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Braille

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Braille is the term used for a tactile orthography (or writing system), designed primarily for use by blind readers, but accessible to anyone who chooses to learn to read tactually. It generally appears as a sequence of dots embossed on paper, but readers of this article in the United States will perhaps be more familiar with braille on signs in public buildings. These signs are posted on elevators, restrooms, or room numbers in public buildings in compliance with the Americans with Disabilities Act (ADA) (Dept. of Justice, 1994). These signs can be made by a variety of methods, including setting blunt pins in plastic or metal to create very durable braille (Engraving Machines Plus, 2006), permanently bonding braille letters to a sign face (Accent Signage Systems), and injecting plastic into a sign face (Advance Corporation).

Braille is not a language. It is a way of writing a language tactually; (CF) braille signs in English speaking countries are written in English; braille signs in Korean speaking countries are written in Korean. A person who chooses to learn to read braille is thus learning only a different way of writing his or her language. Since it is not the name of a language, the word braille is not capitalized unless the reference is to the inventor of the braille system (Louis Braille 1809-1852) or to anyone else with that surname (Braille Authority of North America, 2006).

The Development of Braille

The inventor of the braille system, Louis Braille, was born in 1809 in Coupvray, France. His Father, Simon Braille, was a leather worker and harness maker, and young Louis Braille is said to have injured his eye by playing with one of his father's tools in the family workshop. The wound became infected and the infection spread to his uninjured eye. By school age, he was completely blind.

He learned the shapes of print letters from his father and later attended the neighborhood school. At age ten, he enrolled at the Royal Institute for Blind Youth in Paris (Stein, 2009), where he continued to read using a system of raised letters. Reading in this way was slow, the books were very heavy and the students did not possess the equipment necessary to write; they could only read what had been prepared for them.

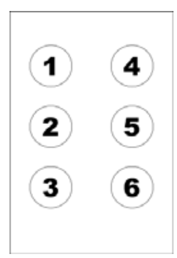
Louis Braille's system was a refinement of a phonetically based, raised-dot military code called night writing, proposed by Charles Barbier (Stein, 2009) and presented to the students at the Royal Institute for Blind Youth in 1821. The basic unit of writing in Barbier's system was a grid of 24 dots arranged in two columns each with twelve dots. Braille refined Barbier's code until the basic unit of writing was small enough to fit under a single fingertip, thus making it possible to read by moving the hand horizontally along a single line of letters rather than moving the hand both up and down and left to right in order to read. Additionally, Braille's system was alphabetic, employing the groups of dots to represent Roman letters rather than the phonetic system Barbier used. (Bickel 1988)

Braille was an almost immediate success with the blind students who learned it quickly and began to copy raised letter books into braille. The sighted teachers however, (who could read raised letters but had not learned braille) resisted its use, feeling it was too difficult and was too different from print. Assistant director of the school during those years, P. Armand Dufau, was so convinced that braille was not the best choice for the blind students that he ordered that all materials written in braille be burned (Kimbrough).

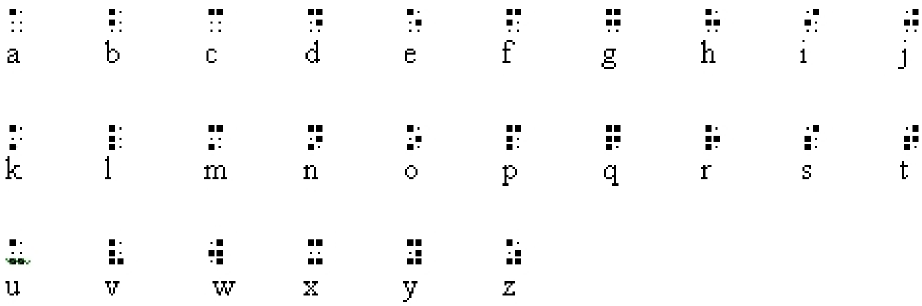
Several factors contributed to the eventual success of braille as a means of literacy for blind people. Among these are it's ability to be read rapidly, learned relatively quickly, and the equipment for writing braille is portable and easy to produce. (For a description of other tactile writing systems which have been proposed and had varying degrees of success, see: http://www.nyise.org/blind/irwin2.htm, and for a discussion of the social and political forces which brought braille into wide use in the United States, see Richard Irwin's historical piece, *War of the Dots*: http://www.nyise.org/blind/irwin2.htm.)

