INVESTIGATIVE REPORT

Approach to teaching adventitiously blinded persons with difficulty in reading braille: Comparison of the degree of ease in reading between braille characters of two sizes

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Abstract: Many of those who become visually impaired after learning normal characters (hereafter, adventitiously blinded persons) can write Braille characters with comparative ease, but have difficulty in reading Braille by touch. The purpose of this study is to clarify the effect of the size of Braille characters on learning during the initial training of Braille reading for adventitiously blinded persons. In the first study, using two types of Braille character with different cell spacings (intervals between Braille characters), we compared the reading speed, the number of misreadings, and the readability between sighted persons inexperienced in Braille reading and Braille users proficient in reading, to examine the effect of cell spacing on Braille reading. In the second study, sighted persons inexperienced in Braille reading were divided into two groups, and Braille characters of different sizes, including dot size (hereafter, normal size and large size), were presented in a different reading order, to compare their reading speed, number of misreadings, and readability. Thus, the effect of providing training materials with large Braille characters on reading training was examined. The results of these two studies revealed that the use of Braille with wide cell spacing and large Braille characters is an effective method for the initial training of Braille reading for adventitiously blinded persons with difficulty in reading.

Key Words: Adventitiously blinded persons, Initial training of Braille reading, Braille size, Braille reading

I. Background

1. Current status of Braille reading for adventitiously blinded persons

Braille, which is an alphabet of characters that people with visual impairments can read and write by themselves, is still insufficiently used, but certainly spreading in our society. For example, the following are available: Braille ballots for elections, bar, civil-service, and university entrance examinations in Braille, and Braille instructions on ticket-vending machines in stations, automatic teller machines at banks and post offices, the handrails of stairs, and in elevators. Thus, Braille is frequently seen in our society. Because we are now living in an information society where obtaining information is becoming a necessity, Braille is an important means of obtaining information for people with visual impairments.

On the basis of the “survey on actual conditions of disabled children and persons” (2001)[3] conducted by the Department of Health and Welfare for Persons with Disabilities, the Social Welfare and War Victims’ Relief Bureau of the Ministry of Health, Labor and Welfare, the number of people with visual impairments aged 18 years or older is estimated to be 301,000, and the number of such people under 18 is estimated to be 4,800. Focusing on the level of impairment, out of the total 305,800 people with visual impairments, 107,200 people are diagnosed as having the severest first-grade level of impairment, and approximately 30,000 of these people use Braille for reading and writing in their daily lives. Moreover, the statistics on the causes of impairments and the ages of onset of impairment reveal that many visual impairments are due to adventitious causes.

For those who have relied on vision to obtain information, it is very difficult to replace vision with touch as the main sense. Kan (1988) conducted an 8-year study on the state of Braille reading for 197 adventitiously blinded persons learning massage, acupuncture, and moxibustion at rehabilitation and relief centers.[1] In his study, the relationship between the number of characters a person can read in one minute and the years of using Braille was as follows. People in their twenties can read 100 characters by touch per minute, and people in their thirties, 85 characters per minute, after learning Braille reading for two and a half years. However, it takes four and a half years for people in their forties to acquire the ability to read 85 characters in one minute. For people in their fifties, it takes three and a half years to acquire the ability to read 60 characters per minute. Thus, the older people become, the longer it takes them to acquire the ability to read Braille. Moreover, in a comparison of the reading ability of adventitiously blinded persons with that of nonsighted children, the reading speed of the former in their twenties was equivalent to that of the latter in fourth grade. Although these results are natural considering functional decline with age, it may cause intense frustration to adventitiously blinded persons who had relied mainly on vision to collect information.

Even in schools for the blind, few adventitiously blinded students have already acquired the Braille literacy required for school lessons before enrolling in physiotherapy or other classes. Because coursework starts immediately after enrolling in the school for the blind, a certain level of Braille literacy is required. However, no sufficient time is spared for Braille training, leaving no other choice but to carry out Braille training in parallel with the coursework. We are currently struggling with this situation.

If adventitiously blinded persons feel reading Braille by touch is difficult, their motivation concerning coursework and the active gathering of information will decline. Moreover, in association with the nonacceptance of impairment, some people may develop a strong aversion to Braille. It is necessary to develop training programs and materials that can increase their motivation towards learning Braille reading or enable the effective acquisition of the Braille reading ability while maintaining high motivation.

2. Training methods and materials

Braille training for adventitiously blinded persons, and particularly the training method for improving reading by touch efficiency, differ depending on the school for the blind or the rehabilitation center and Braille library where the Braille training is carried out. In addition, there are few training materials. Braille training is still on the level of trial and error.

Nakamura (1993) reported that the Braille written using the Perkins Brailler (Fig. 1) is more effective for the initial training of Braille reading than that written using Braille kits because of the wide dot spacing (1-4 dot spacing) and wide cell spacing (4-1 dot spacing).[6] Figure 2 shows the structure of Braille characters, including the dot spacing and cell spacing.

FIGURE 1 Perkins Brailler

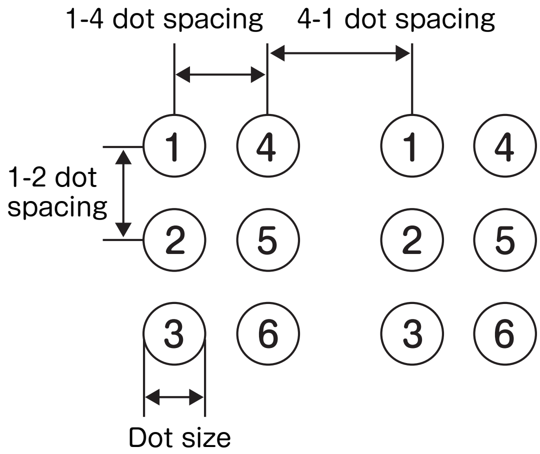


FIGURE 2 Structure of Braille

Furthermore, Kan (1988) proposed the use of a text in which a blank cell is inserted between characters during initial training.[1] In the “Manual for Braille Learning” (1995) by the Ministry of Education (from 2001, Ministry of Education, Culture, Sports, Science and Technology), the following statements are made. “For blind children and students experiencing difficulty in reading Braille, it is effective to make a Braille text with a slightly widened cell spacing to practice Braille. Then, the cell spacing should be gradually narrowed so that they can gradually become accustomed to normal Braille.”[5] Kuroda et al. (1995) considered that the readability of Braille characters by those who have not acquired proficient Braille literacy and those who have a limited tactile function can be improved by changing character size, cell spacing, and line spacing.[4] They examined the effect of cell spacing and line spacing on the reading efficiency of subjects with different degrees of Braille literacy. Subjects who had not acquired a proficient Braille reading ability said that Braille with a wider cell spacing and a wider line spacing was more readable. However, the number of subjects was only three; therefore, to increase the reliability of the results, it will be necessary to carry out such an analysis with a greater number of subjects.

