Research in Developmental Disabilities 91 (2019) 103424

Contents lists available at ScienceDirect

Research in Developmental Disabilities

journal homepage: www.elsevier.com/locate/redevdis

The effects of reading mode and braille reading patterns on braille reading speed and comprehension: A study of students with visual impairments in China

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ARTICLE INFO

Keywords:
Braille reading patterns
Reading mode
Reading performance
Chinese braille

ABSTRACT

The purpose of this study was to examine the effects of reading mode (oral and silent reading) and braille reading patterns (one-handed pattern, mark pattern, parallel pattern, cooperative pattern) on the reading speed and comprehension of students with visual impairments in China. Seventy-three students with visual impairments aged 10–19 years participated in the study; 48 were students with congenital visual impairments and 25 were students with adventitious visual impairments. The participants' braille reading performance was assessed by the Chinese Reading Comprehension Test. Measurement indicators included reading speed (wpm) and reading comprehension. The results indicated that (1) Reading mode had a significant effect on both reading speed and reading comprehension. More specifically, although participants read faster in silent reading than in oral reading, they demonstrated better reading comprehension in oral reading than in silent reading. (2) There was a significant interaction effect between reading mode and braille reading patterns on reading speed. In particular, participants using cooperative and one-handed patterns read faster than other patterns in silent reading. This difference did not exist in the oral reading mode. (3) There was no difference between the measurement indicators of the students with congenital and adventitious visual impairments. Implications and recommendations are given based on the analyses.

What this paper adds?

Previous studies have focused on the effect of braille reading patterns on reading performance among students with visual impairments, but very few studies have explored the effect of reading mode on reading performance. For this reason, this study simultaneously examined the effect of braille reading patterns and reading mode on the reading speed and reading comprehension of students with visual impairments. The results revealed that reading mode had a significant effect on both reading speed and reading comprehension. Specifically, the participants read faster in silent reading than in oral reading; however, they demonstrated better comprehension in oral reading than in silent reading. Furthermore, there was a significant interaction effect between reading mode

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https://doi.org/10.1016/j.ridd.2019.05.003
Received 30 November 2018; Received in revised form 10 May 2019; Accepted 13 May 2019
Available online 22 June 2019

and braille reading patterns on reading speed. In particular, the participants who used cooperative and one-handed patterns read faster than those using other patterns in silent reading. This difference was not found for the oral reading mode.

1. Introduction

Braille reading performance is mainly based on reading speed (wpm) and comprehension (Daneman, 1988; Garcia, 2004; Mohammed & Omar, 2011). In recent years, the braille reading performance of students with visual impairments has drawn the attention of many scholars. Empirical evidence indicates that children who use braille as their primary learning medium read at a much slower rate than their sighted peers (Ferrell, Mason, Young, & Cooney, 2006; Legge, Madison, & Mansfield, 2009; Simon & Huertas, 1998). However, there is controversy about reading comprehension. Douglas, Grimley, Hill, Long, and Tobin (2002) found that the reading comprehension ability of visually impaired children were significantly lower than that of sighted children, while Papastergiou and Pappas (2019) found that the reading comprehension of visually impaired children was better than that of sighted children, especially for literal questions. Mohammed and Omar (2011) reported that there is no difference in reading comprehension between the two groups.

Difficulty reading may affect the study of children with visual impairments in school and their independence later in life. The inability to read proficiently may persist throughout their lives (Oshima, Arai, Ichihara, & Nakano, 2014).The factors that influence braille reading performance include not only a lack of training but also the individual's age at the onset of blindness, educational history, tactile sensitivity, mechanisms of cognitive processing and perceptual characteristics (Legge, Madison, Vaughn, Cheong, & Miller, 2008; Oshima et al., 2014; Veispak, Boets, & Ghesquière, 2012; Veispak, Boets, Männamaa, & Ghesquière, 2012). Among these factors, many researchers have focused on the influence of braille reading patterns (Laroche, Boule, & Wittich, 2012; Papadimitriou & Argyropoulos, 2017; Wetzel & Knowlton, 2000; Wright, Wormsley, & Kameihannan, 2009). Furthermore, it has been shown that reading mode (oral reading vs silent reading) may also affect the reading performance of students with visual impairments, just as it has an important effect on reading processes and reading comprehension in sighted people (Schimmel & Ness, 2017). However, to date, few studies have explored the effect of reading mode on the reading performance of students with visual impairments. As Chinese braille has its own linguistic properties, it is not clear whether the factors influencing the reading performance of Chinese students with visual impairments is consistent with previous studies in other cultures.

