Reports

A Braille-Reading Machine

Abstract. *A new system for publishing and presenting Braille text is delineated. The system requires a new device for actual "reading." Experiments to determine reader preference and acceptance of the device are presented, and performance criteria on the device are listed.*

Braille is an internationally successful method of reading for the blind. Trained readers find it easy to use, and many consider it more satisfactory than auditory substitutes. However, Braille does have some drawbacks: (i) publication has, until recently, required the intervention of a human translator; (ii) the volumes are expensive to produce, ship, and store; and (iii) each volume is very bulky. The relatively low number of volumes produced and the bulk of each volume account for the high cost and limited use of available Braille material.

With modern computers the translation of standard text into higher grades of Braille (that is, Braille spelled with standardized symbols for groups of letters or whole words) is possible without human intervention other than that needed to prepare the text for the computer (*1*). The growing use of coded paper tapes in the typesetting used by industrial printers has aided in the preparation of material suitable for computer input.

Problems of cost and bulk remain if computer translation is used only to produce conventional Braille sheets with embossed characters. It is not practical for one to acquire a library of these Braille volumes, as each volume occupies at least 50 times as much space as its corresponding ink-print volume.

Contemplating the automation of the Braille translation process, we have been impressed by the low cost and the compact method of storing the information on magnetic tape. It thus only seems logical to include these features in the publication and storage system of such a process. Therefore, we are led to consider methods for translating the magnetic tape into Braille text at the time and place of reading. What is needed for such a procedure is a machine for reading Braille text. We present information on the required properties of such a machine (in advance of completion and testing of a prototype) in order to inform others who may be working along similar lines. The utility of such a device seems to justify the technical impropriety.

Three requirements had to be examined before any preliminary design could be attempted. These requirements (reaction of the reader, acceptance by the reader, and speed of presentation) concern the manner in which the raised Braille characters are ultimately presented and the speed of such presentation. The first feature to be considered is the reaction of the reader to the replacement of permanent printout with mechanized display. In addition to the obvious desire to discourage the production and storage of bulky objects, we believed that with little training greater reader comfort would follow the elimination of page handling.

The second requirement, acceptance, is expected to depend on the feature of presentation we have called "mode." Mode concerns the way the raised characters become accessible to the reader, and the direction and timing of corresponding movements. We use the term "A mode" to describe presentation of whole lines (with one or several lines at a time available to the reader). In the A mode the upward motion of the text assumes the role of the conventional downward scanning motion of the reader's hands on the Braille page. In what we call the "B mode" only a single (essentially endless) line of text is presented, and the line moves sideways, corresponding to scanning a single line by hand movements. In addition to the choice of direction, there is a choice of stepped or continuous presentation of information. In continuous modes (option 1) the flow of reading material proceeds continuously. In stepped modes (option 2) material is rapidly presented to the reader, is permitted to remain available for a period, and is then replaced by new material. The last requirement that had to be determined was speed (characters presented per unit of time).