How Braille Works

The most basic unit of braille is called the *cell*: an arrangement of six dots in two columns of three. According to the standards in Canada and the United States, when properly embossed the braille cell is generally 0.092 inches (2.340 mm) by 0.184 inches (4.673 mm) (Braille Authority, 2009). This may vary slightly in different countries (Digital Accessibility Team, 2009; Braille Authority of North America, 2009). A standard enlarged form of the cell, called 'jumbo braille' is occasionally used in the United States as well. For the sake of clarity, each of these dots has a corresponding number from one to six. (See image to right.) The uppermost dot in the left-hand column is designated as *1*. The middle dot in the left column is *2* and the lowest dot in that column is *3*. The right column contains dots *4*, *5,* and *6*, with *4* being in the upper right, *5* in the middle of that column and *6* in the lower right corner of the cell. There are sixty-three possible combinations of these six dots (sixty-four if one counts an empty cell, used as a space between words). Braille characters, be it letters, numbers, punctuation marks, musical notes or mathematical symbols, are made by choosing the appropriate combination of dots within a cell. For example, the Roman alphabet letter *a* is written as a dot *1*: a. A *b* is dots *1* and *2*: b. A *c* is dots *1* and *4*: c.



The Roman alphabet, as it is used in English, is shown below:



The first thing to note about the sequence above is that it is patterned. The first ten letters, *a-j*, are written using only the upper four dots in the cell: dots *1*, *2*, *4*, and *5*. To form the second ten letters, *k* through *t*, this pattern is repeated with the addition of a dot *3*. Examine the first two rows. The first letter, *a*, is a dot *1*. Below *a*, the eleventh letter, *k,* is written using dots *1* and *3*. The *b* (the second letter) is written using dots *1* and *2*. Just below it, *l*, the twelfth letter is written using dots *1*, *2*, and *3*. The *j*, the tenth letter at the right end of the top row is written using dots *2*, *4*, and *5* while just below that, *t*, (the 20th letter) is written with *2*, *3*, *4*, and *5*.

For letters *u-z*, the pattern is repeated again, with the addition of a dot six. Thus, the first letter in each row, we find *a* = dot *1*, *k* = dots *1* and *3* and *u* = dots *1*, *3*, and *6*. Similarly, *b* = dots *1* and *2*, *l* = dots *1*, *2*, and *3*, and *v* = dots *1*, *2*, *3*, and *6*.

The pattern is disrupted at *w*. Recall that the braille system was invented in the early nineteenth century in France. At that time, *w* was not needed in French and thus it was not included in the pattern. Louis Braille added *w* after his system was codified. Other languages, such as Spanish, have similarly had to add (or omit) letters from the braille representation of the Roman alphabet to fit their needs. For example, Spanish *ñ* is written as dots *1*, *2*, *4*, *5*, and *6* and is inserted in the alphabet between *n* and *o*, similarly disrupting the pattern.

Other accented letters (generally vowels) in use in other languages are written as single cells. For example, Spanish accented vowels are as follows:

vowel	accented form	example
á (	sof(	sofá (sofa/couch)
é !	ir!	iré (I will go)
í /	m/a	mía (mine)
ó +	habl+	habló (s/he spoke)
ú)	n)mero	número (number)

These accented vowel characters are not consistent across languages however. The letter, ·, with a spanish accent marking in Spain-Spanish is (dots *1*,*2*,*3*,*5*, and *6*), in Hungarian (dot *4*), in Icelandic (dots *1* and *6*), in Faroese (dots *3* and *4*). (Unesco. & Library of Congress. National Library Service for the Blind and Physically Handicapped, 1990)

Braille numbers take advantage of the same sequence of cells used in the first ten letters of the alphabet. Numerals *1* through *9* are represented by the same forms as are used for letters *a* through *i*. The *j* is used for the numeral, zero. To distinguish, for example, the number *1* from the letter *a*, a number sign (dots *3*, *4*, *5*, and *6*) is placed immediately before the forms. This identifies numbers. Thus, *ad*, `ad` (dot *1* followed by dots *1*, *4*, and *5*), is read as the word 'ad', while the same two cells preceded by a number sign `#ad` is read as *14*. This system has at least three interesting repercussions.