At present, there are two main systems of braille in mainland China: Current Braille and Hanyu Binary Pinyin Braille. Current Braille is a sound-generated braille system mainly used for standard Mandarin in mainland China. The sound of each syllable consists of three parts: initial, final, and tone. There are 18 initials, 34 finals and 4 tones. Each part is represented by a six-point braille cell. In practice, to save space when writing in braille, the tone is omitted in most cases, unless the meaning of the word is vague. For example, the braille for "skiing" (滑雪) is usually "⠒⠿⠒⠶". In the Chinese phonetic alphabet (pinyin), it is "*huaxue.*" If the meaning is not clear from the context, the tones must be marked (⠒⠿⠄⠓⠿⠄) because it is easy to misinterpret the word as "chemistry" (化学), which is also "*huaxue*" in pinyin and in braille. Hanyu Binary Pinyin Braille and Chinese Common Braille were invented to solve this problem. Hanyu Binary Pinyin Braille is a transitional solution; the government is gradually guiding people to use Chinese Common Braille, which is similar to Current Braille, with initials, finals and improved tones. Common Braille requires only five braille cells (⠒⠿⠛⠿⠤) to represent the word "skiing," whereas Current Braille requires six (⠒⠿⠄⠓⠿⠄). As Common Braille is still in an experimental stage, 70% of adults with visual impairments still use Current Braille (Cheng, Gu, Liu, & Wei, 2013), so the braille referred to in this paper is Current Braille. In addition, to express the meaning of the sentence better and link separate words as a whole, all of the Chinese braille schemes have developed a link writing rule, which is to avoid a scattered syllable structure to aid reading, and to join some words together. Spaces are usually inserted to distinguish between different parts of a sentence. For example, in "徐家汇公园",the English is Xujiahui Park, there is a space between "*xujiahui*" and "*gongyuan*" (⠓⠬⠛⠫⠓⠺ ⠛⠲⠯).

The main purpose of this study was to explore the impact of braille reading patterns and reading mode on reading speed and reading comprehension in Chinese individuals with visual impairments.

1.1. *Reading mode: oral reading and silent reading*

Reading modes include oral reading (reading aloud) and silent reading (Schimmel & Ness, 2017). When children begin to read, they are taught to read aloud (Dickens & Meisinger, 2017) because it is convenient for adults' teaching (Dickens & Meisinger, 2016) and also good for connecting words, sounds, and meaning (Schimmel, 2016). However, when children become proficient readers and no longer have to read aloud, they can understand the text quickly and accurately using silent reading (Hiebert, Samuels, & Rasinski, 2012).

Some studies have focused on the impact of reading mode on the speed of reading in braille, and found that the speed of silent reading was significantly faster than the speed of oral reading (Laroche et al., 2012; Wetzel & Knowlton, 2000). Although some evidence indicated that sighted students understand more information when reading aloud than when reading silently (Hale et al., 2011), especially low ability or younger readers (Dickens & Meisinger, 2017; Hale et al., 2007; Kragler, 1995), it was not clear whether differences existed in reading comprehension of students with visual impairments in oral reading and silent reading. Prior et al. (2011) examined the reading comprehension of 170 sighted students from grades one to seven and found that reading comprehension was better when reading aloud than for silent reading for students from grades one to five, the reading comprehension of the two reading modes was comparable in the sixth grade, while students performed better in silent reading in seventh grade. There is a view that the auditory channel can promote reading comprehension when reading aloud, because there is a connection in the brain with memory, which contributes to making associations between the words' pronunciations and meanings (Rack, Hulme, Snowling, &

Wightman, 1994). As the reading speed and reading accuracy of students with visual impairments is generally lower than those of sighted students (Simon & Huertas, 1998; Veispak, Boets, Männamaa et al., 2012, 2012b), reading mode may influence their reading comprehension. To date, there has been little research on this issue.

