Japanese Braille

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Braille is perhaps the only area of Japanese linguistic life in which serious attention was paid to the problem of word and phrase delimiters before the advent of computers. Japanese orthography does not use spaces in the Western manner, but braille texts must if they are to be intelligible. The first part of this paper describes the fundamentals of Japanese braille, and outlines the spacing rules now in general use. Unlike English braille—in which cells correspond to letters of the alphabet, puctuation marks, or special contracted forms—Japanese braille cells are associated with elements of the syllabic script called kana. This leaves no room for contractions, although it does result in some savings in space. Are these savings superior to what could be achieved in a roman-based Japanese braille system? The second part of this paper answers that question in the negative.

This paper has two purposes: to provide a brief description of the Japanese braille writing system *(tenji)*; and to point out the relevance of Japanese braille for the computer treatment of the Japanese language. In particular, braille is one of the very few areas of Japanese linguistic life in which the problem of word spacing *(wakachigaki)* has received serious attention. Also, the Japanese approach to braille transcription raises some interesting questions about the compressibility of Japanese texts.

Krebs (1974:1) defines braille succinctly as "a system of touch reading for the blind which utilizes a cell of 6 dots, three high and two wide, from which 63 different characters can be formed by placing one or more dots in specific positions or combinations within the cell. Each dot within the cell is designated by a position number. Dots 1 & 4 form the top pair, dots 2 & 5 the middle pair, and dots 3 & 6 the bottom pair. The embossed dots . . . are numbered 1-2-3 on the left and 4-5-6 on the right."[1] The following paragraph from Loomis 1936:14 adds some historical perspective:

> Before the adoption of Braille, there were countless systems invented for the use of the blind. These various systems represented to a large extent the work and ideas of sighted people. For many years everyone thought that the raised alphabet should bear a resemblance to our alphabet. Boston Line Letter represents this idea. New York Point and American Braille were both point systems and were based on frequency of occurrence, the letters most commonly

Visible Language, XVIII 3 (Summer 1984), pp. 254-266.
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> used having the fewest number of dots. To a sighted person it seemed a very good and sensible idea. But time and experience proved that the signs containing the least number of dots were not the signs most easily recognized by the blind reader, so frequency of occurrence was abandoned. Of all the systems devised in the years gone by, and there were many of them, only two remain in use today. One is Braille, which is used in all countries, and our own Braille alphabet is to-day the same as Louis Braille devised it in 1829. The other system is Moon, which is read largely by the foreign born and those who lose their sight late in life and cannot master the complicated Braille system. These two systems alone survive, and it is most significant that both these systems were devised by blind men.

To bring this statement up to date, we should note that Moon script is no longer in active use, and that the alphabet of Louis Braille (1809-1852) differed slightly from the one in use today. The original alphabet omitted 'w' since it was not used in French at that time (Krebs 1974:2). More importantly, accented letters, diacritics, non-roman alphabets (e.g., Cyrillic, Greek, Hebrew), and non-standard punctuation (e.g., Spanish inverted interrogation and exclamation points) require special treatment (see Krebs 1974:102-112 [Appendix B]); but they are all built on the original foundation laid by Braille. By contrast, the Japanese braille system, created in 1890 by Ishikawa Kuraji (1859-1945), is radically different from the roman-based braille system of the West.[2] (Special extended codes for music and mathematics [e.g., Nemeth code] have been devised, but are beyond the scope of this paper.)

Braille—unlike, for example, Gregg shorthand—is a transliterative system.[3] Although, as we shall see, it includes many non-alphabetic symbols, English braille does not attempt to treat the language phonemically. Ishikawa's braille, on the other hand, is based on the so-called 50 syllables (*gojūon*) which form the basis of kana orthography. In that sense, Ishikawa's system is also transliterative; but the connection between the structure of the kana writing system and the morphophonemics of the Japanese language is much closer and deeper than the connection between the roman alphabet and the sound system of English, as any Japanese who has had to struggle with English spelling can testify.