First, there is no confusion possible between number zero *0* (`0`) and letter *O* (`o`), as these forms are quite different from each other. The same is true of the number *1* (`1`or `#a`), the uppercase letter *I* (`I`), and the lowercase letter *l* (`l`). These letters may be confused in print, but in braille are quite distinct. Second, the need to use a number sign accounts for the fact that room numbers written in braille appear to have one extra character than their printed equivalents. For example, the number *214* is three characters in print, but the braille equivalent, `#bad`, has four characters. Finally, it is possible, in some cases, to read numbers written in braille as though they were words (such as the number *214*, which is equivalent to the word *bad* in braille). This ability is a handy memory aid in cases where the sequence of derived letters is a pronounceable word. Braille punctuation is written in the lower four dots of the cell. Some examples follow:

Punctuation mark	Print equivalent	braille
comma	,	`1`
hyphen	-	`-`
period	.	`4`
question mark	?	`8`
exclamation point	!	`6`
apostrophe	'	`'`
quotation marks	“ ”	`8 0`
parentheses	( )	`7 7`

Note that while in print, it is possible to use the same mark to both open and close quotes, the braille forms are distinct from one another: `8` and `0`. Opening and closing braille parenthesis, on the other hand, are identical: `7` and `7`. Also note that the character `8` (dots 2, 3, and 6) is employed both as the opening quotation mark and as question mark. Its placement (either immediately before or immediately after other text) determines its meaning.

Upper case (capital) letters in braille are the same as their lower case equivalents. It is not possible to make letters larger as is done in print to distinguish case. Braille uses a prefix dot 6 to indicate that the following letter is capitalized. To capitalize a whole word, two dot 6s are used.

`claire` = claire
`,claire` = Claire
`,,claire` = CLAIRE

Literary English braille also includes a set of short forms or contractions for frequently occurring letter combinations. Some examples follow. Note that some of these use more than one cell and that more than one can occur in a single word:

Symbol	Represents	Example
*	ch	*ur* = church
$	ed	$it = edit
]	er	h]d = herd
>	ar	p>k = park
+	ing	not+ = noting
.e	ance	d.e = dance
;1	ful	h>m;l = harmful

Some commonly occurring words have short forms of their own and these may also use more than one cell, often a prefix followed by a letter:

Braille contraction	Print equivalent
C	can
D	do
N	not
W	will
*	child
&	and
!	the
8!	there
8w	work

Some words are 'outlined' by writing salient consonants.

Braille contraction	Print equivalent
`Gd` (gd)	good
`Tgr` (tgr)	together
`Afn` (afn)	afternoon
`Qk` (qk)	quick

As has been shown with some punctuation marks, the meaning of some characters changes depending on where they are placed. For example, the character *4*, `4` (dots *2*, *5*, and *6*), signifies the sequence *dis* when it begins a word, *dd* word-medially, and a period at the end of a word. The sequence of dots *2* and *5* signifies a colon at the end of a word, *cc* in the middle of a word, and *con* word-initially. The following two examples use these contractions.

My daddy dislikes bro**cc**oli.

```
,my da4y 4likes bro3oli4
```

He **con**sumes only junk**:** cookies, cake and pudding.

```
,he 3sumes only junk: cookies, cake & pud+4
```

Altogether, there are 189 such contractions used in standard English literary braille. The resulting system, formerly known as grade-two braille, is now generally referred to as contracted braille. Use of contractions reduces the length of texts, and increases both reading and writing speeds. All of these types of contractions can co-occur in the same piece of text as shown below:

Written English:
A hard-working child can do her homework quickly.