The size of Braille characters differs among countries, and even within a country. It also differs depending on the type of Braille kit, including those of Braille publishers and Braille printers. In Europe and the United States, to facilitate Braille reading for adventitiously blinded persons, a large-sized Braille called giant-dot Braille has been developed, although the achievable size is limited. In Japan, there is only a slight difference in size between Braille printers and Braille writers of various manufacturers, and it is impossible to freely change the dot size, line spacing, and cell spacing. However, printers supporting dot figure printing and those supporting Braille of a size slightly larger than the conventional size have recently been developed, providing a wider selection range than before, although the choices of printable character sizes are still limited.

Is it better then to enlarge the Braille size without limit? The answer, naturally, is no. There are various related factors, including the difference in the tactile ability of

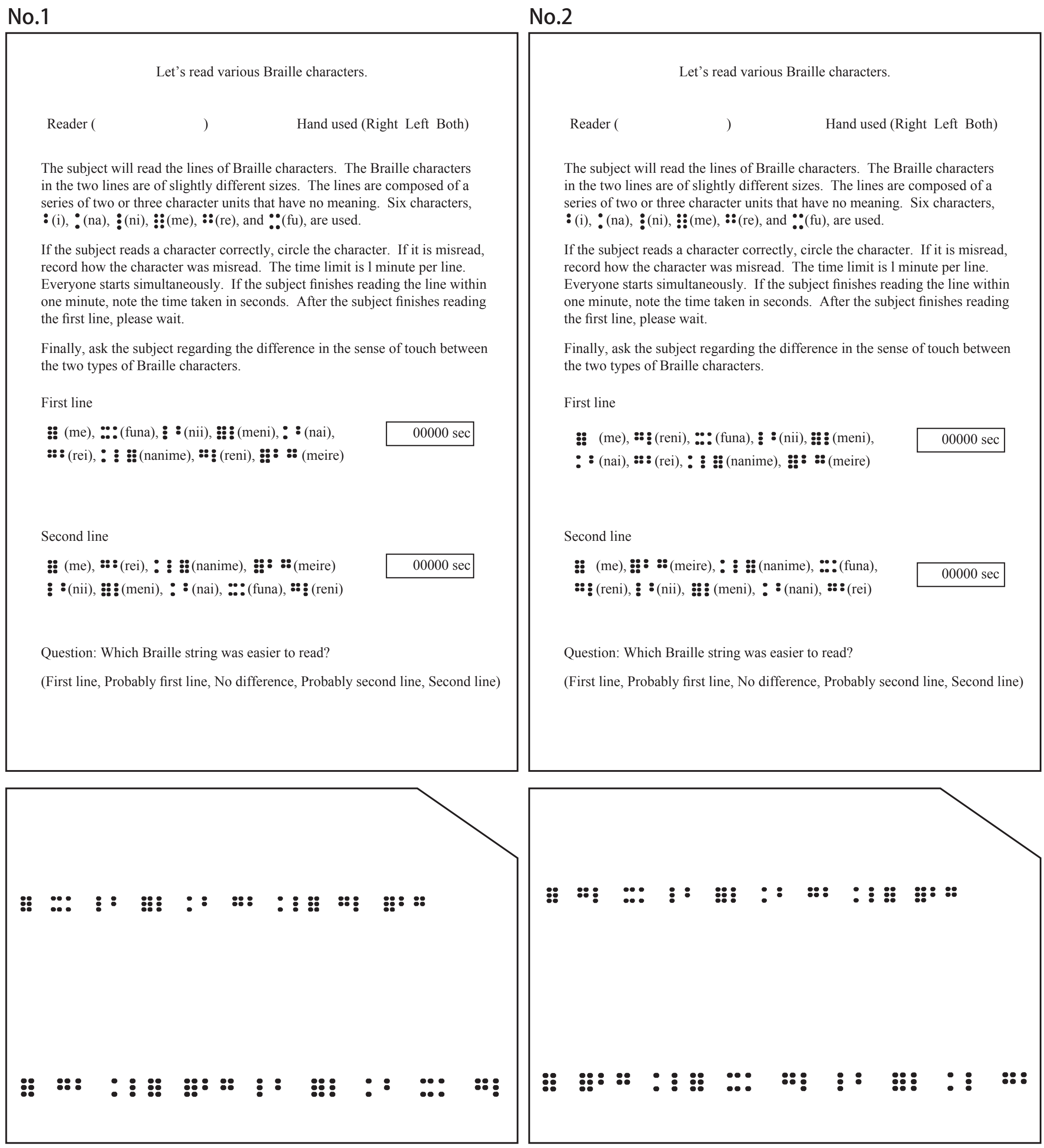


FIGURE 3 Data forms and Braille cards (Study 1)

individuals to discriminate two adjacent dots, the ratio of cell spacing to dot spacing, "reading experience," and the relationship between size and reading speed. For example, Braille with too wide a cell spacing is difficult to read. When a character is expressed using two cells, such as syllables with a voiced consonant and contracted sounds, which is a characteristic of the representation of a Japanese character in Braille, a cell followed by too wide a spacing makes it difficult to detect the second cell and practicality is lost. In addition, even if optimal Braille sizes could be specified for the conditions of individual adventitiously blinded persons, the technology of the current Braille printers is limited in terms of providing adaptable printers for easy production of training materials of optimal Braille sizes at each educational site.

Under these circumstances, to examine the teaching approach, it is considered significant to clarify the effect of the difference in Braille size (dot size, dot spacing, and cell spacing) on the training of Braille reading for adventitiously blinded persons, within the range of Braille size that can be produced in texts at practical educational sites. We hope that such clarification will lead to the provision of easy-to-read texts and new ideas for developing an effective training method.

II. Objective

The purpose of this study is to clarify the dependence of learning effectiveness on the difference in Braille size during the initial training of Braille reading for adventitiously blinded persons.

This study consists of two parts: Study 1 and Study 2. In Study 1, the effect of the difference in cell spacing on reading was examined. In Study 2, the readability of Braille characters of different sizes (hereafter, normal size and large size), including dot size, was compared between groups to examine the effect of using text with large-sized characters on reading. The realization of the objective of this research was approached from these two studies.

III. Experimental Methods

Study 1

Sighted persons who are beginner Braille touch readers and totally blind persons who are expert Braille touch readers (Braille users) were tested on reading two types of Braille with greatly different cell spacings to compare their reading speed, the number of misreadings, and the readability.

(1) Subject

The subjects consisted of 32 sighted males and females (average age, 43 years) and 10 male and female Braille users (average age, 39 years; average time using Braille, 25 years). The age range for both groups is from 23 to 58.

(2) Experimental reading material

Using six Braille characters "⠅ (na), ⠇ (ni), ⠃ (i), ⠛ (re), ⠿ (me), and ⠭ (fu)," which are comparatively easy to read by touch, a series of meaningless units of two or three characters are combined with a blank cell to make four patterns of 19-character strings on a line (Fig. 3). Two string patterns were embossed in the international size and the Californian size using the Braille printer "ET" (Enabling Technologies, U. S. A.). Here, the international and Californian sizes are the size names used by the manufacturer of this printer. At the head of all lines, the Braille character "⠿ (me)" was printed to indicate the starting point of reading.