Because all forms of braille are transliterative, special care must be taken to keep the physical length of texts within reasonable limits. Experienced braille transcribers of English have told me that a normal page of ink-print prose is roughly equivalent to three braille-print pages. In order to keep transcribed texts short, a system of 189 contractions, word signs, and short-form words has been developed to supplement letter-by-letter transcription.[4] According to Krebs (1974:2),

> Through the use of contractions, the finger in coursing across one full line of writing, encounters almost twice the number of words as would be present if full spelling were employed. For example, the sentence 'You have more knowledge.' requires but 9 spaces when contracted, rather than 25 spaces when uncontracted. Due to the advantages derived from the use of contractions, the 'average' braille reader can attain a speed in reading to himself equal to that of a person with sight when reading aloud.

This system of contractions is possible in part because the 26 letters of the alphabet leave 38 cells (including space, ' ') available for other functions. Thus 3-4-5-6 serves as a number sign, allowing the cells for the letters 'a', 'b', . . . 'j' to double for the digits '1', '2', . . . '0'. The same cell (3-4-5-6) also represents the sequence 'ble' when not initial in a word. This illustrates the principle of using mutually exclusive environments (complementary distribution) to distinguish among symbolic functions and thereby increase the power of the system of contractions. Another example is the cell 1-5-6, which stands for the common English digraph 'wh' when part of a word; the word 'which' when in isolation; 'where' when preceded by a dot 5 cell; and 'whose' when preceded by a dot 4-5 cell. Similarly, dot 2-3 is the whole-word contraction for 'be', the digraph 'bb' when word-medial, and ';' when word final. In order to prevent confusion and guarantee consistency when hyphenating, there are numerous rules concerning preferences among contractions when conflicts occur, omission of spaces in certain phrases, and so forth.

In Japanese, since almost all the cells are required from the start for the kana and their associated diacritics, such contractions are impossible. In English, there are many frequently occurring words of more than one or two letters: representing these high-frequency words with a one- or two-cell abbreviation results in a reliable rate of compression because the highest frequency words in any language will show up at roughly the same rate, on average, in any text regardless of content. (Actually, the English contractions deviate from this principle slightly. The word 'blind', for instance, has a contraction, presumably because it is very common in texts for the blind.) Japanese is compressed more homogeneously: each braille cell corresponds to a kana and hence (usually) to more than one phoneme or roman letter. Figures 1 and 2 graphically demonstrate this difference between Japanese and English braille. Another way to describe the situation is to say that in English braille the basic cells are relatively more redundant than in Japanese braille. Such formal redundancy can be seen as a desirable property of individual cells with respect to the rest—desirable because it lessens the chances of misspelling or misreading. In Japanese braille this redundancy is exchanged for overall compression, a desirable global property of texts.[5] An interesting theoretical question is

Figure 1. Letter assignments in English Braille.

Dots	none	4	5	4-5	6	4-6	5-6	4-5-6
none	b̸							
1	a	c	e	d				
2		i		j				
1-2	b	f	h	g				
3								w
1-3	k	m	o	n	u	x	z	y
2-3		s		t				
1-2-3	l	p	r	q	v			

Figure 2. Kana assignments in Japanese braille.

Dots	none	4	5	4-5	6	4-6	5-6	4-5-6
none	b̸	-y-	"	"-y-	P	P-y-		*
1	a	u	ra	ru	ka	ku	sa	su
2	Q	o	:	ro	-w-	ko	"-w-	so
1-2	i	e	ri	re	ki	ke	si	se
3	wa	ya	wo	yo		yu	N	
1-3	na	mu	ta	tu	ha	hu	ma	mu
2-3	wi	no	we	to		ho		mo
1-2-3	ni	ne	ti	te	hi	he	mi	me

Legend

b̸ space

-y- *yōon*; inserts -y- in following syllable. Before 'te', indicates innovative pronunciation [ti]

" *dakuten*; changes k-to g-, s- to z- &c.

P *handakuten*; changes h- to p-. Before 'te', indicates innovative pronunciation [tyu]

* before 'te', indicates innovative pronunciation [dyu]

Q *sokuon*; doubles following k-, s-, t- &c.