Contracted:

```
'! h>d-"w+  * c d h] home"w qkly4
```

Uncontracted:

```
A hard-working child can do her homework quickly.
```

An additional set of whole and part word contractions exists. These, and the rules for their use, are still referred to as grade-three braille (Hayden, 1982). This system, designed primarily for personal note taking, is no longer in wide use.

Some slight differences in the braille code exist between English speaking countries. For example, the rules for contraction are slightly different in the UK than they are in the United States (Unesco. & Library of Congress. National Library Service for the Blind and Physically Handicapped, 1990). These differences are perceived as problematic by some, and attempts have been made to unify the braille code across all English speaking nations (International Council on English Braille, 2009).

The braille contractions mentioned thus far are specific to English. Danish, French, German, Hungarian, Icelandic, Malagasy, Portuguese, Spanish, and Swahili (among other languages) also have systems for contracting braille and these are different than those used in English (Unesco. & Library of Congress. National Library Service for the Blind and Physically Handicapped, 1990).

German Contracted Braille

Braille	Print equivalent
]	st
&	ge
%	es
7	er
*	in
u	und
&w%en	gewesen

Braille in Mathematics and Science

Currently, mathematics is written in braille using a system devised by Dr. Abraham Nemeth, who was born in 1918 in New York. Before joining the faculty of University of Detroit's mathematics department in 1955, Dr. Nemeth developed the Nemeth Code for Mathematic and Science Notation, initially for his personal use, in 1952 (American Printing House for the Blind, 2010). Nemeth Code is an efficient and unambiguous way to write chemical formulae and complex mathematical equations in which numbers and letters must appear next to one another, rendering the use of the number sign cumbersome. In Nemeth code, digits are written in the lower four dots of the cell as shown below:

	1	2	3	4	5	6	7	8	9	0
Nemeth code	1	2	3	4	5	6	7	8	9	0
standard braille	#a	#b	#c	#d	#e	#f	#g	#h	#i	#j

Since the numbers now occupy the lower four dots of the cell, new symbols for some punctuation marks must be used. It is also necessary to distinguish opening from closing parentheses. Here is a sampling of symbols for punctuation marks in the context of mathematics and of mathematical operators. Note that several of these consist of two cell combinations:

Braille	symbol
.	decimal point
( )	left and right parentheses
+	plus
-	minus
*k	divided by
@*	multiplied by
.k	equals

The following are examples of formulae written in Nemeth code and their print equivalents:

Nemeth code	Print
4+8 .k 12	4 + 8 = 12
3.14@*(9+1) .k 31.4	3.14*(9+1) = 31.4
7x-20y .k z	7x-20y = z

Braille Music

The system of music notation in braille is quite different from that used in print. Although all of the information in the print score is present, the braille transcription does not use the staff, and the placement of notes on the page does not reflect their relative pitch. The six-dot cell is used to its full advantage and remapped to carry pitch and note duration information. Thus, the symbols bear no relationship to the Roman alphabet. The following is an octave of quarter notes, beginning on *c* and going up to *b*, followed by a group of whole notes also from *c* to *b*. The top four dots of the cell are used to write the pitch and the bottom two (dot *6* for the quarter notes and dots *3* and *6* for the whole notes in this case) denote duration:

```
? : $ ] \ [ w

y z & = ( ! )
```

Although the instrumentalist cannot readily read the music tactually and play at the same time, the system is widely used by blind musicians and teachers of blind musicians and has been recognized as the standard for writing braille music in many countries of the world (Braille Authority of North America, 2010). Other information, such as key signatures, slurs, bowings, rests and dynamics also have braille equivalents and are included in braille scores.