Table 1 shows the size specifications of international- and Californian-sized Braille. Both Braille characters have the same dot size of 1.4 mm but differ greatly in cell spacing (4-1 dot spacing).

TABLE 1 Comparison of Braille size

Type of Braille	Dot size (mm)	1-4 dot spacing (mm)	4-1 dot spacing (mm)	1-2 dot spacing (mm)
International size	1.4	2.38	4.17	2.34
Californian size	1.4	2.65	5.13	2.65

(3) Reading test

The decision of which hand and which fingers to use for reading and the reading method was left to the subject. The subjects (in the case of sighted persons, their eyes were covered) were given one minute to read aloud each of two strings of Braille characters of different sizes to examine their reading speed and number of misreadings. After reading two patterns, they rated which of the first or second Braille string was easier to read on a scale of five (First string, Probably first string, No difference, Probably second string, Second string).

Study 2

The sighted persons, who are beginner Braille touch readers, were divided into two groups to whom the Braille characters of different sizes were presented in a different order. By examining their reading speed, the occurrence of misreading, and the readability of Braille characters, the effect of the size of the Braille characters on reading efficiency and that of the presentation order were compared between the two groups.

(1) Subjects

As subjects, 28 male and female sighted persons aged 24 to 69 were divided into two groups (A and B). The number of subjects in each group and the average age are shown in Table 2.

TABLE 2 Number and average age of subjects

Group	*N*	Average age (years old)
A	13	41.3
B	15	41.5

(2) Experimental reading material

Using eight Braille characters "⠉ (u), ⠛ (re), ⠯ (me), ⠍ (fu), ⠁ (a), ⠃ (i), ⠇ (ni), and ⠅ (na)," which are comparatively easy to read by touch, four patterns - of 20-character strings consisting of meaningless units of two characters and four characters were prepared (Fig. 4). Two-character units were combined such that each character was used at least once as the first character and the last character of a unit in one string. Four-character units were combined such that each character was used at least once as the first character, a middle (second or third) character, and the last character of a unit in one string. This was carried out for the following reasons. As shown in Table 3, among the eight characters in these reading samples, the characters "⠁ (a)," "⠃ (i)," "⠇ (ni)," and "⠅ (na)," consist of dots only on the left side of the cell; therefore, the spacing between one of these characters and the subsequent character will be wide, which may cause difficulty in detecting the actual cell spacing and hence affect reading efficiency.

TABLE 3 Eight characters used as reading samples

u	re	me	fu	a	i	ni	na
⠉	⠛	⠯	⠍	⠁	⠃	⠇	⠅

Four string patterns of two-character units and of four-character units were prepared using the two character sizes shown in Table 4, and each pattern was embossed on a card. Normal- and large-sized characters were embossed using the Braille printer "ESA721" (JTR company) and "ESA2000/L" (JTR company), respectively. At the head of all lines, the Braille character "⠯ (me)" was printed to indicate the starting point of reading.

TABLE 4 Comparison of Braille sizes

Type of Braille	Dot size (mm)	1-4 dot spacing (mm)	4-1 dot spacing (mm)	1-2 dot spacing (mm)
Normal size	1.4	2.0	3.2	2.25
Large size	1.9	2.4	3.84	2.7

(3) Reading test

The subjects in group A read the strings of normal-sized two-character units, large-sized two-character units, normal-sized four-character units, and large-sized four-character units in that order, whereas the subjects in group B read the strings of large-sized two-character units, normal-sized two-character units, large-sized four-character units, and normal-sized four-character units in that order. This sequence was used because the order of reading of Braille of a different size may affect reading efficiency. The decision of which hand and which fingers to use for reading and the reading method was left to the subject. The sighted subjects, whose eyes were covered, were given one minute to read aloud each string of Braille characters of a different size to examine their reading speed and the characters that were misread in each of four trials. They compared the readability of normal-sized Braille with that of large-sized Braille in two- and four-character units on a scale of five (First card, Probably first card, No difference, Probably second card, Second card).

IV. Results and Discussion

Study 1

For the 32 sighted persons who are beginner Braille touch readers, the speed of reading one character of international size and that of Californian size were compared, as shown in Fig. 5. The positive direction on the Y-axis indicates a higher speed of reading (in seconds) one Californian-sized Braille character than reading one international-sized Braille character.