Modes A and B and options 1 and 2 can be combined to describe four

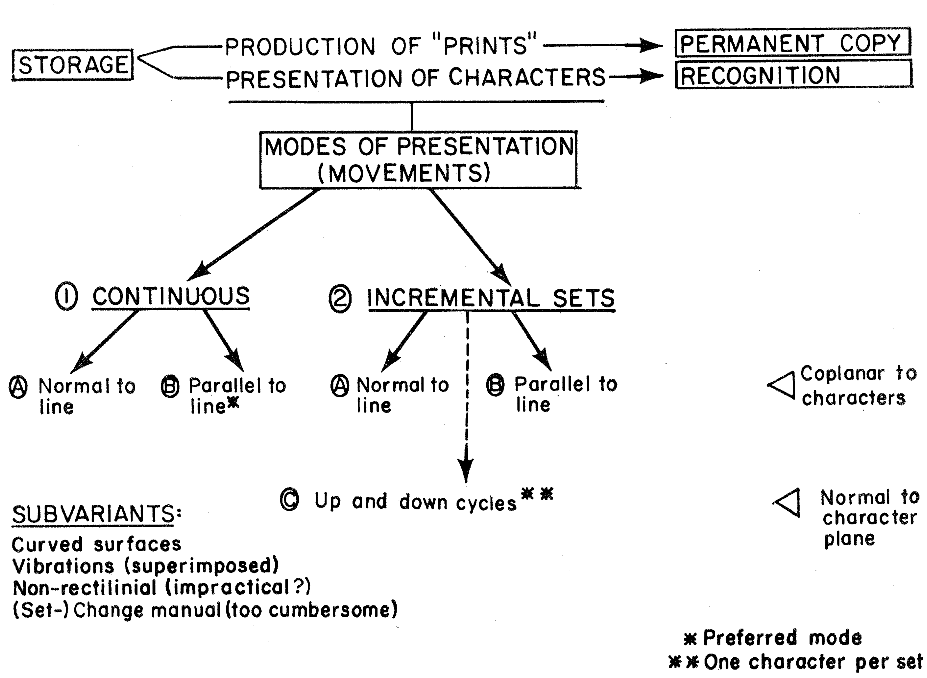

Fig. 1. Modes of presentation of characters to a reader.

modes. (i) Mode A.1 consists of several lines moving continuously upward as the reader scans each line from left to right. (ii) Mode A.2 is the same as mode A.1 but with the upward motion stepped. (iii) Mode B.1 consists of a single line flowing past the reader (right to left) while the reader's hands are essentially stationary. (iv) mode B.2 is the same as mode B.1 but with sideways motion stepped and the reader scanning each stationary line from left to right. The many possibilities of presentation may be seen in Fig. 1.

Initial prejudice of the Braille readers whom we consulted was for the A.1 mode, which they expected to be most similar to page reading. However, we thought it necessary to get more conclusive evidence, in view of the fact that the B modes (especially the B.1 mode) hold promise for a machine of much less complex design. A testing device was built (Fig. 2). This device consists of two rolls between which a sheet of paper can be fed. Each roll is equipped with two independent drives, one for continuous rotation (adjustable over a wide range of speeds), and the other for achieving feed in steps of either 10 mm (interline Braille spacing) or 230 mm (width of a Braille page). Two interchangeable cover plates with rectangular cutouts were used; on one the long axis of the cutout was parallel to the direction of travel, and on the other it was normal to it. The paper fed into the machine was embossed with Braille characters which were available to the reader within the field defined by the cutouts. Proper selection of drive mechanisms, cover plates, and test sheets of Braille enabled us to test read in the four modes described above. For the most part, the reading material used consisted of single words of controlled length (in terms of Braille characters per word), arranged in such a way that one word was not related to the next by alliteration, spelling, or similarity of meaning. Empty spaces were left between words on the test sheets. The inclusion of these empty spaces was necessary to permit pronunciation. Rapid speech was still slower than fast Braille reading by a factor of two.

These test sheets were presented to readers who pronounced the words aloud as they were presented to them at various rates. Reading speed was defined as the number of characters and blank spaces which the reader could sweep (per minute) while pronouncing 95 percent of the words correctly.

This method of testing was used in preference to subjective testing to avoid having fast readers get the meaning of a sentence by skimming rather than really reading every word, and to eliminate factors such as memory from interfering with the measurement of reading speed. However, such an interpretation of reading rate requires verification. For this purpose three subjects, all fast readers, were asked to read silently (that is, without vocalization or subvocalization) a page of Braille (descriptive text from a high-school biology book) as quickly as possible. Their maximum speeds agreed with their maximum speeds in the pronunciation tests. We also used some test sheets which consisted of randomly spaced dots presented in the B.1 mode. The speeds at which the presence or absence of each dot could be recognized were determined. For fast readers the recognition speed corresponded (in terms of finger sweep rate) with the maximum reading speed.

Tests were then performed on ten subjects of both sexes, ranging in age from 12 to 52 years, and varying with respect to years of education received from grade school to Ph.D.; their Braille reading speeds ranged from 60 to more than 300 words per minute. Adjustment to living as handicapped persons was good, and in some cases extraordinary. All readers found the A.1 mode unacceptable. The best readers were ultimately able to cope with it, but found it tiring and unsatisfactory, their speeds having been greatly reduced when compared with other modes. Good readers (200 words per minute) and excellent readers (300 words per minute) showed consistent