: *chōon*; indicates vowel lengthening

-w- *yōon*; inserts -w- in following syllable. Before 'to', indicates innovative pronunciation [tu]; before 'ha','hi' & c., indicates [fa], [fi] & c.; before 'ta', 'ti' & c., indicates [tsa], [tsi] & c.

N *hatsuon*; syllabic nasal

N.B. *dakuten* and *handakuten* can be combined with *yōon*; dots 2-5-6 ("-w-) before 'wa', 'wi', 'u', 'we', 'wo' indicate the innovative syllables [va], [vi], [vu], [ve], [vo].

whether the Japanese alternative to contractions, which capitalizes on the phonological structure of the Japanese language at the cost of drastically reducing the redundancies among the different basic cell shapes, is in some sense optimal. More concretely, how would it compare with a braille system based on romanized rather than all-kana strings?

There is a second reason why a system of contractions for Japanese would, at present, be impossible to implement. In Japanese orthography there is no tradition of using spaces to separate words. The Grade 2 braille contractions are made possible to a large extent because the same signs can serve different functions in different positional contexts. Without spaces in Japanese texts, this strategy could not be applied. As a matter of fact, Japanese braille does use spaces to separate words; as remarked at the beginning of this paper, this is perhaps its most interesting feature for those in fields unrelated to the problems of the blind. The task of teaching Japanese Braillists to space properly occupies a position comparable to the problem of teaching U.S. braillists to use the contractions correctly. Of course, this complicates the question of optimal compression for Japanese texts since some sort of spacing is evidently necessary: surely Japanese braillists would not bother with spaces at all if blind Japanese readers could do without them.

The primary purpose of the small dictionary NMFK 1982 is to clarify the proper use of spaces in braille transcription, although it also discusses other aspects of Japanese braille usage. In standard orthography or *kanji kanamajiribun*, in which semantically pregnant morphemes are generally written with Chinese characters (kanji) while inflectional endings, particles, and other high-frequency low-content morphemes are written in kana, there is little if any need for the visual reinforcement of word separators; but in braille, such separators become crucial. All-kana text written without spaces is called *betagaki* to distinguish it from *wakachigaki (wakatsu* 'to separate, split'). Because of a lack of unanimity among Japanese experts as to the proper unit for analyzing sentences, and because there is room for disagreement when different people try to apply the same method of analysis, the parsing of *betagaki* strings has become an outstanding problem of Japanese computer research. According to Yoshida and Tanaka (1981:9), there are five different ways in which all-kana text can be input on computers:

1a. betagaki hōshiki—no spaces.
2a. kanjibu shitei hōshiki—parentheses surrounding those substrings which are to be converted into kanji.
3a. bunsetsu wakachigaki—spaces separating syntactically defined phrases.

4a. jiritsugo/fuzokugo wakachigaki—spaces separating so-called 'independent' and 'dependent' words.

5a. tango wakachigaki—spaces separating all lexical items.

As an example, they write the sentence "There are some remarkable things in technological development" in five different ways which are reproduced here in romanized transliteration:[6]

1b. gizyutunohattennihamezamasiimonogaaru.

2b. (gizyutu)no(hatten)niha(meza)masiimonogaaru.

3b. gizyutuno hattenniha mezamasii monoga aru.

4b. gizyutu no hatten niha mezamasii mono ga aru.

5b. gizyutu no hatten ni ha mezamasii mono ga aru.

Where does the *wakachigaki* of Japanese braille practice fall on this spectrum of all-kana input techinques? The following translation of the *wakachigaki* rules in NMFK 1982:18-20, supplemented by references to the examples in TTB 1981:36-47, provides the basis for an assessment:

1.1 Break before independent words *(jiritsugo).* [Rule 1.5 makes it clear that this means all words other than particles *(joshi)* and inflecting suffixes *(jodōshi).* The example *Hananoyōni kireidatta* 'It was as pretty as a flower' in TTB 1981:35 shows that *yōni* and *datta* are considered *jodōshi.*]

1.2 As a rule, break before formal nouns (*keishiki meishi*) except when they serve as components of compounds or affixes. [*Keishiki meishi* refers to nouns such as *koto* 'thing' when used with a weak sense as the heads of noun phrases. According to this rule, one should write *kau kotoga dekiru* 'can buy' but *kaimono* 'shopping', not **kai mono*. TTB 1981:36 calls attention to the fact that the same phrase can be treated differently depending on context; e.g., *sono ue* is correct when the meaning is literally 'its top', but *sonoue* 'moreover' should not have a space.]