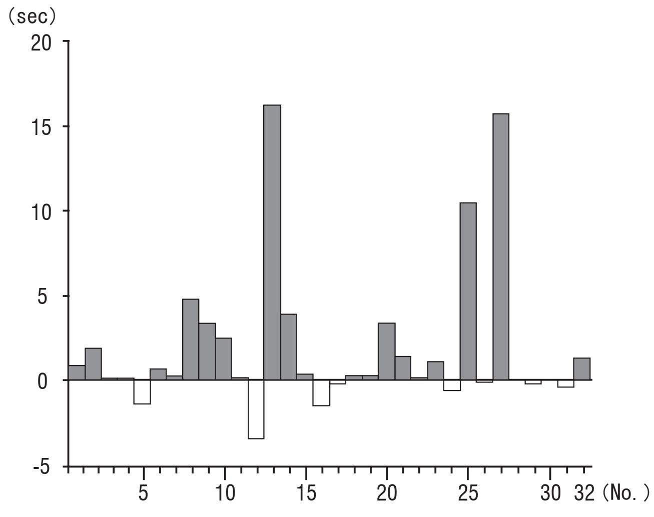
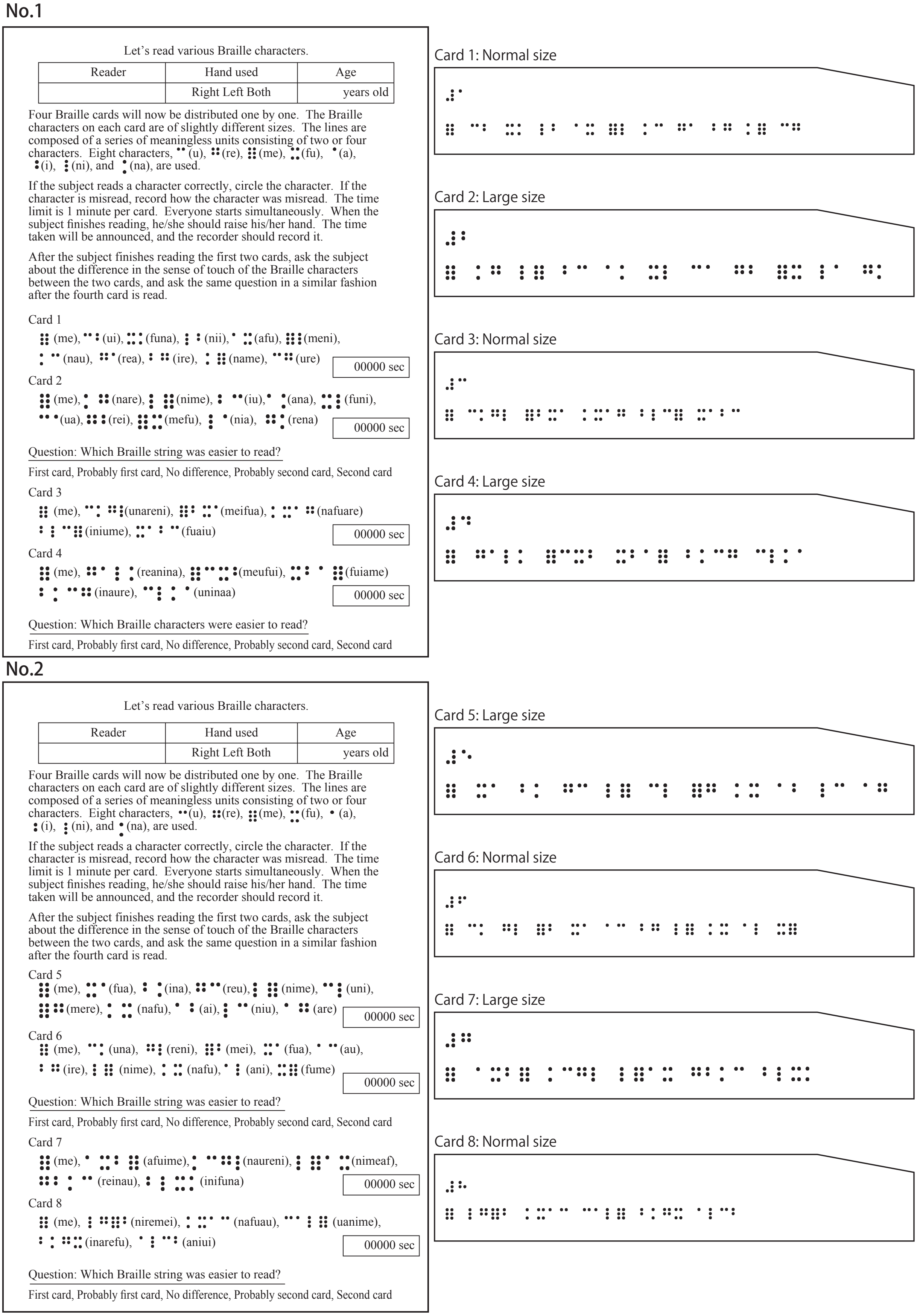


FIGURE 5 Comparison of reading speed per character

Next, 20 sighted persons who read all 19 characters within one minute in either the international size or Californian size and 10 Braille users were classified in terms of the size of the character read faster, the readability of Braille characters, and the occurrence of misreadings. The results are shown in Tables 5-1 to 7-2.



No.1

Let's read various Braille characters.

Reader	Hand used	Age
	Right Left Both	years old

Four Braille cards will now be distributed one by one. The Braille characters on each card are of slightly different sizes. The lines are composed of a series of meaningless units consisting of two or four characters. Eight characters, (u), (re), (me), (fu), (a), (i), (ni), and (na), are used.

If the subject reads a character correctly, circle the character. If the character is misread, record how the character was misread. The time limit is 1 minute per card. Everyone starts simultaneously. When the subject finishes reading, he/she should raise his/her hand. The time taken will be announced, and the recorder should record it.

After the subject finishes reading the first two cards, ask the subject about the difference in the sense of touch of the Braille characters between the two cards, and ask the same question in a similar fashion after the fourth card is read.

Card 1
(me), (ui), (funa), (nii), (afu), (meni),
(nau), (rea), (ire), (name), (ure) 00000 sec

Card 2
(me), (nare), (nime), (iu), (ana), (funi),
(ua), (rei), (mefu), (nia), (rena) 00000 sec

Question: Which Braille string was easier to read?

First card, Probably first card, No difference, Probably second card, Second card

Card 3
(me), (unareni), (meifua), (nafuare)
(iniume), (fuaiu) 00000 sec

Card 4
(me), (reanina), (meufui), (fuiame)
(inaure), (uninaa) 00000 sec

Question: Which Braille characters were easier to read?

First card, Probably first card, No difference, Probably second card, Second card

No.2

Let's read various Braille characters.

Reader	Hand used	Age
	Right Left Both	years old

Four Braille cards will now be distributed one by one. The Braille characters on each card are of slightly different sizes. The lines are composed of a series of meaningless units consisting of two or four characters. Eight characters, (u), (re), (me), (fu), (a), (i), (ni), and (na), are used.

If the subject reads a character correctly, circle the character. If the character is misread, record how the character was misread. The time limit is 1 minute per card. Everyone starts simultaneously. When the subject finishes reading, he/she should raise his/her hand. The time taken will be announced, and the recorder should record it.

After the subject finishes reading the first two cards, ask the subject about the difference in the sense of touch of the Braille characters between the two cards, and ask the same question in a similar fashion after the fourth card is read.

Card 5
(me), (fua), (ina), (reu), (nime), (uni),
(mere), (nafu), (ai), (niu), (are) 00000 sec

Card 6
(me), (una), (reni), (mei), (fua), (au),
(ire), (nime), (nafu), (ani), (fume) 00000 sec

Question: Which Braille string was easier to read?

First card, Probably first card, No difference, Probably second card, Second card

Card 7
(me), (afuime), (naureni), (nimeaf),
(reinau), (inifuna) 00000 sec

Card 8
(me), (niremei), (nafuau), (uanime),
(inarefu), (aniui) 00000 sec

Question: Which Braille string was easier to read?

First card, Probably first card, No difference, Probably second card, Second card

FIGURE 4 Data forms and Braille cards (Study 2)

TABLE 5-1 Size of characters read faster and readability

Sighted persons (n=20)	Size of characters read faster: Californian size	No difference	International size
Readability			
Californian size, n (%)	11 (55)	0 (0)	3 (15)
No difference, n (%)	1 (5)	0 (0)	0 (0)
International size, n (%)	0 (0)	0 (0)	5 (25)
Total, n (%)	12 (60)	0 (0)	8 (40)

TABLE 5-2 Size of characters read faster and readability

Braille users (n=10)	Size of characters read faster: Californian size	No difference	International size
Readability			
Californian size, n (%)	1 (10)	0 (0)	1 (10)
No difference, n (%)	1 (10)	0 (0)	0 (0)
International size, n (%)	0 (0)	2 (20)	5 (50)
Total, n (%)	2 (20)	2 (20)	6 (60)

TABLE 6-1 Size of characters read faster and errors

Sighted persons (n=20)	Size of characters read faster: Californian size	No difference	International size	Total
Errors, n (%)				14 (70)
Both sizes, n (%)	3 (15)	0 (0)	2 (10)	
Californian size, n (%)	1 (5)	0 (0)	4 (20)	
International size, n (%)	3 (15)	0 (0)	1 (5)	
No error, n (%)	5 (25)	0 (0)	1 (5)	6 (30)

