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BRAILLE AS A PATH TO WRITTEN CONTENT

Mislav Benić [1], Hrvoje Glavaš[2]
[1]Institute of Croatian Language, Department of Dialectology, Zagreb, Croatia
e-mail: mbenic@ihjj.hr
[1]Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Osijek, Croatia
e-mail: hrvoje.glavas@ferit.hr

Abstract: The aim of the paper is to describe the development, structure and practical application of Braille as a tactile writing system. By questioning the assumption that 90% of information is transmitted visually, the understanding of the importance of individual senses is re-examined. The article gives an overview of the history and the beginning of the development of Braille. The structure of modern Braille and the reading and writing processes are described. The historical overview gives an insight into the most important milestones from the early Latin relief scripts to the innovations of Louis Braille binary code with six dots, optimized for tactile reading and efficient writing. The article analyses the adaptations for different types of written content, including letters, numbers and musical notes, as well as auxiliary symbols and polysemic use to overcome the inherent limitations of the Braille cell. Modern aspects covered include reading techniques, average speeds and advances in Braille printing technology, electronic notebooks and adaptive digital devices that have greatly improved accessibility for blind users. The conclusion emphasizes the synergy between tactile and auditory technologies in development, with the goal of equal access to written information in education and daily life.
Key words: Braille, Braille alphabet, black print, reading, writing

INTRODUCTION

It is a common belief that we receive 90% of information through the sense of sight, [1]. This belief overlooks facts that senses often overlap. The data that makes up what we might roughly consider the same information is often received simultaneously through different senses. Therefore, depending on what we consider as information, it may very well be the case that, for example, we receive 90% of information through sight, 40% through hearing, another 15% through some other sense, etc. In that case, the claim that we receive 90% of information through sight says very little by itself. Available scientific sources state that our brains acquire about 90% of information from two senses only: sight (about 80%) and hearing (about 10%). The remaining 10% of information is distributed between smell, touch, and taste senses, [2]. The overlapping of the senses is confirmed by the fact that a blind person will not recount the plot of a typical film that is not overly visual but also not adapted for the blind significantly worse than a sighted person who watched the film without sound or subtitles—and in some cases, the blind person may even recount it better. Second, the brain supplements the data it receives based on prior knowledge. Such supplementation is very important for creating "coherent information." It is particularly significant in the case of hearing and smell, but by no means negligible in the case of vision, as various optical illusions confirm. For instance, a person who hears an insect (its flight, hopping, or chirping) can often fairly well identify which insect it is, even without seeing it. Conversely, a person who sees the insect may, due to optical effects, sometimes incorrectly conclude the species, or in extreme cases, mistake the insect for something that is not an insect, e.g., a twig. Third, vision is a directed sense, while hearing and smell, with certain qualifications, can be said to receive information from all directions. In the animal kingdom, for example, only fish have strict directional hearing and the localization of sound sources without moving the ear or head [3]. Fourth, there is the important question of how we measure the amount of information we receive. The amount of information a person receives is very difficult to measure objectively. This fact further diminishes the value of the claim made at the beginning of this paper. Moreover, if we take at face value the claim that we receive 90% of information through sight, we might easily arrive at the inductive conclusion that it is nine times better to have good vision but lack all other senses combined than to lack only sight. Nevertheless, for completely blind people and people with very little residual vision—hereafter referred to briefly as the blind—the lack of vision significantly complicates life in many areas which negatively affect the overall quality of life, and to some extent the quality of social life as well. Various household tasks are much more accessible to the blind, although there are certain difficulties in this area as well.

There is yet another area that, especially today, is very important for quality of life but is not equally accessible to the blind as it is to the sighted: the use of written content. By the term "written content," we mean everything that we write down and read. This is primarily the written word, which, at least in Western culture, we usually encode with letters (as symbols largely corresponding to individual sounds), punctuation marks, and other auxiliary means. Another important type of written content is everything connected with numbers and arithmetic, usually encoded with digits and many auxiliary symbols regularly used in mathematics and natural sciences. A third important type of written content is recorded music, usually encoded with notes and numerous auxiliary symbols. In addition to these three main types of written content, there are also some peripheral ones, such as chemical reaction equations. In order to reduce, as much as possible, the difficulties that the blind face in various areas, various products and services exist. In this paper, we will focus on the Braille that reduce the inaccessibility of written content for the blind. The main aim of this paper is to familiarize the public with the methods by which blind people make use of written content.

