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Braille Reading Accuracy of Students Who Are Visually Impaired: The Effects of Gender, Age at Vision Loss, and Level of Education

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Structured abstract: *Introduction:* The present study assesses the performance of students who are visually impaired (that is, those who are blind or have low vision) in braille reading accuracy and examines potential correlations among the error categories on the basis of gender, age at loss of vision, and level of education. *Methods:* Twenty-one visually impaired Greek school-aged children participated in the present study. The students who participated were enrolled in different educational settings; that is, special schools and mainstream educational settings. The research tool was a subset (three subscales) of a standardized instrument (Test A, Padeliadu & Antoniou, 2008) that evaluates reading accuracy in Greek. All interactions between researchers and students were videotaped, and the analysis of the obtained data was focused on phonological and nonphonological-type errors. *Results:* Significant differences in performance were found between male and female participants—$t(19) = 2.12$, $p < .05$—as well as between students who attained primary and secondary education: $t(19) = 1.96$, $p \cong .05$. The average number of errors in the three subscales correlated very highly, signifying that performance was very similar. Positive correlation was found between replacement and subtraction types of error ($p < .05$), and replacement and recognition ($p < .001$), and the total number of errors was positively correlated with replacement ($p < .001$), subtraction ($p = .001$), and recognition errors ($p < .001$). Male participants made more replacement errors: $t(19) = 2.09$, $p \cong .05$; participants in secondary education made significantly fewer errors of recognition: $t(19) = 2.49$, $p < .05$; and students who were congenitally blind made significantly more errors of addition: $t(19) = 1.96$, $p \cong .05$. Regarding the recognition type of error, there was a significant interaction effect between grade and age at loss of vision: $F(3/17) = 3.09$, $p = .05$. *Discussion:* Participants did not benefit exceptionally from semantic information, and it is unclear whether a higher school level leads to the improvement of braille reading accuracy. “Reading the entire word” seems the most effective decoding strategy. Nevertheless, further research is needed to obtain relevant data from longitudinal studies. *Implications for practitioners:* Listing and analyzing braille reading errors systematically may reveal error patterns. Based on these patterns, teachers would be able to differentiate their instruction to improve students' performances in braille speed and accuracy.

Braille reading constitutes a highly specific and active tactile process, in which fingers, arms, and even elbows are involved (Millar, 1997). It seems that appropriate hand movements for reading braille depend on (a) brain asymmetry, (b) the sensitivity of each finger, and (c) training received at an early stage of learning (Lorimer, 2002). A very recent hypothesis suggests that the necessary level of tactile sensitivity for braille reading is already achieved during the beginning stages of reading and no further improvement in tactile spatial resolution occurs (Veispak, Boets, & Ghesquiere, 2013). Braille reading presupposes effective tactile spatial acuity, so that the reader will be able to identify the relative spatial position of the braille dots and eventually acquire the maximal amount of information from each braille character (Vakali & Evans, 2007).

Additional factors that determine the levels of braille reading are (a) phonological awareness, (b) verbal short-term memory skills corroborated by auditory processing, and (c) speech perception aptitude (Veispak et al., 2013). Nonetheless, it is still unclear to what extent braille readers purely decode each character individually or whether they also develop larger perceptual units (Veispak, Boets, & Ghesquiere, 2012). Millar (1997) supported the idea that proficient braille readers use lexical, contextual, and perceptual cues to accomplish fast reading, whereas Hughes (2011) has suggested that braille reading imposes constant successive decoding. Finally, braille readers are likely to apply from the beginning more or less the same cognitive strategy for reading words and pseudowords, which does not change fundamentally during their growth and academic development (Veispak, Boets Mannamaa, & Ghesquiere, 2012).

Braille reading accuracy

Reading accuracy constitutes one of the three indicators of reading effectiveness. Braille reading accuracy relies mainly on systematic and active exploratory movements rather than passive perception (Millar, 1997). Braille reading accuracy is highly related to phonological awareness (Gillon & Young, 2002). In addition, due to the complexity of the braille code, the correct identification of the relative spatial position of the braille dots is critical for decoding braille characters (Dodd &

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Conn, 2000). Some studies indicate that braille readers read slightly less accurately than do print readers (Veispak, Boets, & Ghesquiere, 2012; Veispak et al., 2012), while Dodd and Conn (2000) estimated that the braille readers who participated in their study were approximately 10 months behind the level of accuracy of their sighted peers.

The above inferences may be attributed mainly to (a) the nature of the braille code, since the high degree of similarity between the letters leads braille readers to be error prone (Millar, 1997); (b) the inability of students who are blind to practice braille reading outside school hours (Vakali & Evans, 2007); and (c) the lower resolution of tactile processing, which demands a conscious effort to maintain braille accuracy (Veispak et al., 2012) (that is, the left index finger constantly decodes each character of a word individually, while the right index finger tracks down the next line).