TABLE 6-2 Size of characters read faster and errors

Braille users (n=10)	Size of characters read faster: Californian size	No difference	International size	Total
Errors, n (%)				1 (10)
Both sizes, n (%)	0 (0)	0 (0)	1 (10)	
Californian size, n (%)	0 (0)	0 (0)	0 (0)	
International size, n (%)	0 (0)	0 (0)	0 (0)	
No error, n (%)	2 (20)	2 (20)	5 (50)	9 (90)

TABLE 7-1 Readability and errors

Sighted persons (n=20)	Size of characters read faster: Californian size	No difference	International size	Total
Errors, n (%)				14 (70)
Both sizes, n (%)	5 (25)	0 (0)	0 (0)	
Californian size, n (%)	2 (10)	0 (0)	3 (15)	
International size, n (%)	3 (15)	0 (0)	1 (5)	
No error, n (%)	4 (20)	1 (5)	1 (5)	6 (30)

TABLE 7-2 Readability and errors

Braille users (n=10)	Size of characters read faster: Californian size	No difference	International size	Total
Errors, n (%)				1 (10)
Both sizes, n (%)	1 (10)	0 (0)	0 (0)	
Californian size, n (%)	0 (0)	0 (0)	0 (0)	
International size, n (%)	0 (0)	0 (0)	0 (0)	
No error, n (%)	1 (10)	1 (10)	7 (50)	9 (90)

Figure 5 shows that 22 out of 32 sighted persons who are not accustomed to Braille reading can read the Californian-sized Braille, which has wider cell spacing, faster than the international-sized Braille.

Tables 5-1 and 5-2 show the relationships between the size of the character read faster and readability for sighted persons (Table 5-1) and Braille users (Table 5-2).

For 12 (60%) out of 20 sighted persons, the speed of reading Californian-sized Braille was higher than that of international-sized Braille, and all subjects answered that the Californian-sized Braille was more readable, except for one person answering that there was no difference in readability. Although eight sighted persons (40%) had a higher speed of reading international-sized Braille, some answered that international-sized Braille was more readable and others answered that Californian-sized Braille was more readable.

For six (60%) out of ten Braille users, the speed of reading international-sized Braille was higher than that of Californian-sized Braille, and they answered that the international-sized Braille was more readable, except for one person who answered that Californian-sized Braille was more readable. The two Braille users who read both types of Braille at the same speed answered that the international-sized Braille was more readable. Of the two Braille users whose speed of reading Californian-sized Braille was higher, one answered that the Californian-sized Braille was more readable and the other answered that there was no difference.

Tables 6-1 and 6-2 show the classifications of subjects in terms of the size of the Braille read faster and the occurrence of misreadings. Fourteen (70%) out of 20 sighted persons misread characters. Five out of the six sighted persons who did not misread any characters read the Californian-sized Braille faster.

In the case of Braille users, misreading was observed for only one subject. However, there was no significant difference in the occurrence of misreadings between Braille sizes for subjects who use Braille daily.

Tables 7-1 and 7-2 show the classifications of subjects in terms of the readability and the occurrence of misreadings. In the case of sighted persons, four out of six subjects who did not misread any characters answered that the Californian-sized Braille was more readable, one answered that there was no difference, and the other answered that the international-sized Braille was more readable. Among the 14 sighted persons who misread characters, 10 answered that the Californian-sized Braille was more readable.

In the case of Braille users, seven out of nine subjects who did not misread any characters answered that the international-sized Braille was more readable, and the remaining subjects answered that there was no difference or that the Californian-sized Braille was more readable.

From the above results, it was found that the international-sized Braille is more readable and is read with fewer misreadings by Braille users who are accustomed to Braille reading, whereas the Californian-sized Braille, which has a wider cell spacing, is more readable and is read with fewer misreadings by sighted persons who are inexperienced in Braille reading. Therefore, it was demonstrated that the adoption of Braille with a wide cell spacing is effective for training adventitiously blinded persons in Braille reading at the initial stage.

Study 2

Tables 8-1 to 9-2-b show the results on the size of the Braille character efficiently read (the size of the Braille character read faster), the size of the Braille character correctly read, and the readability of two- and four-character units for groups A and B.

TABLE 8-1 Comparison of strings of two-character units (Group A)

Subject number	Size of characters efficiently read	Size of characters correctly read	Readability
1	L	L	L
2	L	L	L
3	L	L	Probably L
4	L	L	L
5	L	Same	L
6	L	Same	Probably L
7	L	L	L
8	L	Same	No difference
9	L	L	Probably L
10	L	L	L
11	L	L	L
12	L	L	Probably L
13	L	L	L

TABLE 8-1-a Comparison and summary for strings of two-character units (Group A) ($N = 13$)

Size of characters efficiently read	*n* (%)	Size of characters correctly read	*n* (%)	Readability	*n* (%)
L	13 (100)	L	10 (77)	L	8 (62)
Same	0 (0)	Same	3 (23)	Probably L	4 (30)
Normal	0 (0)	Normal	0 (0)	No difference	1 (8)
				Probably normal	0 (0)
				Normal	0 (0)

TABLE 8-2 Comparison of strings of four-character units (Group A)

Subject number	Size of characters efficiently read	Size of characters correctly read	Readability
1	L	L	L
2	L	L	L
3	L	L	L
4	L	L	L
5	L	Same	L
6	L	Same	Normal
7	L	L	L
8	L	L	Probably L
9	L	L	Probably L
10	L	L	L
11	L	L	Probably L
12	L	L	L
13	L	L	L

TABLE 8-2-a Comparison and summary for strings of four-character units (Group A) ($N = 13$)

Size of characters efficiently read	*n* (%)	Size of characters correctly read	*n* (%)	Readability	*n* (%)
L	13 (100)	L	11 (85)	L	9 (69)
Same	0 (0)	Same	2 (15)	Probably L	3 (23)
Normal	0 (0)	Normal	0 (0)	No difference	0 (0)
				Probably normal	0 (0)
				Normal	1 (8)

TABLE 9-1 Comparison of strings of two-character units (Group B)

Subject number	Size of characters efficiently read	Size of characters correctly read	Readability
1	L	L	L
2	Normal	Normal	Probably normal
3	Normal	L	Normal
4	Normal	Normal	Probably normal
5	L	Same	L
6	L	L	L
7	L	L	L
8	Normal	Normal	No difference
9	L	L	Probably L
10	Normal	Normal	L
11	L	L	Probably L
12	L	L	L
13	Normal	Normal	No difference
14	L	L	Probably L
15	L	L	Probably L

TABLE 9-1-b Comparison and summary for strings of two-character units (Group B) ($N = 15$)

Size of characters efficiently read *n* (%)		Size of characters correctly read *n* (%)		Readability *n* (%)	
L	8 (53)	L	7 (47)	L	6 (40)
Same	1 (7)	Same	3 (20)	Probably L	4 (27)
Normal	6 (40)	Normal	5 (33)	No difference	2 (13)
				Probably normal	2 (13)
				Normal	1 (7)