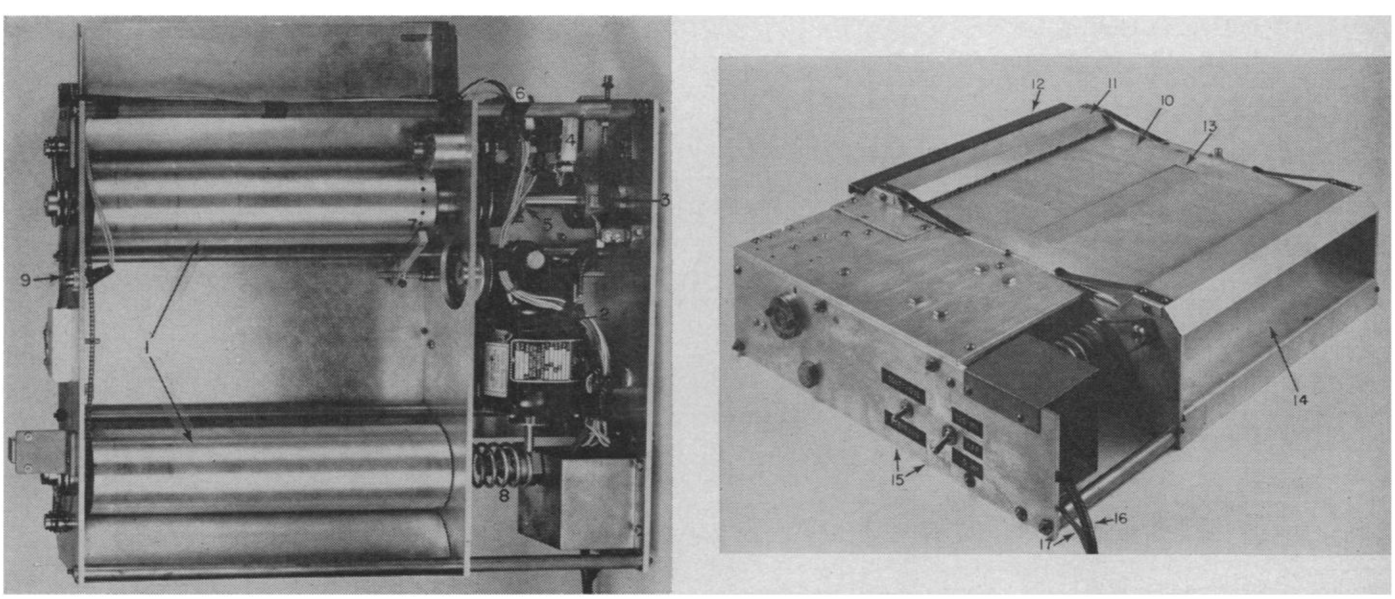

Fig. 2. A Braille-reading device. (Left) Bottom view with parts labeled. (Right) Top view of the device, ready for loading, with parts labeled. (*1*) Feed rolls; (*2*) motor for continuous rotation; (*3*) unidirectional clutch (for 10-mm steps); (*4*) solenoid (for 10-mm steps); (*5*) single-revolution clutch (1 revolution = 230-mm feed); (*6*) clutch trigger solenoid; (*7*) escapement (10 mm); (*8*) brake; (*9*) socket for (external) adjustable time switch; (*10*) cover plate; (*11*) roll guard; (*12*) paper release bar; (*13*) cutout (A-mode cutout shown); (*14*) paper exit chute; (*15*) mode-selector switches; (*16*) cable leading to motor speed control unit; (*17*) power-supply cable.

reading speeds in all modes but A.1. In the A.2 and B.2 modes there appeared to be about a 10 percent reduction in maximum reading speed as compared with the B.1 mode. Perhaps this is the result of the need to sweep back to the left margin after each line is read. Fair readers (100 to 150 words per minute) and poor readers (less than 100 words per minute) had even more pronounced preference for the B.1 mode than did the superior group, and, in fact, some of them achieved much higher rates with it than they did with the usual Braille text.

It thus appears that the B.1 mode, which we had considered desirable for engineering reasons, is preferred by readers. To substantiate our conclusions we asked each reader for comments on the B.1 mode. (Unfortunately, we revealed our prejudices for certain modes.) There was unanimous agreement that it was acceptable, and probably easy to adjust to. Several hoped that use of such a mode would improve their reading speeds (the B.1 mode has some features akin to those that are used in training for speed reading, and many thought that it might improve their reading comfort and enjoyment.