1.2. Braille reading patterns

Braille reading patterns can be one-handed or two-handed (Mousty & Bertelson, 1992; Papadimitriou & Argyropoulos, 2017). Early research mainly focused on one-handed reading patterns, and found varying results. It was reported that the left hand was more effective at reading braille because the left hand had an advantage in letter discrimination (Hermelin & O'Connor, 1971), others reported that the right hand was more effective in letter naming (Fertsch, 1947), and others reported that neither hand was more effective because hand advantages depended on current task requirements and individual strategy preferences (Millar, 1984).

Later, researchers identified more sophisticated braille reading patterns. Wright et al. (2009) found that there were four two-handed reading patterns: left marker, parallel, split and scissors. Papadimitriou and Argyropoulos (2017) reported that the main braille reading patterns included (a) using the right hand to read, (b) using the left hand to read, (c) using both hands to read, the left index finger placed flat and the right index finger advanced forward (the marker pattern in the Wright et al. (2009) study) and (d) reading with both hands and using them independently (the scissors pattern in the Wright et al. (2009) study). Two-handed reading is generally more effective than one-handed reading in reading speed (Laroche et al., 2012; Millar, 1984, Mousty & Bertelson, 1992; Wright et al., 2009). Specifically, people who use this reading pattern first read with their left hand and then the right hand takes over somewhere in the line and, while the right is reading the rest of the line, the left begins to look for the beginning of the next line (Mousty & Bertelson, 1985, 1992; Wright et al., 2009).

Although most studies have suggested that the two-handed pattern is better than the one-handed pattern in terms of reading speed (Laroche et al., 2012; Millar, 1984; Mousty & Bertelson, 1992), we do not know if there is an advantage in reading comprehension. If braille readers simply read the article quickly, but do not understand the content, then the investigation of reading patterns is of little value. To date, there has been little research on how braille reading patterns affect reading comprehension. Therefore, this study examined the braille reading patterns of a sample of students with visual impairments and explored the impact of these patterns on braille reading performance in terms of reading speed and reading comprehension.

Furthermore, although many studies have investigated the effects of braille reading patterns on reading speed and comprehension, very few studies have considered reading mode. Reading mode may moderate the association between braille reading patterns and reading performance. For example, in a study by Laroche et al. (2012), participants were divided into one-handed reading and two-handed reading groups, and the reading modes were silent reading and reading aloud. The results showed that the speed of one-handed reading and two-handed reading was comparable in the reading aloud mode. When the participants changed from reading aloud to silent reading, the reading speed increased in both groups, but more significantly for the participants using two-handed reading. However, research in this area is still insufficient and further exploration is needed.

1.3. The current study

In addition to the potential impact of braille reading patterns and reading mode on reading performance, the age of onset of blindness should also be considered. Some studies have suggested that the congenitally blind obtain sensory compensation during brain development, and they also tend to master braille at a younger age (Beisteiner et al., 2015; Hannan, 2006). In the course of learning to read, they improve their tactile identification skills and accumulate more tactile experience, so their braille reading performance is better than that of the adventitiously blind. However, the adventitiously blind may have an advantage in their accumulation of visual experience, and when they touch and read, they will often be able to stimulate their visual schema and gain a more comprehensive understanding (Sampaio & Philip, 1995; Trent & Truan, 1997). Unlike previous researchers, Mousty and Bertelson (1985) found no difference in reading speed between those who are congenitally blind and those who were adventitiously blind. Furthermore, Laroche et al. (2012) reported that congenitally blind individuals read faster than the adventitiously blind, but the former made more errors in decoding when reading aloud. The impact of the onset of blindness on braille reading has thus been unclear.

Compared to many other countries, little is known about braille reading in China. According to the China Disabled Persons' Federation, by the end of 2010, there were about 12.63 million people with visual impairments in China. The National Study Centre of Sign Language and Braille in China investigated 1808 students with visual impairments, 530 special education teachers and 370 adult people with visual impairments and found that Chinese braille still plays a major role in the lives of the blind. In fact, 93.2% of students with visual impairments use braille at school and 94.1% of adults with visual impairments use braille (Cheng et al., 2013). The focus of the study was the effect of reading mode and braille reading patterns on the reading rate and comprehension of the congenitally and adventitiously blind as measured by the Chinese Reading Comprehension Test.

1.4. Research questions

The aim of the present study was to investigate the effect of reading mode and braille reading patterns on reading performance in Chinese students with visual impairments. The research questions were as follows:

1 Is there a difference in reading performance when students with visual impairments read orally versus silently?

Table 1
Demographic characteristics of the participants (individuals - % distribution).