BRAILLE RAISED SCRIPT

Prehistory and the Beginning of the Development of Braille

From the perspective of an inventor who is not also a user, the most intuitive way to make written content accessible to the blind is by relief representation of characters that are otherwise usually written in ink (hereafter, such non-relief characters will be referred to as black print). In other words, in such an adaptation no special script for the blind is used; rather, the script used by the sighted is presented in relief form and usually somewhat simplified—for example, only uppercase block letters are used, in a size that is easily accessible to the sense of touch.

There were several attempts at such adaptations, and here we mention some of the more significant ones. Valentin Haüy, [4] the founder of the Royal Institute for Blind Youth in Paris, used wooden letters and especially embossed letters pressed into paper in his teaching at the end of the 18th and the beginning of the 19th century. Letters made of copper wire were pressed into damp paper, leaving a trace in the form of raised relief lines. Paper thus inscribed could be bound into books. Haüy's adaptation was not particularly practical. The books were very bulky, and the relief wore out relatively quickly, becoming difficult to read. Finally, writing Haüy's letters was not simple, so only institutions could do it. In other words, Haüy's invention allowed blind people to read to some extent, but not to write in a script that they themselves could read.

Johann Wilhelm Klein, founder of the Institute for the Education of the Blind in Vienna, at the beginning of the 19th century devised a technique for producing Latin block letters not with solid lines like Haüy, but with dotted lines—lines made up of a dense sequence of raised (embossed) dots on paper. This technique was more practical than Haüy's—easier writing, greater durability of the text—but still not practical enough to take hold. Writing characters in Klein's technique was still relatively complicated, and besides, embossed reproduction of black print was too complex to be read quickly with the fingers.

Louis Braille, figure 1., in 1839 also devised a method of writing the Latin alphabet with raised dots: the so-called decapoint (French décapoint), [5]. At first, writing such letters was relatively complicated, but Braille's friend Pierre François Victor Foucault, with Braille's help, created in 1841 the raphigraph, a machine that greatly simplified the writing of decapoint. The specific feature of decapoint was that it was not conceived as a script for the blind (by then Braille already existed), but as a means to facilitate written communication between the blind and the sighted. Namely, Braille had become completely blind at the age of five, and while at the Royal Institute for Blind Youth, he wanted to correspond with his parents and other sighted persons, which was impossible with Haüy's technology.

Fig. 1. *Louis Braille, source [4]*

William Moon, a blind teacher from Brighton (blind from the age of 21), in 1845 devised a specific, much-simplified embossed script of the Latin alphabet for the blind. For example, the letter a was two lines forming an upward-pointing angle; b was a vertical line with an arc on the lower right; c was a semicircle open to the right; d a semicircle open to the left; e a right angle (like a printed f without the middle horizontal stroke), etc. The simplified shapes were meant to contribute to easier reading. Similar to Braille, the first ten letters were also used to represent numbers. The script was bulky (taking up much more space than Braille), so there was also a kind of shorthand. This technique was probably the most practical for those who became blind later in life, like Moon himself. For a time it was relatively popular, but it was ultimately displaced by Braille.

The principle of embossed reproduction of black print was also used in the Optacon (short for optical to tactile converter), an electronic device that displayed characters in black print (on paper or on a monitor) in relief, i.e., as somewhat enlarged characters of identical shape, formed by tiny vibrating pins (at about 50 Hz). It consisted of a small camera with a guide that was moved across the surface with written content, and a converter with a small display approximately the size of the first two joints of the index finger, which was used to read the written content by touch. Optacons were manufactured from 1971 to 1996. They were expensive, reading with them was demanding, slow, and not particularly pleasant due to the pin vibration, so they never gained widespread use. Still, in the 1970s and 1980s, and to some extent in the 1990s, the Optacon was the only tool by which a blind person could independently read black print.