TABLE 9-2 Comparison of strings of four-character units (Group B)

Subject number	Size of characters efficiently read	Size of characters correctly read	Readability
1	Normal	Normal	L
2	L	L	L
3	Normal	Normal	Probably normal
4	L	L	No difference
5	Same	Same	L
6	Same	Same	L
7	Same	Same	Probably L
8	L	Same	L
9	Normal	Normal	L
10	L	Same	L
11	L	Same	L
12	L	L	L
13	Normal	Same	No difference
14	L	L	L
15	L	Same	Probably L

TABLE 9-2-b Comparison and summary for strings of two-character units (Group B) ($N = 15$)

Size of characters efficiently read *n* (%)		Size of characters correctly read *n* (%)		Readability *n* (%)	
L	8 (53)	L	4 (27)	L	10 (67)
Same	3 (20)	Same	8 (53)	Probably L	2 (13)
Normal	4 (27)	Normal	3 (20)	No difference	2 (13)
				Probably normal	1 (7)
				Normal	0 (0)

Figures 6-1 to 7-2 show the differences in reading speed between the normal-sized Braille and the large-sized Braille for each group. The positive direction on the Y-axis indicates a higher speed of reading (in seconds) one large-sized Braille than reading one normal-sized Braille.

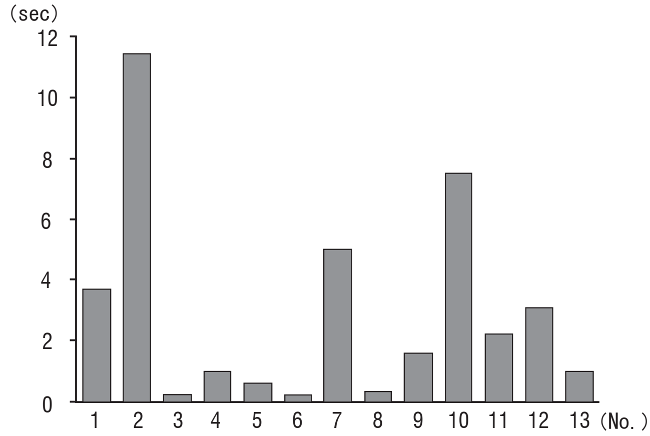


FIGURE 6-1 Comparison of speeds of reading strings of two-character units (Group A)

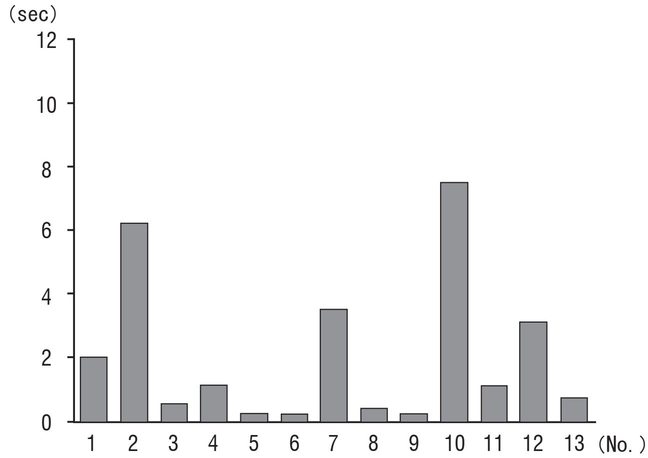


FIGURE 6-2 Comparison of speeds of reading strings of four-character units (Group A)

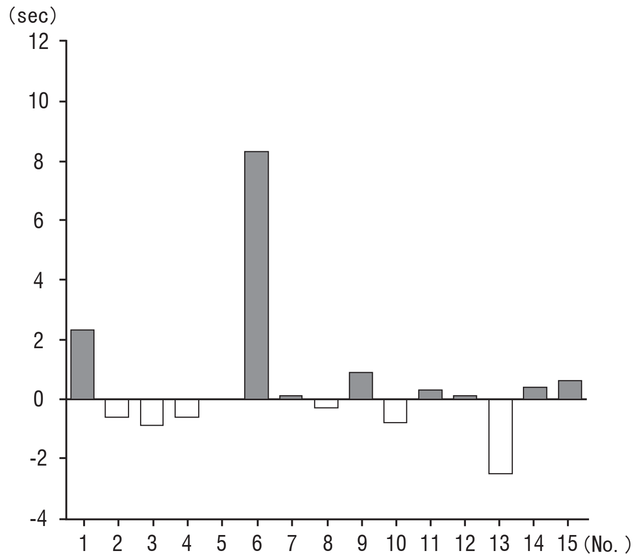


FIGURE 7-1 Comparison of speeds of reading strings of two-character units (Group B)

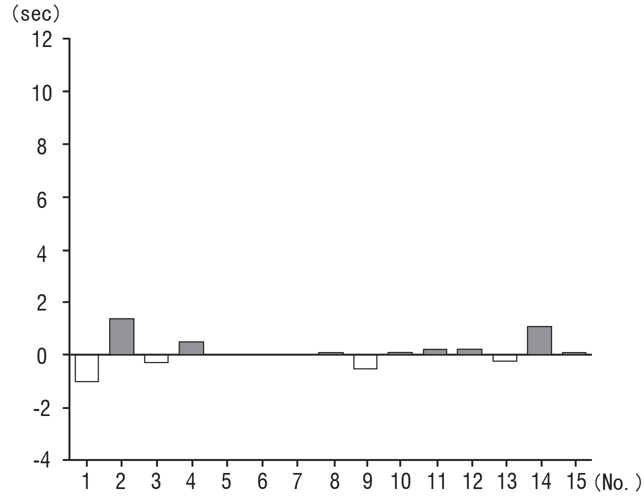


FIGURE 7-2 Comparison of speeds of reading strings of four-character units (Group B)

Next, examples of misreading two- and four-character units in both normal and large sizes are shown in Tables 10-1 to 11-2 for group A (Tables 10-1 and 10-2) and group B (Tables 11-1 and 11-2).