Characteristic	Congenitally blind (n = 48)	Adventitiously blind (n = 25)
Gender		
Male	31	18
Female	17	7
Grade		
4	3	4
5	6	4
6	13	4
7	14	4
8	7	2
9	5	6
Age when tested (months)		
M (SD)	178.71 (26.01)	175.16 (33.51)
Range	137–265	126–237
Onset of blindness (months)		
M (SD)	3.44 (1.89)	63 (43.16)
Range	0–10	12–156
Months reading braille (months)		
M (SD)	74.12 (19.69)	59.76 (22.78)
Range	31–127	19–115

2 Is there a difference in reading performance when students with visual impairments read with different braille reading patterns?
3 How do reading mode and braille reading patterns interact to affect reading performance?
4 Is there a difference in reading performance between the congenitally and adventitiously blind?

2. Method

2.1. Participants

Seventy-three students from Grade 4 to Grade 9 at schools for children with visual impairments in Guangdong province in southern China participated in this study. Forty-eight were congenitally blind (born blind or lost their sight before age one) and 25 were adventitiously blind (lost their sight at the age of one or older) and had lost their visual acuity more than two years before the study. The corrected visual acuity of the better eye of all participants was less than 0.05, and all had no other significant disabling conditions. All participants were native Chinese speakers. The university's institutional review board approved the study. Informed consent was obtained from the children and their parents prior to data collection. Table 1 presents the distribution of participants based on their gender, grade, age, onset of blindness and months of reading braille.

2.2. Research design

A 2 × 2 × 4 mixed factorial design was used, with two *between group* factors and one *within group* factor. The reading mode (oral reading or silent reading) was the within-group independent variable, visual condition (congenitally blind or adventitiously blind) and braille reading patterns (one-handed, mark, parallel or cooperative) were between-groups independent variables, and reading comprehension (percentage of correct answers) and reading speed (wpm) were the dependent variables.

2.3. Materials

Stopwatches and a Sony video camera were used to record the reading speed and performance of the participants. The reading material was from the Chinese Reading Comprehension Test, which is a formal reading comprehension test published in China, and validated within the Chinese population (Lin & Qi, 1999). After consulting with experienced teachers from the college and a special school for children with visual impairments, two articles with 120 and 124 words in length and of a comparable degree of difficulty were selected. One of the two articles was read aloud and the other was read silently. Both articles were unfamiliar to the students and considered to be appropriate reading material for braille readers of their age. Each article provided two factual questions, two inferential questions and one global coherence question. Each question had four possible answers. The reliability coefficient (Cronbach's α) of the articles for reading aloud and reading silently were 0.89 and 0.85, respectively. The test was converted to braille by teachers at the school for the blind. The materials were printed in Chinese Current Braille on a 30 × 30 cm card. The participants wrote down their answers on an answer sheet.

2.4. Procedure and data analysis

The participants were invited individually to a classroom that they were familiar with. They were instructed to read as quickly and precisely as they could and they were informed that only their hands would be video recorded while they were reading, with a camera placed in front of the desk. To measure their reading rate, the time they spent on oral reading and silent reading was recorded using a stopwatch. Prior to the formal test, the researchers told the participants that they would read a passage aloud or silently and then answer multiple-choice questions related to the passage. Because these participants had already taken a similar reading comprehension test in school, they were familiar with the process. Before the formal test, the researchers ensured that the participants understood the test method. Half of the participants (selected at random) were instructed to read one article aloud, followed by silent reading of the other article; the other half were instructed to read silently first and then read aloud. After each article was read, the examiner asked the students multiple-choice questions. The participants scored one point if they chose the correct answer and zero points for answering incorrectly. The full score for each article was five points. Reading rate was calculated as the number of words students read per minute (wpm). Reading comprehension was calculated by using the percentage of correct answers to the questions. The whole process took about 20–30 min.

