ability, they should be able to read text displayed on a moving tape faster than text displayed as a succession of discrete characters presented one at a time. Of course, since readers would not be able to manage their access to the information contained in such a display, they would not be able to increase reading rate by skipping predictable words and parts of words. Therefore, the rate at which they could read text displayed in this manner would be slower than the rate at which they can read when text is displayed on a page and read in the normal manner.

Obviously, there is a great deal of research to be done, and our current understanding of the Braille reading process does not warrant final conclusions regarding the manner in which braille is read, or the manner in which it might be read if it were properly displayed to adequately trained readers. However, the picture of the Braille reading process that can be supported by the data gathered so far is rather disappointing. Because of the limited sensing area on the fingertips, not much more than one Braille character can be observed at a time. Even if this were not the case, the mass of the finger, hand, and arm prevents the kind of extremely rapid movement from one fixation to the next that would correspond to the saccadic movements of the eyes. Furthermore, tactual perception requires movement of cutaneous tissue, and little movement takes place while the fingertip is at rest, as it would be during periods of fixation. The efficient perception of Braille requires continuous lateral movement of the fingertip that is actively engaged in reading, and as a result of this movement, Braille characters are encountered and perceived serially. The serial perception of Braille characters has been demonstrated by Nolan and Kederis (1969, Study 2), who have shown that the time required for the identification of a word written in Braille is frequently greater than the sum of the times required for identification of the characters of which it is composed. This is not always the case, because readers can predict some words and syllables, and the use of contractions sometimes reduces the time required for identification of words, but there is a strong suggestion that Braille readers must first register and accumulate percepts of single characters, and then integrate these stored percepts to achieve the perception of whole words.

There are many who dispute this description of the Braille reading process. They maintain that although the patterns identified by Braille readers are discovered temporally, there is no reason to believe that readers are necessarily limited to the serial perception of single characters. They believe that the patterns identified by Braille readers can have enough temporal extension to encompass entire words, and they cite the performance of a few exceptionally fast Braille readers as proof of their contention. This point of view has merit, and it deserves to be investigated. However, there has been very little systematic observation of the behavior of unusually fast braille readers, and as yet, we have no data which could support a detailed description of the perceptual processes employed by such readers.

Notes

1. Foulke, E. The Perceptual Alternatives Laboratory: Annual report to the Dean of the Graduate School, 1973-1974. Louisville, Ky.: University of Louisville, Perceptual Alternatives Laboratory, June 1974.

2. Foulke, E., & Warm J. The development of an expanded reading code for the blind (Final Progress Report No.3104). Louisville, Ky.: University of Louisville, Perceptual Alternatives Laboratory, July 1978.

3. Foulke, E. The development of an expanded reading code for the blind (Final Progress Report Project No.7-1185). Louisville, Ky.: University of Louisville, Perceptual Alternatives Laboratory, September 1973.

References

Bürklen, K. [Touch reading of the blind] (F. K. Merry, trans.). New York: American Foundation for the Blind, Inc., 1932. (Originally published, 1917.)

Cattell, J.M. The time it takes to see and name objects. Mind, 1886, 11, 63-65.

Challman, B.E. Variables influencing the identification of single braille characters. Unpublished master's thesis, University of Louisville, 1978.

Eatman, P.F. An analytic study of Braille reading. Unpublished doctoral dissertation, University of Texas, 1942.

Foulke, E. Transfer of a complex perceptual skill. Perceptual and Motor Skills, 1964, 18, 733-740.

Foulke, E., & Warm, J. Effects of complexity and redundancy on the tactual recognition of metric figures. Perceptual and Motor Skills, 1967, 25,177-187.

Harris, A.J. How to increase reading ability. New York: Longmans, Green & Co., 1947.

Kusajima, T. Visual reading and braille reading: An experimental investigation of the physiology and psychology of visual and tactual reading. New York: American Foundation for the Blind, May 1974.

Nolan, C.Y., & Kederis, C.J. Perceptual factors in braille word recognition. Research Series #20. New York: American Foundation for the Blind, 1969.

Taylor, E.A. The fundamental reading skill, as related to eye movement photography and visual anomalies. Springfield, IL: C.C. Thomas, 1966.

Troxell, D.E. Experiments in tactile and visual reading. IEEE Transactions on human factors in electronics (HFE-8), 1967, 261-263.

Uniform Type Committee of the American Association ofWorkers for the Blind. Fourth Biennial Report, Outlook for the Blind, 1913, 7, 1-48.

Warm, J., Clark, J.L., & Foulke, E. Effects of differential spatial orientation on tactual pattern recognition. Perceptual and Motor Skills, 1970, 31, 87-94.

Warm, J., & Foulke, E. Effects of orientation and redundancy on the tactual perception of form. Perceptual and Motor Skills, 1968, 27, 83-89.

Warm, J., & Foulke, E. Effects of rate of signal rise and decay on reaction time to the onset and offset of acoustic stimuli. Perception and Psychophysics, 1970, 7(3), 159-160.

This article was taken from the braille.org website: (www.braille.org/papers/invea/invea.html.)