At this point we prepared the following set of criteria for a Braille-reading machine. (i) The machine should be conveniently portable. This implies at least an optional battery operation, and a weight of approximately 4.54 kg. (ii) The machine should be inexpensive. An estimated production cost of less than $500 should put it within the financial means of professionals. There are approximately 380,000 blind or severely visually handicapped people in the United States. Let us assume that one out of eight in this population reads Braille intensively when Braille reading material is more widely available. Free distribution of reading machines to those who need them would then entail expenditure of approximately $25 million—not an excessive amount by government or foundation standards. (iii) The machine should be durable, with simple and convenient controls, and should require standard supplies such as batteries. (iv) Presentation of material should be in the B.1 mode, and the characters should be erased after they have been read. (v) The machine should allow the magnetic tape to move quickly forward and backward, permitting the reader to locate any desired page or passage of text easily. (vi) The code used on the magnetic tape should be producible as direct computer output. It should include pagination, indexing, and cueing features for the reader. (vii) The tape (including box and reel) should contain at least 1000 words per cubic centimeter of space it occupies to make the system competitive with ink-print volumes. (viii) The maximum rate at which the machine presents characters should exceed 22 characters per second. (Three of our subjects routinely achieved this remarkable speed.)

In addition to these requirements, certain accessory features would be highly desirable with regard to the use of the machine for writing and annotating. With the addition of a device incorporating a Braille typewriter keyboard it should be possible to type directly onto magnetic tape. A blind author could then have his text translated into standard print by means of a computer. More commonly, it would simplify his letter writing and note taking, and would also be useful for making annotations in space provided on book tapes. Acoustic recording (perhaps on an extra channel provided in a multichannel book tape) would permit oral annotation. Further features may emerge as development of the machine proceeds.

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References and Notes

1. The American Printing House for the Blind, in cooperation with IBM, has developed a method of translating Braille by means of standard punch cards for computer input. The Computer Science Laboratory and Honeywell have developed a similar system. The Mechanical Engineering Department of the Massachusetts Institute of Technology is working on computer translation bypassing the step of the punched card. [See also R. W. Mann, "Enhancing the Availability of Braille," *Proc., Int. Congr. Technol. Blindness*, vol. 1 (American Foundation for the Blind, New York, 1963).]
2. I thank E. Groh, T. Pienas, B. Burson, P. Grunwald, L. Wos, B. Spinrad, Mrs. Gretel Grunwald, and Mrs. Julian Levi for their valuable support.

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Turbulent-Gas Chromatography

Abstract. *Turbulent flow in gas chromatography was achieved and its effect was studied with high-speed, high-pressure equipment. A gas-solid capillary and several packed columns were used. The onset of turbulence was associated with abrupt decrease in peak width in the capillary and gradual leveling off and decrease in the packed columns. The existence of separation under turbulent conditions was shown. The potential of the method was demonstrated by its short elution times and rapid generation of theoretical plates.*

We now report the first experimental realization of fully developed turbulence in gas chromatography. With the aid of high-speed, high-pressure equipment, we have operated at Reynolds numbers (*Re*) to 16,000, 10^4-fold beyond conventional laboratory operation. Correspondingly, mean gas velocities exceeding 2000 cm/sec and outlet velocities near the sonic level have been reached, compared with the usual velocity range of 2 to 10 cm/sec. These extremes of velocity have revealed a clear maximum in the plate height (or peak dispersion)–velocity plots for both packed and capillary columns (*1*). This maximum is of particular interest for high-speed, high-resolution gas chromatography since, beyond the maximum, both separation speed and resolution increase simultaneously to rather high values; ordinarily one must sacrifice one in order to gain in the other.

The role and potential value of turbulence in gas chromatography has been discussed by several: Giddings and Robison (*2*) first pointed out that flow conditions frequently approach the threshold of turbulence; Sternberg and Poulson (*3*), adverting to increased mass-transport rates, were the first to draw attention to the unusual promise of turbulence. That "velocity equalization" in turbulent flow might be advantageous was suggested by Giddings (*4*); both he and Knox (*5*) have shown that turbulent and "coupling" effects overlap one another in high-velocity, packed columns. Turbulent effects have been treated mathematically by Pretorius and Smuts (*6*).

The transition from laminar to turbulent flow in packed columns is grad-