At the end of this brief overview, it should be emphasized that the reproduction of black print is yet another piece of evidence showing that what is most intuitive from the inventor's perspective is not always the best for the user.

A revolutionary step towards Braille was taken by Nicolas-Charles-Marie Barbier de La Serre. Already during Haüy's directorship, Barbier sent his invention to the Royal Institute for Blind Youth: a dotted script that did not reproduce the shapes of black print characters. Haüy was not interested in the script because the institute used embossed reproduction of black print according to his own already described technology. After Haüy's death, Barbier presented his invention to the new director, and this time he received support. Barbier's script at first glance is relatively similar to Braille. One cell, i.e., one character space, contained twelve positions, i.e., up to twelve dots: six dots in two columns. In such a system it was possible to obtain 4,096 (2^{12}) characters, from the character without any dot (space), through various combinations with different numbers of dots, to the character consisting of all twelve dots. In such a multitude of characters it was certainly impossible to find one’s way, nor was such a number of characters necessary. Therefore, Barbier devised three systems with a relatively small number of characters: a system of 25, a system of 30, and a system of 36 characters.

Barbier chose the characters that would enter his systems by using tables of 5×5, 5×6 (i.e., 5 rows and 6 columns), and 6×6 cells. The coordinates of each cell in the table defined a character in such a way that the row number of the table indicated the number of dots in the first column of the character cell, arranged in a continuous sequence from the top of the column downward, while the column number of the table indicated the number of dots in the second column of the character cell, also arranged in a continuous sequence from the top downward. Thus, the letter numerically marked by Barbier as 1,1 (the letter a) consisted of the two topmost dots of the character cell. The dots in the character marked as 5,5 (the letter Z) occupied ten of the twelve positions in the character cell, i.e., all except the two lowest. The character marked as 4,2 (the letter q) had the four topmost dots in the first column and the two topmost dots in the second column.

Barbier’s script had certain advantages over Haüy’s embossed reproduction of black print: the characters were more durable, they were easier to read, and most importantly, they were relatively simple to write. Writing in Barbier’s script used tools that blind people could handle without difficulty. Writing was done with a stylus and equipment similar to the so-called slate. Barbier’s script also had some easily removable shortcomings: the character cell was too tall, and individual characters contained too many dots (both slowed down reading), while at the same time the number of available characters was too small.

Louis Braille noticed these shortcomings. Unlike Haüy, Klein, and Barbier, Braille was himself blind, so he approached the problem from the perspective of the user. Braille was a student at the Royal Institute for Blind Youth, and later worked there as a teacher.

He devised the first version of Braille in 1824, at only fifteen years of age, and published it in 1829, Figure 2. The main specific feature of the first version of Braille, compared both with the later, modern version published in 1837 and with Barbier’s script, was that the components of the characters could be both dots and horizontal dashes. The character cell in the first version of Braille, if we look only at the dots, had six positions, just as in the second version. In other words, up to six dots could be arranged in two columns of three dots each. The dots were counted from top to bottom, first in the left column and then in the right, i.e., dots 1, 2, and 3 were in the left column from top to bottom, and dots 4, 5, and 6 were in the right column. In addition, the place of two horizontally adjacent dots—dots 1 and 4, 2 and 5, or 3 and 6—could also be occupied by a horizontal dash. Horizontal dashes could appear in three positions, which are marked with underlined numbers from top to bottom as 1, 2, and 3. In this way the system could have at most 125 different characters, including the space. Of these 125 characters, Braille catalogued only 90, which he divided into nine decades, i.e., nine groups of ten characters each. However, even among these 90 catalogued characters, he left several without assigned value.