1.3 Even in cases in which a formal noun gives rise to a sound change, break before it; however, if the final sound of the preceding word is altered, the break is optional. [E.g., following TTB 1981:37, *donna monda* < *donna monoda* 'What sort of thing is it?', not **donnamonda,* but either *antoki* or *an toki* < *ano toki* 'that time'.]

1.4 Break before auxiliary (*hojo*) verbs and adjectives since they are independent words. But if part of an auxiliary verb or adjective is contracted with the end of the preceding word, run them together. [Thus, *itte iru* 'has gone' shortens to *itteru,* not **itte ru.*]

1.5 Run dependent words together with independent and other dependent words. [Dependent words (*fuzokugo*) are particles *(joshi)* and inflecting suffixes *(jodōshi*). Besides *jiritsugo* and *fuzokugo,* there is a small class of words called *setsuji* or 'affixes'; hence the "other".]

1.6 [But] break before particles and inflecting suffixes which immediately follow roman letters or foreign-language quote signs. [E.g., from TTB: 1981:35, *CM dattamitai* 'It seems that it was a CM (= Commercial Message)', not **CMdattamitai.*]

1.7 Break before dependent words that follow commas even when not transcribing commas. [A later rule of punctuation on NMFK 1982:21 says, "When using commas in the middle of sentences, make no break before the comma and take one space after it. When, however, commas are used in ink-print in lieu of *wakachigaki,* to break up multidigit numbers or in a similar manner, ignore them."]

2.1 Do not break up short compounds that have become single lexical items. [E.g., TTB 1981:40, *otokonoko* 'boy', not **otokono ko,* literally 'male child'.]

2.2 As a rule, when compounds are enlarged with prefixes or suffixes, do not break them up; however, divide the compound if the meanings of the constituents are independent and the pronunciation allows. [E.g., according to TTB 1981:41, *hankakumei* 'counterrevolution', not **han kakumei,* but *han shakaiteki* 'antisocial'. Apparently, the presence of an accent-phrase juncture in normal speech plays a role here since in both cases the *han* 'anti-' is the same prefix.]

2.3 As a rule, break up long compounds if there are two or more parts which can be taken as having independent meanings. [E.g., TTB 1981:41, *Nihonkoku kenpō* 'the Japanese constitution'.]

2.4 Even if a compound is composed of words which could [otherwise] be independent, do not divide it if doing so results in the loss of the original meaning. [E.g., TTB 1981:42, *keizaigakusha* 'economist', not **keizai gakusha,* literally 'economy' + 'scholar'.]

2.5 Even if a compound is composed of two words which could [otherwise] be independent, do not divide it if the initial consonant of the second word has been voiced. [E.g., *udedokei* 'wristwatch' < *ude* 'arm' + *tokei* 'clock'.]

2.6 Words written with three or more kanji in which the kanji are all on a par with one another should either be written all together or divided character by character depending on the pronunciation and meaning. In four-character compounds, when the first and second pairs could be independent words, one may break between the second and third characters. [Thus, TTB 1981:42 shows *shunkashūtō* 'spring/summer/autumn/winter', the Sino-Japanese pronunciation for the four-character compound indicating the four seasons, but *haru natsu aki fuyu,* the Japanese rendition of the same four-character compound. On the other hand, *tōzai nanboku* 'east/west/south/north', the four directions, has only one space since *tōzai* and *nanboku* are compounds in their own right.]

2.7 Run together compound names used in botany, zoology, and other sciences in which the compounding is strong, or insert hypens between the constituent parts.

2.8 Break between numbers and their units. [In Japanese, this includes two important cases besides the '10 meters' sort of phrase common in English. One is *san gatu* 'March' (literally, 'Month 3'), *jūku niti* 'the 19th' (literally, 'Day 19') and other dates, including names of years; the other is 'numeral-plus-counter' constructions such as *yon mai* 'four sheets (of paper etc.)', *ni hai* 'two cups (of coffee, etc.)'.]