Seventy-three videotapes were collected and reviewed by two independent observers. In line with Wright et al. (2009), braille reading patterns in this study were categorized into two major groups: one-handed reading and two-handed reading. The one-handed pattern refers to reading with one hand only (either left or right), while the two-handed pattern can be subdivided into four patterns (mark, parallel, split and scissors). As described above, the mark pattern involves reading with both hands simultaneously, with one hand marking the beginning or end of the next line, and the other hand following. In the parallel pattern, both hands work in parallel in reading and in return movements. As the split pattern and the scissors pattern both involve two hands reading cooperatively and independently, they can be combined. According to Wright et al. (2009), and in Wormsley (1996) study of the 22 braille readers, the fastest readers either read in a split pattern or scissors pattern. Therefore, in this study we combined the split pattern and scissors pattern into one pattern, which we call a “cooperative pattern”. The cooperative pattern refers to both hands reading together or the left hand reading until half or almost the end of the line, then the left hand returning to locate the next line while the right one continues to finish the line, rejoining the left in the next line, and so on. The first and second authors separately classified all braille reading patterns in the videotapes. The percentage agreement was calculated by dividing agreements by disagreements then multiplying by 100 to yield a percentage. The percentage agreement was 90.4%.

3. Results

3.1. Reading speed

As shown in Table 2, the mean reading speed ranged from 133.46 wpm to 169.17 wpm for the congenitally blind and from 143.40 wpm to 156.64 wpm for the adventitiously blind.

The repeated measurement analysis revealed a significant main effect of reading mode, $F(1, 65) = 15.656$, $p < .001$, $\eta^2 = .194$, indicating that the speed of silent reading ($M = 164.88$, $SD = 64.953$) was higher than that of reading aloud ($M = 136.86$, $SD = 48.011$).

There was a marginally significant main effect of braille reading patterns, $F(3, 65) = 2.602$, $p = .059$, $\eta^2 = .107$. A post hoc LSD test demonstrated that participants who used the one-handed pattern read much more quickly than participants with the parallel pattern ($p < .05$) or the mark pattern ($p = .089$). Those who used the cooperative pattern read significantly faster than those who used the parallel pattern ($p < .05$) or mark pattern ($p < .05$). However, no differences were found between the reading rates of participants using the one-handed pattern ($p > .10$) and the cooperative pattern ($p > .10$), or between those using the mark pattern ($p > .10$) and the parallel pattern ($p > .10$) in oral or silent reading. This showed that the participants with a one-handed pattern or cooperative pattern read much faster than those using a mark pattern or parallel pattern.

A significant interaction effect was observed between reading mode and braille reading patterns, $F(3, 65) = 3.584$, $p < .01$, $\eta^2 = .142$. A simple effect test showed that the reading rate of participants with different braille reading patterns was not significantly different under oral reading mode, $F(3, 69) = 2.04$, $p > .10$. However, the reading rates of participants with different patterns were significantly different under silent reading mode, $F(3, 69) = 3.87$, $p < .05$. Participants who used a one-handed pattern or cooperative pattern ($M = 178.05$; $SD = 63.104$) read significantly faster than those who used a mark pattern or parallel pattern ($M =$

Table 2
Reading rate(wpm) of braille readers with different braille reading patterns.

Braille reading patterns	N	Oral reading rate		Silent reading rate	
		M	SD	M	SD
One-handed pattern	16	141.19	48.414	195.56	77.911
Mark pattern	18	121.11	42.255	156.78	53.968
Cooperative pattern	22	154.64	40.262	178.05	63.104
Parallel pattern	17	126.47	57.476	127.53	47.177
Total	73	136.80	48.011	164.88	64.953

Table 3
Reading comprehension(%) of braille readers with different reading patterns.

Braille reading patterns	N	Oral reading comprehension		Silent reading comprehension	
		M	SD	M	SD
One-handed pattern	16	73.75	25.000	76.25	13.102
Mark pattern	18	76.67	23.009	65.56	24.548
Cooperative pattern	22	84.55	23.850	73.64	15.598
Parallel pattern	17	85.88	22.096	69.41	29.255
Total	73	80.55	23.564	71.23	21.340

127.53, $SD = 47.177$).

The main effect of group was not significant ($p > .10$), and no interaction effect was found between the visual condition and the reading mode ($p > .10$) or reading mode and braille reading patterns ($p > .10$). Neither was there any interaction effect between the visual condition, reading mode and reading patterns ($p > .10$).

3.2. Reading comprehension

The mean reading comprehension scores of the participants are shown in Table 3.