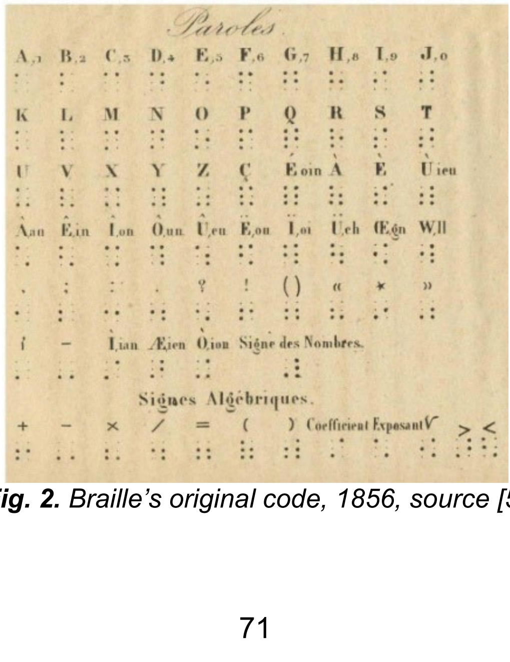

***Fig. 2.** Braille’s original code, 1856, source [5]*

The first four decades consisted only of dots, and in form and content they basically corresponded to the characters of modern Braille. These characters primarily denoted letters. The fifth decade denoted the digits 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0, and looked like this:
1, 12, 12, 125, 15, 12, 142, 42, 4, 45.
The sixth decade contained punctuation marks and was obtained by adding dash 3 to the characters of the first decade. The seventh decade denoted mathematical symbols and notes. It was formed by moving the characters of the first decade to the bottom of the cell, with dash 1 placed at the top of the cell: for example, 13, 123, 136, 1256, etc. Part of the eighth decade also represented mathematical symbols, while part had no assigned value. All characters of the eighth decade contained dash 2, and they were obtained from the seventh decade by switching the positions of the upper dash and the middle dots: for example, 23, 123, 236, 1246, etc. In the ninth decade, only the first three characters had the value of auxiliary signs, while the rest had no assigned value. They were obtained from the fifth decade by adding dash 3.
Such a system had certain advantages over Barbier's. The main advantage was that Braille's characters were of an optimal size for reading with the fingertip, whereas Barbier's were too large. In this respect, Braille's system proved only partly redundant, since about thirty characters had no value. By contrast, the number of possible characters in Barbier's system greatly exceeded the number needed, while in practice too few characters were actually used—significantly fewer than in Braille's system.
Still, the first version of Braille had certain shortcomings. It turned out that during faster reading the dashes were difficult to distinguish from the dots. Moreover, dots and dashes were certainly harder to write than dots alone. In this sense Braille's ternary code was actually a step backward compared to Barbier's binary code. True, such a ternary code allowed for more characters than a six-digit binary code, but after a few years Braille realized that the future lay in binary code, and that the insufficient number of characters would have to be compensated for in other ways.
The second version of Braille is, generally speaking, the best writing system for the blind to date. The characters are of optimal size for fingertip reading. They consist exclusively of dots. The fact that the characters consist only of dots, and of a relatively small number of dots, simplifies writing, whether with the slate and stylus (adapted from Barbier's writing tools), the Braille typewriter, or its modern equivalents. The same fact also allows for relatively fast reading. Braille characters form very simple letter shapes that the fingertip quickly recognizes. A Braille character is perceived primarily as a simple dotted shape: the reader does not focus on each dot separately and does not need, as in the first version, to concentrate on distinguishing between dots and dashes.
The number of characters is relatively large (greater than the number used in Barbier's systems), and the insufficient number of symbols is compensated for through polysemy of individual characters and combinations of characters.

Modern Braille as a System

Classical modern Braille (six-dot Braille) is a six-digit binary code designed for the blind, in which a raised dot corresponds to the value 1, and the absence of a dot corresponds to 0, figure 3. Braille characters encode letters, numbers, musical notes, various auxiliary symbols (punctuation, mathematical symbols, auxiliary signs in music notation), as well as abbreviations, symbols, and more. In this sense, although Braille is usually considered a script, it is not actually a typical script, since scripts are usually limited to the written word and, in some cases, to the specific notation of numbers. Braille is rather a relief code that makes written content accessible to the blind. As a six-digit binary code, classical Braille has only 64 (i.e., 2^6) single-cell characters, including the space. In the original second version of Braille, these characters were organized into sequences. There are six sequences of ten characters each, and one sequence of four characters. The corresponding system of sequences is essentially valid for all Braille systems in which the coding is close to that of the second version.

These are the systems predominantly used by the blind in Europe and America, as well as many others.