2.9 In the case of compound verbs formed by a four-or-more character compound plus *suru*, break before the *suru* if you put breaks in the body of the compound.

2.10 Conjunctions and compound adverbs are, as a rule, undivided; but they may be divided where there are breaks in pronunciation.

2.11 Do not divide reduplicated words of up to four syllables. For six syllables or more, divide the word unless this results in a change of meaning. [This appears to be overly cautious; it is hard to think of a reduplicated word of six or more syllables which would change in meaning even if broken.]

3.1 Divide surnames from personal names. [E.g., *Tanaka Tarō*.] Chinese and Korean names of three or fewer kanji may, however, be run together. [E.g., *Mōtakutō* 'Mao Zedong'.] And in other foreign names, hyphens may be inserted as necessary.

3.2 Divide titles following names if they could be independent words; otherwise, run the name and title together or insert a hyphen. [E.g., *Yamada sensei* 'Professor Yamada' but *Homeinishi* 'Ayatollah Komeini'.] But to make it easier to recognize surnames, break before the [common] suffixes *san, sama, kun, dono, shi,* and *uji.*

3.3 Run together nicknames, affectionate names, etc.

3.4 Run together titles when they are attached to common nouns.

3.5 Break between prefecture and city, etc., in place names; but between place names and their designations, use a hyphen or make no break. [E.g., *Tōkyōto* or *Tōkyō-to* 'metropolitan Tokyo', not **Tōkyō to;* but *Tōkyōto Fuchūshi* 'Tokyo metropolitan area, Fuchu City'.]

3.6 Run together the old names for the provinces. [E.g., *Yamatonokuni* 'Yamato province' which, were it not for this rule, would be *Yamatono kuni* 'province of Yamato'.]

3.7 Names of rivers ending in *-kawa* ['river'], and of mountains ending in *-san* or *-yama* should be divided if longer than two characters; otherwise, they should be run together. [Presumably, in view of 2.5, this rule does not apply to names such as *Shinagawa* or *Hieizan*; however, the use of kanji in the text leaves some room for doubt.]

3.8 Names of countries, products, groups, corporations, etc., should be divided where the meaning permits.

4.1 Division of classical Japanese should conform to modern usage.

4.2 Division of dialects should conform to the standard usage.

Although the word *bunsetsu* 'syntactic phrase' does not occur anywhere in these rules, their net effect is to prescribe a system of *bunsetsu wakachigaki*.[7] Significantly, certain extra breaks are called for even when the *bunsetsu* criterion does not require them. A similar though more complex set of rules for word divisions has been adopted for bibliographic purposes outside Japan (Library of Congress 1982), suggesting that these extra breaks are desirable for reasons which go beyond the immediate exigencies of braille. At any rate, when considering the question of text compression, we can assume that the rules for Japanese braille spacing are also suitable for spacing romanized Japanese texts as well.[8]

What, in fact, is the compression achieved in Japanese braille by using a kana-based system rather than a roman-based system? To answer this question, we can use the statistics reported in Hayashi et al. 1982:319. This is a synopsis of a 1960 study of Japanese digrams (two-kana sequences) based on 40,000 kana of running text culled from a wide variety of popular and professional literature. The units for this survey were 102 syllables of following types: the Q and N syllables (*sokuon* and *hatsuon*) shown in Figure 2; 33 syllables with intrasyllabic glides *(yōon*, e.g., 'hya', 'byu', 'pyo'); 5 syllables with initial /p/ (*handakuon*, e.g., 'pa'); 18 syllables with voiced obstruent initials (*dakuon*, e.g., 'ba'); and 44 other syllables (*seion*, e.g., 'ha', 'ya', 'a').[9] Syllables of the type 'bya' and 'pya' are counted as *yōon*, not *dakuon* or *handakuon*. In Japanese braille, there are an additional three *seion* ('wi', 'we', 'wo'), two *dakuon* ('di', 'du'), and three *yōon* ('dya', 'dyu', 'dyo'). Except for 'wo', which is used exclusively to write the accusative marker, these and the 'innovative' syllables found in some recent foreign loanwords occur very seldom. In the survey, long /a/, /i/, /u/, and /e/ are counted as double vowels; long /o/ is treated as 'o' + 'u'. The braille rules for long vowels are different, but always call for one cell (sometimes a 'long mark', sometimes the single-vowel syllable corresponding to the vowel of the preceding). Also, the postpositional particles pronounced /wa/ and /e/ but written with the kana for 'ha' and 'he' respectively are counted in the survey and written in Japanese braille as they are pronounced. Thus, the reported frequencies of syllables in the survey can be assumed to reflect the frequencies of syllables in transcribed Japanese braille texts.