Furthermore, Vakali and Evans (2007) pointed out that as students who have visual impairments become more experienced readers, they also become more accurate readers, whereas students in the ABC Braille Study began to show deficiencies in acquiring higher-level decoding skills after grade 2 (Wall Emerson, Holbrook, & D'Andrea, 2009). According to the researchers of the ABC Braille Study, possible explanations may lie in the increased stress of the readers as they moved up in age and grade level, because they were confronted with greater amounts of connected reading or a lack of instruction or sufficient practice. Nevertheless, students who were introduced to more contractions earlier in instruction performed better on decoding (Wall Emerson et al., 2009). Finally, Millar (1997) showed that braille readers read meaningful words more accurately than pseudowords. This, according to Millar (1997), may be attributed to a compensatory system that braille readers use in order to extract semantic information from a coherent text to enhance accuracy. Also, it seems that the above system improves with increased reading experience (Veispak, Boets, & Ghesquiere, 2012).

Veispak et al. (2012) also reported that the length of and familiarity with words may influence accuracy in reading. It seems that the length of words affects the reading performance of braille readers more than that of print readers. The impact of sufficiently sensitive fingers on reading accuracy becomes apparent when the words are short enough not to overload verbal short-term memory and when semantic information cannot be used to aid comprehension. Finally, the categorization of error patterns of braille readers has not been sufficiently investigated, and consequently the knowledge in this area is limited. Some researchers hold the view that the recognition of braille characters seems to be affected by the position and the density of the braille dots (Challman, 1978, in Papadopoulos, 2005; Nolan & Kederis, 1969), while others believe that the majority of errors in recognizing braille characters may fall into two overall categories; that is, reverse and mirroring. According to Millar (1997), such errors are highly frequent due to the nature of braille, in which all characters derive from the same matrix and differ only in the presence or absence of dots, and almost all characters are developed as rotations of some other braille cell.

The aim of the present study was to describe types of errors in braille reading accuracy of students with visual impairments and if possible to correlate them with the type of visual impairment and grade level of the participants. In particular, the research aims were as follows:

1. to assess the braille accuracy of visually impaired students on the basis of gender, the cause of the visual impairment (or age at sight loss), and level of education; and
2. to find out potential correlations among the error categories on the basis of gender, age at loss of vision, and level of education of visually impaired students.

Methods

Participants

The authors followed the ethical principles of the Declaration of Helsinki and obtained signed consent from the participants using the appropriate forms and procedures suggested by the World Medical Association. Specifically, the authors obtained consent from the Greek Institute of Educational Policy (GIEP), which was established in 2011 with Public Law 3966 (Government Gazette A′ 118/24-05-2011). GIEP operates for the benefit of public interest as an executive scientific body that supports the Greek Ministry of Education and Religious Affairs. In turn, the Ministry of Education provided contact information for the visually impaired students who were braille learners as well. All teachers and parents of the students who participated in the present study were informed in advance about the present research, and the authors obtained consent from those who wished to participate.

The date for the administration of the test was arranged by telephone. Twenty-one school-aged children who were visually impaired participated in the present study, 11 female (age $M = 13$, $SD = 2.19$) and 10 male (age $M = 13.2$, $SD = 3.55$). Eleven participants attended primary educational settings and 10 were in secondary educational settings, ranging from the 4th grade up to the 12th grade (final year of high school). Furthermore, 11 participants were congenitally visually impaired, while the rest were adventitiously visually impaired with no additional disabilities. According to their teachers, all participants had proficient braille literacy skills and had no additional disabilities (no other personal data was provided such as etiology of participants' vision loss).

Instrument

The selected research tools in the present study were the subscales (three in total) of the standardized Test A (Padeliadu & Antoniou, 2008), which evaluates reading accuracy in Greek. In total, Test A consists of 10 subscales, which comprise 4 structural axes: decoding, fluency, morphology-syntax, and comprehension. It aims at assessing the reading ability of students who are in the 3rd grade up to the 12th grade (Padeliadu & Antoniou, 2008). The original form of the research tool was designed and standardized for sighted students, so the authors transcribed the test into the Greek braille code. Greek braille code consists of 63 characters, out of which 7 are called diphthongs and combine 2 vowels in 1 character. Most Greek words need to be spelled out in their entirety (Argyropoulos & Martos, 2006). Accent was not taken into account, since accented characters are not used in the Greek braille system. Also it needs to be mentioned here that the Greek braille code is uncontracted.