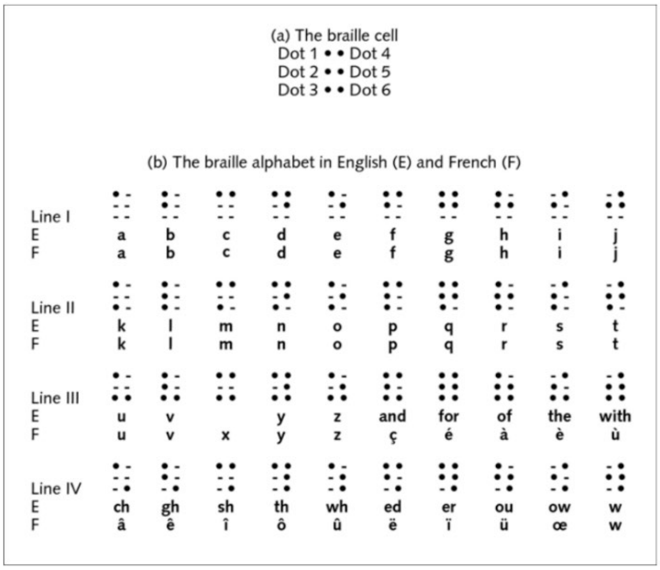

Fig. 3. *The Braille alphabet in english and french, source [6]*

The dots in a Braille cell, as stated earlier, are arranged in two columns of three dots each, and are counted from top to bottom: first in the left column (1, 2, 3) and then in the right (4, 5, 6).

The first four sequences essentially encompass the French alphabet, so that the letters with diacritics are placed at the end of the list, and the last letter in the fourth sequence is w, which is visible in Figure 3. The Braille alphabet in English and French, [6].

The characters of the first sequence correspond to the letters a, b, c, d, e, f, g, h, i, j. However, these same characters also denote the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 if preceded (not each digit individually) by the number sign (3456). The letters from d (145) to j (245) also denote quaver (eighth) notes.

The second sequence corresponds to the letters k, l, m, n, o, p, q, r, s, t. The fourth through tenth characters of this sequence (letters n to t) also denote half notes.

The third sequence corresponds to the letters u, v, x, y, z, plus five French letters with diacritics. However, the fourth character (y) through the last in the sequence also denote whole notes: C, D, E, F, G, A, B.

The first nine characters of the fourth sequence generally denote various letters with diacritics, digraph abbreviations, and the like, while the tenth character is w. The fourth through tenth characters also denote quarter notes. In other words, a half note is derived from a whole note by subtracting dot 6, a quarter note by subtracting dot 3, and an eighth note by subtracting dots 3 and 6 from the whole note. Sixteenth notes are written as whole notes, and thirty-second notes as half notes.

Reading and Writing Modern Braille

When reading Braille, the reader usually glides both hands across the embossed surface. The main role in reading is played by the index finger of one hand, while the other fingers mostly help in tracking the lines and only slightly in recognizing the characters. The preference for the left or right index finger in reading does not strictly correlate with left- or right-handedness. Some right-handed people read primarily with the left index finger, others with the right. Braille can be read relatively well with only the hand that plays the primary role. Reading exclusively with the hand that plays a secondary role, however, is significantly more difficult. There are, to be sure, certain ambidextrous Braille readers. The question remains whether such ambidexterity can be acquired through training.

The average reading speed of Braille in Croatian is 60 to 80 words per minute. The index finger does not follow the text at a constant speed, but moves more quickly over more predictable parts of the text, and more slowly over less predictable parts, where it may also pause or, if necessary, move back. Since Braille is basically read with one finger, the reader cannot perceive the content of a larger section of text at once. The skin contains receptors for warmth, cold, touch, and pain. All more or less successful attempts to bring written content closer to the blind through the skin are based precisely on the sense of touch. Clearly, it would never occur to a normal person to bring written content closer to the blind through the sense of pain. But what about warmth and cold? A new idea has emerged at the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek to explore the possibilities of making a Braille display based on long-wave infrared radiation. Approach represents a new technical solution that proposes the use of passive elements positioned in a six-dot Braille grid instead of actuators. The above solution requires fewer resources, reduces investment costs and provides the opportunity to expand the use of Braille. During the implementation of the project "Braille display screen based on long-wave infrared radiation" NPOO.C3.2.R3-I1.05.0191 preliminary research have shown that the senses of warmth presents a challenge for reading, most likely for two reasons, [7]. On the one hand, the fingertips, which are most suitable for following text, are not particularly sensitive to small temperature differences which could be detected on the first prototype. On the other hand, the human reaction to temperature changes is relatively slow and cannot perceive the ten or so tiny changes per second that the sense of touch perceives when reading Braille.