By using the graph in Hayashi 1982 it is easy to calculate that for every thousand syllables of running Japanese text, 250 will be expressible with one letter in romanization, 718 with two letters, and the remaining 32 with three letters.[10] Thus, 1,782 letters will on average be needed to transcribe 1,000 syllables. On the other hand, 142 of every thousand syllables will require two Japanese braille cells; the remaining 858 will require only one.[11] Therefore, 1,142 braille cells on average will suffice to transcribe the same text.[12] Thus the compression ratio of roman over kana is 1.560. If, instead of comparing roman with kana, we were to compare it with a hypothetical roman-based braille that makes use of contractions, what would be the result?

Let's assume that contractions can be formulated for Japanese which are at least as efficient as the Grade 2 English contractions at reducing sentence length. Even if Krebs' estimate of "almost twice the number of words" is interpreted conservatively, this would still be better than the current kana-based system. Of course, it is one thing to *assume* that such a set of contractions exist for Japanese and quite another to produce it. On the other hand, since Japanese syntax is agglutinative, the same strings of syllables occur over and over at the ends of phrases and clauses; a set of Japanese contractions might actually be more efficient at shortening texts than the English contractions. A rough calculation using KKK 1970:281ff., a table of word frequencies in newspapers based on extensive random sampling, supports this view. The definition of 'word' in the context of KKK 1970 is closer to the linguistic concept of morpheme than to the 'word' defined by the rules of Japanese braille spacing; but for our purposes, these differences can be ignored. If the first N most frequently occurring words of Japanese were, in a roman-based Japanese braille, replaced by single-cell contractions, how would this affect the ratio of cells to syllables? KKK gives the cumulative number of the N most frequent words per mil (i.e., per thousand); the average number of syllables per word is just over two (Yoshida & Tanaka 1981:318). Thus every high-frequency word replaced by a contraction removes two syllables and adds a single cell; the number of cells per thousand syllables, C, can be calculated from the cumulative number of high-frequency words per mil, w, for the first N words in the list with the formula $C = 1782\ (1 - 2w/1000) + w$, which makes use of our earlier finding that 1,782 cells would be needed on average to transcribe a thousand syllables without contractions. Sample results follow:

N	W	C
100	343.815	900.46
125	359.669	859.81
150	372.393	827.18

Grade 2 braille has about 190 contractions, but, of course, many of these are two cells long; in this respect, our C are too low. On the other hand, our calculation excludes all those strings of two or more syllables within lower frequency words that would also be contracted; in this respect, the C are too high. These two effects tend to cancel each other out. Clearly, our hypothetical roman-based Japanese braille with contractions would outperform the current kana-based system. Of course, there are many cultural, practical, and historical factors which favor the continuation of the current Japanese braille system. But, interestingly, compression efficiency does not seem to be one of them. Kana are, at least in this respect, not optimal.

1.Those familiar with computers may find it convenient to think of dots 1 through 3 and 4 through 6 as the three bits of an octal digit; thus each braille cell is a six-bit byte with a value in the range o00 to o77 (i.e., 0 to 63). E.g., 'm' (dots 1-3-4) is o51 (= 41); 'j' (dots 2-4-5) is o23 (= 19); cf. Figure 1. This is one way to number the cells so that they can be ordered.

2. The Kokugogaku jiten (1955) does not say whether Ishikawa himself was blind, but the outline of his career suggests that he was not. (Incidentally, the biography of Ishikawa and other 'short entries' [*shōkō*] have been omitted from the new [1982] edition of the Kokugogaku jiten.)