A significant main effect of reading mode was found, $F(1, 65) = 4.303$, $p < .05$, $\eta^2 = .062$, indicating that the comprehension of oral reading was better than that of silent reading ($p < .05$). There was no significant main effect of group ($p > .10$) or reading pattern ($p > .05$), indicating that the comprehension of each group was similar. No interaction effect was found between group and reading mode ($p > .10$) or visual condition and reading pattern ($p > .05$). There was also no interaction effect between reading mode and reading pattern ($p > .05$); neither was there any effect between visual condition, reading mode and braille reading patterns ($p > .05$).

4. Discussion

The aim of the present study was to analyze the effect of reading mode and braille reading patterns on the reading speed and comprehension of students with congenital and adventitious visual impairments in China.

We found that the participants demonstrated better reading comprehension with oral reading than silent reading. This result is in line with the findings of Hale et al. (2007), in which 42 middle school students (grades 10, 11 and 12) and 51 pupils in grades 4 and 5 read articles silently and aloud. The students' comprehension ability was significantly higher when they read the text aloud than when they read the text in silence. During the silent reading, the students with visual impairments were likely to mumble, which is considered to be a sign of transformation from silent reading to oral reading and could leave more time to process the article and achieve better comprehension (Kragler, 1995). Oral reading may require more time to focus on and decode each word to work out its pronunciation and meaning (Schimmel, 2016), which leads to a slowing of reading speed. However, it can provide auditory feedback for further processing, making it an efficient way to read for students with visual impairments who depend mostly on hearing (Rack et al., 1994). Daneman (1988) reported that braille reading comprehension was associated with listening comprehension and working memory. Similarly, a recent study found a significant correlation between working memory and reading comprehension in students with visual impairments (Argyropoulos, Masoura, Tsiakali, Nikolaraizi, & Lappa, 2017). Therefore, a braille reader who reads aloud may improve listening comprehension and working memory, and this will eventually lead to better reading comprehension. In addition, participants who used different reading patterns showed no differences in reading comprehension. This finding is consistent with a previous study (Garcia, 2004), in which the participants' reading comprehension was comparable regardless of braille reading pattern. Thus, the participants in this study did not sacrifice reading comprehension for a faster reading speed.

Secondly, there was a significant interaction effect between reading mode and braille reading patterns on reading speed. Specifically, participants with a one-handed pattern or a cooperative pattern read significantly faster than those who used the mark pattern and parallel pattern in silent reading, but there was no difference in the oral reading mode. These results are similar to those of Laroche et al. (2012), who also found no difference in reading speed when people with visual impairments read aloud with different braille reading patterns, but significant differences in silent reading mode. As noted above, when individuals read aloud, they need to pay attention to the pronunciation of the words, but silent reading does not require that, so reading aloud may slow down reading speed. As a result, the speed advantages of one-handed and cooperative patterns disappeared as the participants read aloud.

The observed superiority of the cooperative pattern and the one-handed pattern over the mark pattern and the parallel pattern in silent reading mode is consistent with previous studies (Bertelson, Mousty, & D'Alimonte, 1985; Laroche et al., 2012; Wormsley, 1996). However, not all two-handed reading patterns are effective. Only braille readers who prefer reading with two hands that work collaboratively and independently in the split pattern or scissors pattern are reported to be more efficient, because they can use one hand to process language information and the other hand to deal with spatial information (Papadimitriou & Argyropoulos, 2017; Wright et al., 2009).Moreover,although the cooperative pattern has an advantage in reading speed, we found that the one-handed pattern does not perform worse than the cooperative pattern, and, sometimes performs even better than the other two-handed

patterns. This finding is, to some extent, the opposite of many previous studies. The superiority of the one-handed pattern may be due to continuous practice in braille reading with one hand only. In China, students with visual impairments are instructed to read with one hand and write with the other to improve efficiency, which has become a reading habit for them (Xu, 2015). The result of this study is similar to the research conducted by Papadimitriou and Argyropoulos (2017). They found that Greek students with visual impairments had the highest reading accuracy when they read with only their left hand, and argued that the advantage might not come from the use of a two-handed cooperative pattern, but from training. The participants in this study had been taught braille for more than four years, and according to Wormsley (1996), this makes them experienced braille readers who may have mastered automatic decoding.