Today, in printing houses—and partly also for private use—we employ Braille printers. In the Braille printing house of the Croatian Blind Union, printers have been in use since the 1990s. Some printers print only single-sided, but nowadays double-sided printers are generally used. Many printers still use continuous feed paper with guiding holes, but printers that use cut-sheet paper are more highly valued.

Braille printers are generally much larger, much slower, much louder, and of course, much more expensive than black-print printers. Their speed varies, but more common speeds are 140, 300, and 330 characters per second. Braille printers have certainly made a major contribution to the speed of book production and, more broadly, to the availability of written content for the blind. Braille can also be written with some electronic devices. Electric Braille typewriters are rare. Much more common today are so-called electronic notetakers: relatively compact electronic devices with a six-dot or eight-dot Braille keyboard as the input module, and speech, a Braille display (usually 18 or 40 cells), or both as the output module. For reading purposes there are braille lines and screens, although screens are much less accessible. Braille can also be written with some electronic devices. Electric Braille typewriters are rare. Much more common today are so-called electronic notetakers: relatively compact electronic devices with a six-dot or eight-dot Braille keyboard as the input module, and speech, a Braille display (usually 18 or 40 cells), or both as the output module.

Electronic notetakers have their own memory and the ability to export data, and more recently they can also hold memory cards. Simpler notetakers store data as files in txt format. Notetakers with a Braille display (module) can be connected to a computer and used as a Braille display (device).

Electronic notetakers often have additional functions such as a clock, alarm, stopwatch, timer, calendar, calculator, etc. Some notetakers are small computers in their own right and can connect to the Internet. We believe that an electronic notetaker is not a good replacement for a computer, but it can be an excellent supplement to one. This is especially true of simpler notetakers, which respond quickly and conserve rechargeable batteries.

They are useful as a tool for taking lecture notes: unlike Braille typewriters, they are light, compact, and quiet, and the text created with a notetaker can easily be retrieved in various formats. They are excellent as notebooks for all kinds of notes, as a book—or rather, a whole library of books and other texts—that one can carry around, and so on. Some notetakers store text automatically as it is entered, while with others the text must be saved before switching the device off (as with documents on a computer). Automatic saving during input is by far the

better option, since a user can easily forget to save and, upon switching the device off, lose everything written. As might be expected, electronic notetakers are also very expensive.
Finally, even a smartphone adapted for the blind can have a virtual Braille keyboard as the input module. The user enters data by "writing" on the screen in a way similar to typing on a real Braille keyboard. In this case, as to some extent also with electronic notetakers, we are no longer dealing with the writing of Braille itself, but with the writing of digital text using the method originally designed for Braille entry.

CONCLUSION

In this paper, we have tried to present Braille as intermediary of written content for the blind to the general public, hoping that this topic might be of interest to those who do not know much about it. Naturally, we have also aimed for the information provided here to be not only interesting but also useful, especially to those who work with or intend to work with assistive technologies for the blind. The most important thing we wished to emphasize—because, despite being self-evident, it is sometimes overlooked—is that potential users usually know best what they need. In this regard, it is desirable: that scientists and manufacturers of assistive technologies consult with potential users when designing and implementing projects; those actual users of finished products are given the opportunity to suggest how those products could be improved. When it comes to providing access to written content for the blind, those less familiar with the field often have in mind only one of the two basic methods—or predominantly one: often Braille, as the older method specifically tied to the blind, even though speech is probably the more important means today. In this paper, we have presented written Braille in an abbreviated form. Due to the limited scope of the paper, many details related to the adaptation of written content for the blind could not even be mentioned, let alone described in more detail.

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