3. In discussing the problems that arose in unifying British and American Grade 2 braille in the '30's, due largely to American disapproval of the British practice of contracting sequences of letters even if they crossed syllable boundaries, Loomis (1936:6) comments that, "In the effort to protect the reader from anything that might be considered illiterate or confusing, one thing was always permitted and never questioned: *the use of the contraction irrespective of its sound or pronunciation.*" The emphasis is Loomis's. For our purposes, however, the interesting part is what comes before the colon. Statements like this tend to suggest that braille is transliterative rather than phonological as a result of preconceptions held by sighted educators; but this is probably not the case. Although the principles of phonology were not clearly articulated in the early 19th century, when the words 'letter' and 'sound' were often used interchangeably, the fact remains that, in French, rules of *liaison* and *enchaînement* would have made a strictly phonemic treatment quite difficult; and, in view of dialectal and personal variations, it is obviously much easier to train transcribers to transliterate according to a fixed standard than to phonemicize (consider, for example, English words like 'either'). Finally, one must take the social and historical setting into account: Braille's object was to put the blind on as nearly an equal footing with the sighted as possible. The major obstacle to be overcome was, as Loomis points out, resistance to the idea of characters that bore no visual relationship to the shapes of the letters of the alphabet.

4. Grade 2, with 189 contractions and short-form words, is now standard in the English-speaking world. Grade 1 is simply uncontracted (straight transliterative) braille. A Grade 1½ was standard in the U.S. before the compromise discussed by Loomis: it used only 44 contractions, and avoided contractions across syllable

boundaries. Grade 3 "is an extension of Grade 2, by using additional contractions and short-form words, and by the use of the outlining (the omission of vowels). Grade 3 contains more than 500 contracted forms and is used mainly by individuals for their personal convenience" Krebs 1974:109). Krebs also mentions braille shorthand "for use by blind stenographers."

5. Considerations of this kind obviously played some role in Braille's original formulation of signs for the letters of the alphabet. Only one letter, 'a', is represented by a one-dot cell, viz. dot 1. Presumably, this is because it is relatively difficult to sense the relative location of a single dot within its frame of reference unless one can depend on certain kinds of cells being adjacent to provide supporting context. Likewise, it is obviously difficult to sense the difference between a l & 3 and a 4 & 6 when flanked by spaces. Thus, not all cells are equal: the whole theoretical range of 64 distinct cells cannot in practice be used with complete freedom. (This seems to be what Loomis has in mind when she criticizes those systems in which high-frequency letters were associated with those cells which contain the fewest dots.)

6. I have altered examples 3b through 5b since the sentences given in Tanaka & Yoshida do not conform to the standard definitions and might be misprints.

7. This point is made explicitly in TTB 1981:34. Another (but less detailed) presentation of the *wakachigaki* rules is to be found in Honma et al. 1983:64-68. Apparently, there are some differences among the various agencies that serve the blind in Japan, particularly between Kantō (Eastern) and Kansai (Western) organizations.

8. Honma et al. (1983:91f). do not mention automated transformation of *betagaki* into *wakachigaki* in their brief discussion of computer-aided braille printing. I have seen brochures for U.S. computer systems designed to carry out the analogous task of transforming standard English input into Grade 2 braille (i.e., with the correct contractions). These systems are reported to be quite expensive for this age of cheap personal computers (in the $20,000 range), but this is no doubt due to low demand, not the complexity of software. In Japan, on the other hand, it would seem that the problem is finding a program that works at all.

9. I am using the word 'syllable' as an equivalent for the Japanese term *onsetsu*, which is sometimes translated as 'mora' in linguistic studies.

10. The 250 single-letter syllables are the five *agyō* 'single vowel' syllables (180), *sokuon* 'Q' (23), and *hatsuon* 'N' (47); the 32 trigrams are the *yōon*.

11. The 142 two-cell syllables are *dakuon* (107), five *handakuon* (3), and the *yōon* (32).

12. Notice that even kana-oriented braille requires more cells than actual syllables; this is due to the way in which *dakuon, handakuon* and *yoōn* syllables are handled.

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