Braille Codes for Languages Which Do Not Use the Roman Alphabet

Languages which do not use the Roman alphabet are still written in cells of six dots in the standard configuration. This means that the same equipment can be used to write any language. As was done for braille music, the same six-dot cell is remapped without reference to what was done to create the Roman alphabet. For example, the first ten letters of the Russian Cyrillic alphabet, with the Roman alphabet and braille equivalents follow:

Cyrillic letter	Roman equivalent	Braille
а	a	a
б	b	b
в	v	w
г	g	g
д	d	d
е	ye	e
ё	yo	*
ж	zh	j
з	z	z
и	i	i

Languages, which do not use an alphabet per se, are still written with the six dot cell. Here is an example of Japanese writing in braille. In Japanese orthography, a single character denotes a whole syllable. (For a more precise discussion of Japanese orthography for print, see: http://www.tiresias.org/research/guidelines/braille_codes/japanese.htm). In Japanese braille, Dots *3*, *5*, and *6* indicate the consonant (if any), which begins the syllable and dots *1*, *2*, and *4* are used to denote the vowel.

Examples of Japanese Braille:

Japanese	English	Braille
あ	a	a
か	ka	*
ら	ra	e
い	i	b
き	ki	<
り	ri	h
う	u	c
く	ku	%
る	ru	d

Note that all this means that the same configuration of dots will mean different things depending on its context. For example, *c* in American braille (dots *1* and *4*) has a number of denotations depending on context:

c in American braille	= c
c in Russian braille	= ts
c in Algerian Arabic braille	= t
c in Korean braille	= n
c in Sinhala braille	= cha
c in Japanese braille	= u
c in music braille	= a slur or tie

Reading Braille

Braille is read tactually by moving the finger horizontally over a line of braille cells. The reading surface is the pad of the finger not the tip thus braille reading is unaffected by calluses developed by players of stringed instruments such as the guitar or violin. Scrubbing, or moving the pad of the finger up and down, is generally considered undesirable. However, the horizontal motion is essential; the pattern of dots is exceedingly difficult to detect, unless the finger is moving. Many would-be braille readers are unnecessarily discouraged by their first unsupervised attempts to perceive braille dots tactually because they simply place an unmoving fingertip squarely on a braille character and fail to get any idea what the shape of the character is. While reading braille one should also avoid having 'heavy hands,' or pressing to too forcefully on the brailled page. It is easiest to read when the hands are lightly touching the braille as they move across (Mangold,1987).

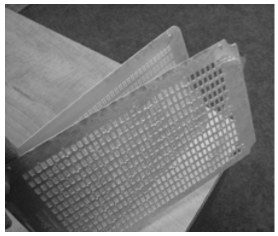
Often the preferred reading finger is the index finger of the nondominant hand, which means that many right-handed braille readers prefer to use the left hand to read (Ford and Walhof, 1999). Ideally, however, both index fingers are trained to perceive braille characters. The fastest reading speeds are attained by adults who learned to read braille as children and can be up to 400 words per minute, (Ford & Walhof, 1999). This speed is achieved with a two-handed reading method (Mangold, 1987). The left hand reads to the middle of a braille line where it is met by the right hand. The right hand reads the rest of the line while the left traces back to the left margin and locates the beginning of the next line (Mangold, 1987). The hands meet again at the middle and the pattern continues. Many people who learn to read braille tactually as adults, blind or sighted, find that even with the two-handed technique, their reading rate plateaus between sixty and ninety words per minute (Bailey, 2003). Higher speeds are achievable but increased effort is required.

Braille dots can, of course, be read visually if the reader has sufficient visual acuity and most sighted teachers of the blind rely on visual reading of braille, failing to master tactile reading entirely. Informal observation indicates that visual reading of braille is always slower than skilled tactile reading.