Finally, there was no significant difference in reading rate and comprehension between congenitally blind and adventitiously blind participants. This result is consistent with previous studies (Argyropoulos & Papadimitriou, 2015; Mousty & Bertelson, 1985) and may be attributed to similar tactile sensitivities and braille reading strategies, given that the majority of students with visual impairments receive their initial braille instruction at a similar age and at an early stage at special primary schools in China. Although the adventitiously blind may have more visual schemata and experience (Sampaio & Philip, 1995; Trent & Truan, 1997), the visual center of the congenitally blind may be activated by high-frequency tactile stimulation during a critical stage of brain development, making it easier to decode braille cells during reading (Hannan, 2006).

Although there was no statistical difference between congenitally blind students and adventitiously blind students for any measure, some subtle differences in reading were found. During the experiment, the researchers noticed that congenitally blind students had fewer mispronunciations (inconsistency with the pronunciation of the target word), less repetition (continuous pronunciation of the same target word) and less self-correction (immediate correction after preforming any errors) while reading orally, which may indicate that congenitally blind students have a potential advantage over adventitiously blind students in terms of reading accuracy. This made us wonder whether the congenitally blind students have a better balance between the risk of decoding errors and the benefit of speed and comprehension while reading. Papadimitriou and Argyropoulos (2017) found that etymological-type errors were correlated with age for vision loss: adventitiously blind students made more etymological errors than congenitally blind students.

Most research on braille reading is related to English braille, and there have been few research studies on braille reading in other languages (Jarjoura & Karni, 2014). In this study, the mean oral reading speed for Chinese braille was 136.8 wpm, while the mean silent reading rate was 164.88 wpm, meeting the requirements of the Chinese Curriculum Standards for Compulsory Education in Blind Schools in 2016 (Ministry of Education, 2016). The minimum required silent reading rate is 110 wpm for Grade 5, 120 wpm for Grade 6 and 140 wpm for Grade 7. The results of this study were similar to those of the study by Wetzel and Knowlton (2000), who found that the average oral reading speed of students with visual impairments was 134.26 wpm and that of silent reading was 168.55 wpm. However, the participants in that study were adults, while those in the current study were all young students. The speed of braille reading in this study was faster than in many English-speaking countries. For example, Nolan and Kedris (1969) reviewed nine studies and reported that the speed of reading was 59 wpm and 83 wpm for students with visual impairments in sixth grade and high school respectively. Legge et al. (2009) reported a median reading rate of 124 wpm. The speed found in this study may have been higher because Chinese braille is monosyllabic; each word has only one or two braille cells, each of which is generally shorter than in English. For example, the word "braille" is "⠠⠃⠗⠇" in English Grade 2 braille and "⠠⠃⠗⠁⠊⠇⠇⠑" in Grade 1 braille, but "⠍⠦⠒" in Chinese Braille. In this example, English Grade 2 braille has four cells and English Grade 1 has eight cells, while Chinese braille only has three. In addition, because Chinese braille adopts the rules of link writing, related words are closer, which helps students with visual impairments to use context to guess meaning.

This research has certain practical implications. It confirms that in silent reading, when considering only the reading speed of students with visual impairments, a two-handed cooperation pattern, such as the split and scissor patterns, is effective. However, we do not recommend that students with visual impairments in China stop using a one-handed pattern because the reading speed with a one-handed pattern is not bad and many students are used to reading braille with one hand and writing braille with the other. In addition, when teaching students to read braille, teachers may require them to read aloud as much as possible, to deepen their understanding of the content of the article. However, there are some limitations in this study. Firstly, there was an imbalance in the sample, which included fewer adventitiously blind than students with congenital visual impairments. The second problem is that the proportions of each group of braille reading patterns were quite different. Thirdly, this study does not provide an in-depth analysis of reading comprehension questions because Papastergiou and Pappas (2019) found that students with visual impairments have an advantage over sighted students in terms of literal questions. Fourthly, braille reading requires an appropriate hand movement posture; this study only discusses the effect of braille reading patterns on braille reading. Lastly, other factors affecting braille reading, such as age, gender, braille reading fluency and intensity of braille instruction, were not taken into consideration.

Conflict of interest statement

No potential conflict of interest was reported by the authors.

Acknowledgements

We thank all the teachers that participated in this study. This work was supported by grants from the Guangzhou Research Base of Humanities and Social Science, Guangdong Philosophy and Social Science project (Grant no. GD17YJY02), and Social Science and the research project Palacký University Olomouc (Czechia) (Grant No. IGA_PdF_2018_008).

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