TABLE 10-1 Examples of misreadings of strings of two-character units (Group A)

Normal size	Number of errors	Large size	Number of errors
⠃ (i) → ⠇ (ni)	4	⠛ (re) → ⠿ (me)	2
⠭ (fu) → ⠅ (na)	1	⠃ (i) → ⠇ (ni)	1
⠛ (re) → ⠁ (a)	1	⠅ (na) → ⠭ (fu)	1
⠅ (na) → ⠁ (a)	1		
⠿ (me) → ⠛ (re)	1		
⠉ (u) → ⠁ (a)	1		
⠅ (na) → ⠭ (fu)	1		

TABLE 10-2 Examples of misreadings of strings of four-character units (Group A)

Normal size	Number of errors	Large size	Number of errors
⠭ (fu) → ⠅ (na)	2	⠃ (i) → ⠇ (ni)	1
⠃ (i) → ⠁ (a)	2	⠅ (na) → ⠭ (fu)	1
⠇ (ni) → ⠃ (i)	2	⠛ (re) → ⠿ (me)	1
⠅ (na) → ⠇ (ni)	2		
⠁ (a) → ⠅ (na)	1		
⠉ (u) → ⠡ (ka)	1		

TABLE 11-1 Examples of misreadings of strings of two-character units (Group B)

Normal size	Number of errors	Large size	Number of errors
⠃ (i) → ⠇ (ni)	3	⠭ (fu) → ⠅ (na)	3
⠭ (fu) → ⠅ (na)	2	⠿ (me) → ⠛ (re)	2
⠁ (a) → ⠉ (u)	2	⠇ (ni) → ⠃ (i)	2
⠿ (me) → ⠭ (fu)	1	⠃ (i) → ⠁ (a)	2
⠭ (fu) → ⠉ (u)	1	⠁ (a) → ⠉ (u)	2
⠛ (re) → ⠿ (me)	1	⠉ (u) → ⠁ (a)	1
⠇ (ni) → ⠅ (na)	1	⠉ (u) → ⠅ (na)	1
⠿ (me) → ⠛ (re)	1	⠭ (fu) → ⠇ (ni)	1
⠉ (u) → ⠁ (a)	1	⠉ (u) → ⠿ (me)	1
⠅ (na) → ⠇ (ni)	1	⠃ (i) → ⠛ (re)	1

TABLE 11-2 Examples of misreadings of strings of four-character units (Group B)

Normal size	Number of errors	Large size	Number of errors
⠅ (na) → ⠇ (ni)	3	⠉ (u) → ⠁ (a)	3
⠇ (ni) → ⠅ (na)	3	⠃ (i) → ⠇ (ni)	2
⠃ (i) → ⠅ (na)	3	⠁ (a) → ⠉ (u)	2
⠉ (u) → ⠁ (a)	2	⠃ (i) → ⠁ (a)	2
⠇ (ni) → ⠭ (fu)	1	⠉ (u) → ⠃ (i)	1
⠉ (u) → ⠃ (i)	1	⠁ (a) → ⠃ (i)	1
⠅ (na) → ⠁ (a)	1	⠿ (me) → ⠭ (fu)	1
⠭ (fu) → ⠅ (na)	1	⠇ (ni) → ⠃ (i)	1
⠿ (me) → ⠛ (re)	1	⠃ (i) → ⠅ (na)	1
		⠿ (me) → ⠃ (i)	1
		⠭ (fu) → ⠁ (a)	1
		⠇ (ni) → ⠅ (na)	1

Table 12 shows all cases of misreading depending on group and Braille size.

TABLE 12 Misreadings according to group and size

Example of error	Normal size		Large size		
	Group A	Group B	Group A	Group B	Total
⠃ (i) → ⠇ (ni)	4	3	2	2	11
⠇ (ni) → ⠃ (i)	2			3	5
⠭ (fu) → ⠅ (na)	3	3		3	9
⠅ (na) → ⠭ (fu)	1		2		3
⠿ (me) → ⠛ (re)	1	2		2	5
⠛ (re) → ⠿ (me)		1	3		4
⠉ (u) → ⠁ (a)	1	3		4	8
⠁ (a) → ⠉ (u)				4	4
⠅ (na) → ⠇ (ni)	2	4			6
⠇ (ni) → ⠅ (na)		4		1	5
⠅ (na) → ⠁ (a)	1	1			2
⠁ (a) → ⠅ (na)	1				1
⠃ (i) → ⠁ (a)	2			4	6
⠁ (a) → ⠃ (i)				1	1
⠃ (i) → ⠅ (na)		3		1	4
⠭ (fu) → ⠁ (a)				1	1
⠁ (a) → ⠭ (fu)		2			2
⠿ (me) → ⠭ (fu)		1		1	2
⠉ (u) → ⠃ (i)		1			1
⠃ (i) → ⠉ (u)				1	1
⠛ (re) → ⠁ (a)	1				1
⠉ (u) → ⠅ (na)				1	1
⠭ (fu) → ⠇ (ni)				1	1
⠇ (ni) → ⠭ (fu)		1			1
⠉ (u) → ⠿ (me)				1	1
⠃ (i) → ⠛ (re)				1	1
⠭ (fu) → ⠉ (u)		1			1
⠿ (me) → ⠃ (i)				1	1
⠉ (u) → ⠡ (ka)	1				1

As shown in Tables 8-1 to 8-2-a and Figs. 6-1 and 6-2, for all subjects in group A, in which the test started with the reading of the normal-sized Braille, the efficiency of reading large-sized Braille was higher than that of reading normal-sized Braille for both two- and four-character units. The large-sized Braille was more frequently read correctly, in the case of two-character units, by 77% of the subjects, and there was no difference in the number of characters correctly read between Braille sizes for 23% of the subjects. In the case of four-character units, the large-sized Braille was more correctly read by 85%, and there was no difference in the number of characters correctly read for 15% of the subjects. Twelve subjects (92%) answered that "large size" or "probably large size" was more readable for both two- and four-character units, whereas the remaining 8% of subjects answered "no difference" for the two-character units and "normal size" for the four-character units. However, for all subjects who answered "no difference" or "normal size," the large-sized Braille was actually read more efficiently.

Next, in group B, for which the test started with the reading of the large-sized Braille, as shown in Tables 9-1 to 9-2-b and Figs. 7-1 and 7-2, 53% of the subjects read the large-sized Braille more efficiently than the normal-sized Braille for both two- and four-character units. In the case of two-character units, 40% of the subjects read the normal-sized Braille more efficiently than the large-sized Braille, and 7% of the subjects read both types of Braille at the same efficiency. In the case of four-character units, 27% of the subjects read the normal-sized Braille more efficiently and 20% of the subjects read both at the same efficiency. In the case of two-character units, 47% of the subjects correctly read large-sized Braille more frequently, 33% of the subjects correctly read normal-sized Braille more frequently, and the remaining 20% of the subjects correctly read both Braille at the same rate. In the case of four-character units, 27% of the subjects correctly read large-sized Braille more frequently, 20% of the subjects correctly read normal-sized Braille more frequently, and the remaining 53% of the subjects correctly read both Braille at the same rate. Regarding readability, in the case of two-character units, 10 subjects (67%) answered that units of "large size" or "probably large size" were more readable, and eight out of the 10 subjects actually read the large-sized Braille more efficiently than the normal-sized Braille. Two out of seven subjects who read the normal-sized Braille more efficiently or read both at the same efficiency answered that the large-sized Braille was more readable. Three subjects (20%) who answered that characters of "normal size" or "probably normal size" were more readable actually did read the normal-sized Braille more efficiently. The subjects who answered "no difference" (13%) actually read the normal-sized Braille more efficiently. Furthermore, in the case of four-character units, 12 subjects (80%) answered that characters of "large size" or "probably large size" were more readable, but seven out of these 12 subjects actually read the large-sized Braille more efficiently. Seven percent of the subjects answered that those of "probably normal size" were more readable, but they actually did read the normal-sized Braille more efficiently. The subjects who answered "no difference" in readability accounted for 13%, and the sizes of the characters efficiently read by them in actuality included both normal and large sizes.