The literacy rate in braille among blind people who could benefit from braille is between ten and twenty percent and only ten percent of blind children in school are learning braille (National Federation of the Blind, 2010). There is no agreement as to a definitive list of causes for this low and decreasing literacy rate, but some factors include the following: newly blinded adults are often discouraged from learning braille under a false belief that it cannot be mastered after childhood; since approximately 1965, there has been an emphasis on teaching children with some remaining vision to read print, to the exclusion of braille; insufficient number of braille teachers; some teachers of blind children have received inadequate training; many educators do not think braille instruction is even necessary; negative attitudes toward braille; greater reliance on speech output and print-magnification technology; and a rise in the number of blind children with additional disabilities who are nonreaders (National Federation of the Blind, 2009, 2010). Motivation to correct this downward trend is high among blind readers and teachers of blind adults and children. A report by the National Federation of the Blind (2009) indicates that where there is a seventy percent unemployment rate among blind adults, eighty percent of braille readers do have jobs. This is a correlational finding, of course, but the sheer size of the discrepancy is quite notable.

Writing

Braille can be written in a variety of ways including slate and stylus, Perkins brailler or via computer. The slate is a template which is placed above a piece of paper, and a stylus is a moderately sharp awl-like instrument for embossing holes on the paper, guided by the template. (See images below)

stylus	slate	using slate and stylus
		

(National Federation of the Blind)

Since the writer presses down with the stylus to emboss dots in combinations, the resulting braille characters appear on the back of the page. Thus, the person using the slate and stylus writes from right to left, forming each letter in reverse. Heavy-duty paper is used to prevent or at least postpone the time when the braille characters will flatten with wear. The thickness of the paper and thus the pressure needed to emboss each dot, along with the need to make each dot separately are the two factors that slow writing with a slate and stylus. However, a well-trained writer, often using slightly lighter paper, can write quickly enough to keep up with note taking even in a graduate level college course. The slate and stylus were the first means of writing braille and is still used today by braillists who need a way of writing that is as portable as a pencil. Slates are now made from either plastic or metal and come in a variety of sizes and styles. Using a pocket slate, a braillist can write in a standard notebook, although the thinness of notebook paper means that the braille cell will be flattened more quickly and will be more difficult to read. A slate and stylus may also be used to write notes directly on pieces of printed paper (such as files, letters, bills, or other documents) which a blind person may wish to identify later. A slate and stylus can also be used to braille on adhesive labeling tape, which can then be affixed to any number of objects such as labels on appliances, spines of print books or files.

In the later part of the nineteenth century, attempts were made to invent a machine that would emboss braille on paper. In 1892, superintendent of the Illinois School for the Blind, Frank H. Hall, invented a brailler that functioned more like a typewriter than previous models, which remained popular into the twentieth century. The Perkins brailler, designed by David Abraham and Edward J. Waterhouse (Seymour-Ford, 2009), was first produced in 1951. It offered various improvements over previous braillers, including a sturdier design, ability to emboss with a lighter tough from the braillist than needed in previous models, functioned more quietly, and paper could be easily loaded. This Perkins brailler is essentially the same model today (Seymour-Ford, 2009, p. 3) and the Perkins brailler is currently perhaps the most common way of writing braille. The paper in a Perkins brailler is rolled into the machine much as it would be into a typewriter. There are six keys, one corresponding to each position in the cell. The braillist presses these keys together in combinations to form the desired braille character. The embossing head moves across the paper and comes forward as the embossing of each character is complete and the keys are released. There are also buttons on the brailler to advance the paper by one line, to backspace the writing head and to place a space between words.

Newer braillers are now available including, the electric brailler which is the same kind of machine, but requires a lighter touch to operate, a light-touch brailler which requires less finger pressure, a unimanual brailler for those able to use only one hand, and a large cell brailler for those with tactile problems (Seymour-Ford, 2009).

Braille and Computers

Braille printers can be hooked to computers to emboss braille rapidly. Some braille printers are able to print up to 850 sheets per hour (Abledata, 2004). Fanfold braille paper can be used with these printers. Generally, these printers are quite loud and are often housed in sound-dampening enclosures.

The equivalent to the visual display on a computer is the refreshable braille display. First available commercially in the United States in 1982 (Gerven & Taylor, 2009), this is a strip of braille cells with thin rods or pins available in all six positions of each cell. Pins are raised and lowered in combinations so that contents of the screen can be read. Adaptive software connects the refreshable braille display to the computer and helps the user determine what all is being represented on the screen.

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