Focusing on the misreading examples for each Braille size shown in Tables 10-1 to 11-2, the number of misreadings of large-sized Braille was smaller than that of normal-sized Braille for both two- and four-character units in group A. In group B, there was no difference in the number of misreadings between the normal- and large-sized Braille. As shown in Table 12, the number of misreadings between ⠃ (i) and ⠇ (ni), (i.e., read ⠃ (i) instead of ⠇ (ni) and vice versa) is as many as 16, followed by 12 misreadings between ⠭ (fu) and ⠅ (na) and between ⠉ (u) and ⠁ (a), 11 misreadings between ⠅ (na) and ⠇ (ni), 9 misreadings between ⠿ (me) and ⠛ (re), and 7 misreadings between ⠃ (i) and ⠁ (a). This may occur because the cell spacings and the cells themselves were not detected by the fingertips. Between ⠅ (na) and ⠇ (ni), misreadings were less frequent for the large-sized Braille. This may occur because the dot at position 2, which is difficult to detect in the case of the normal-sized Braille, is more detectable in the large-sized Braille.

From these results, it was found that training materials with large-sized Braille are effective in the initial training of Braille reading for adventitiously blinded persons who have difficulty acquiring the ability to read normal-sized Braille.

V. Conclusions and Remaining Issues

From the results of Studies 1 and 2, it was found that Braille with wide cell spacing or large-sized Braille is effective for adventitiously blinded persons who have difficulty in reading normal-sized Braille by touch. As stated in "Background," it is not effective to simply increase Braille size or cell spacing without limit, because there are various related factors. Moreover, there is a limitation in printers that can support several Braille sizes. Kizuka (1999) commented on Braille size as follows. "When it comes to problems of Braille size, not only the absolute size but also the ratio of the spacing between dots in a cell to the spacing between cells become problems. In addition, the ratio of dot spacing to dot diameter cannot be overlooked." [2] Kizuka compared the ratio of cell spacing to dot spacing among Braille systems of various countries. In comparative experiments in his study of reading Braille written with foam ink, his subjects commented that Braille with the ratio of 1.41 is the most readable and that Braille with the ratio of 1.65 has too wide a cell spacing. Considering these comments, Kizuka stated that Braille with ratios ranging from 1.4 to 1.8 is readable by ordinary users. What then are the ratios for the Braille examined in our study, namely, international-, Californian-, normal-, and large-sized Braille? The ratios for the Braille examined in our study are shown in Table 13 together with Kizuka's ratios for comparison.

TABLE 13 Ratios of cell spacing (4-1 dot spacing) to dot spacing (1-4 dot spacing)

Type of Braille	Dot spacing (4 • 1) ÷ (1 • 4) = Ratio
Soviet Union	3.93 ÷ 3.17 = 1.24
Czech Republic	3.97 ÷ 3.00 = 1.32
Brazil	3.53 ÷ 2.60 = 1.36
Taiwan	3.13 ÷ 2.27 = 1.38
Nakamura-made	2.98 ÷ 2.10 = 1.42
Korea	3.17 ÷ 2.17 = 1.46
Japan	3.27 ÷ 2.13 = 1.54
China	3.97 ÷ 2.53 = 1.57
France	3.80 ÷ 2.30 = 1.65
Braille Everyday	3.80 ÷ 2.30 = 1.65
America	4.05 ÷ 2.35 = 1.72
Perkins	4.00 ÷ 2.30 = 1.74
Giant	6.70 ÷ 3.10 = 2.16
International size	4.17 ÷ 2.38 = 1.75
Californian size	5.13 ÷ 2.65 = 1.94
Normal size	3.20 ÷ 2.00 = 1.60
Large size	3.84 ÷ 2.40 = 1.60

Cited from the study by Kizuka (1999).[4] Four Braille sizes are additionally listed.

Except for the Californian size, the ratios at which Braille is readable by ordinary users are from 1.4 to 1.8, and are close to the upper limit of the range. The ratio for the Californian-sized Braille is higher than the upper limit but lower than that for the giant-dot Braille, which is used for adventitiously blinded persons in Europe and the United States. Because the range of ratios reported by Kizuka was not obtained from data on adventitiously blinded persons, this ratio range cannot be simply compared with our ratio range. However, this ratio will be very helpful when considering the gradual reduction of Braille size during the stepwise training of Braille reading for adventitiously blinded persons.

Sighted persons who adventitiously lose their vision are also severely traumatized psychologically. Even some period after losing their vision, they may still be emotionally unstable. In addition, many people experience declining sensory function of their fingertips due to aging, and many people who adventitiously lose their vision due to diabetic retinopathy, which is recently becoming a particularly common cause of loss of vision, also have disorders of peripheral nerves. Therefore, the sensitivity of their fingertips is dulled, causing difficulty in identifying an aggregation of points. This most likely decreases their motivation to learn Braille. Therefore, the initial training stage is very important, and it is necessary to arrange the educational environment such that adventitiously blinded persons can gain confidence and motivation through concrete learning achievements, such as success in reading. In the future, we will provide training materials with Braille having a wide cell spacing or large-sized Braille, the effectiveness of which was clarified in this study, in the initial training of Braille reading for adventitiously blinded persons having difficulty in learning Braille, and we will demonstrate the effectiveness of this Braille learning system in practice. In addition, we hope to develop such training materials as instruction manuals, taking into consideration the transition to normal-sized Braille.

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References

1. Kan, I.: *People with visual impairments and Braille*. Fukushi Tosho Shuppan, pp.18-30, 1988. (in Japanese)
2. Kizuka, Y.: *Development of comprehensive Braille learning system for improving reading efficiency of adventitiously blinded persons: Evaluation method for Braille size. Braille embossing system supporting various sizes, development of learning program and CAI*, National Institute of Special Education. pp.143-160, 1999. (in Japanese)
3. Department of Health and Welfare for Persons with Disabilities, the Social Welfare and War Victims' Relief Bureau of the Ministry of Health, Labor and Welfare: *Outline of survey result on actual conditions of disabled children and persons*. 2001. (in Japanese)
4. Kuroda, H., Sasaki, T., & Nakano, Y., et al.: Effect of braille size on reading efficiency. *Proceedings of 21st Sensory Substitution Symposium*, 55-58, 1995. (in Japanese)
5. Ministry of Education, Culture, Sports, Science and Technology: *Manual for braille learning (Revised version)*. Keio Tushin, pp.252-265, 1995. (in Japanese)
6. Nakamura, T.: Examination of braille training materials. *Proceedings of 2nd Visual Impairment Rehabilitation Research*, 34-37, 1993. (in Japanese)

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