As stated above, reading accuracy constitutes one of the three indicators of reading effectiveness, not only in print reading but also in braille reading. *Decoding* is the process of recognizing and interpreting the alphabetic code. The reader recognizes phonemes of a word through decoding and afterwards composes the phonemes in order to read the word accurately (Porpodas, 2002). Two subscales of Test A that assess reading accuracy address the decoding of pseudowords (subscale 1) and meaningful words (subscale 2), while the third subscale consists of mixed words. Reading of nonmeaningful words (subscale 1) reflects exclusively the interpreting of the braille code, which is based on graphophonemic correspondences. Recognition of the pseudowords is unattainable via reading experience, since the student has never before seen these words. As for the meaningful words (subscale 2), participants who have visual impairments would not be able to recognize words immediately because of the nature of tactile reading. Thus, they would be expected to spend more time and effort to decode the individual letters of the word accurately compared to their sighted peers (Simon & Huertas, 1998). Finally, subscale 3 assesses the contribution of semantics in the decoding process, since the participant has to decode nonmeaningful words and meaningful words and then choose the meaningful ones (Padeliadu & Antoniou, 2008).

Subscale 1

The first subscale assesses the ability of students to decode nonmeaningful words (pseudowords). The first subscale consists of 24 pseudowords that embody a large variety of letter combinations that occur in the Greek language (for instance, *τευλαιντευως*) (Padeliadu & Antoniou, 2008).

Subscale 2

The second subscale assesses the ability of students to decode meaningful words, and it consists of 53 words. These words can be read either based on the rule of "grapheme-phoneme" (Vakali & Evans, 2007), or based on the spelling rule that recognizes the whole word or part of it (for instance, *εγγειοβελτιωτικός*) (Padeliadu & Antoniou, 2008). In both subscales, the level of difficulty gradually increases.

Subscale 3

The third subscale assesses students' ability to identify meaningful words in a set of mixed meaningful and nonmeaningful words. The total number of the words is 36, out of which 20 are meaningful. Both the number of the words and their level of difficulty gradually increase. Subscale 3 is exceptionally significant because it allows the investigator to examine and interpret the reading accuracy of the children's reading strategies (for instance, *ραμε–πίρτα–βιβλία*) (Padeliadu & Antoniou, 2008).

Research procedure

After the researcher asked the student for personal data, the student proceeded to begin the test in question. There was no time restriction for the participants to complete the test. In case the participant failed to decode a word, they could carry on to the next word. The procedure stopped after five sequential decoding errors in the same subscale (subscales 1 and 2), whereas in subscale 3 the procedure was terminated if the student did not find a meaningful word within three sequential lines. The interviewer videotaped and recorded the answers on an answer sheet. Correct answers were marked with 1, while wrong or no answers were marked with 0.

Data analysis

In line with Argyropoulos and Martos (2006), errors were categorized in two broad groups, phonological-type errors (PT) and nonphonological-type errors (NPT). PT errors alter the acoustical image of the word (for instance, "mine" instead of "wine"). In this category the following types of errors were included: addition of letters, replacement of letters, omission of letters, letter transpositions, omission of a syllable, and replacement of a complex (for instance, ''*st*eam'' instead of ''*cr*eam,'' ''*πλωφορασματικων*'' instead of ''*πλωχθρασματικων*''). NPT errors were considered either the nonrecognition of words (for instance, an absolute inability to decode "simultaneous") or the substitution of an entire word (for instance, "sign" instead of "signify," or "signens" instead of "segment").

The last NPT error category was coded as "other word."

Results

Research aim 1

The first goal of the research was to assess the braille accuracy of students on the basis of gender, age at loss of vision, and level of education. Table 1 shows that the minimum and maximum values of errors were similar in subscales 1 and 2 (also similar were the means and standard deviations), whereas a small modification took place in subscale 3. In total, the minimum number of errors overall for the three subscales was 2 and the maximum was 29 (M = 8.71, *SD* = 7.99).

Table 1
Descriptives for the three subscales.

Subscale	*n*	Min.	Max.	M	*SD*
Subscale 1	21	0	12	3.57	3.34
Subscale 2	21	0	13	3.52	3.63
Subscale 3	21	0	6	1.62	1.72
Total errors	21	2	29	8.71	7.99

Table 2 refers to the mean number of errors in all three subscales by gender, age at loss of vision, and grade in school. It appears from Table 2 that female participants who were congenitally blind and attended primary educational settings made more errors in subscale 1.

However, *t*-tests showed no significant differences between the performances of the two groups (participants who were congenitally blind and those who were adventitiously blind). Female participants who were adventitiously blind and attended primary educational settings made more errors in subscale 2, and *t*-tests showed significant differences in performance only between male and female participants: $t(19) = 2.12$, $p < .05$. Specifically, female participants who were adventitiously blind and attended primary education settings made more errors in subscale 3. The *t*-tests showed significant differences in performance only between participants in primary and secondary education: $t(19) = 1.96$, $p \cong .05$.

Generally, the number of errors in the three subscales was very similar, and more errors on average were identified

Table 2
Means for the three subscales according to gender, age at loss of vision, and level of education.

Subscale	*n*	Mean	*SD*
Subscale 1			
Gender			
Male	10	2.90	2.28
Female	11	4.18	4.09
Age at loss of vision			
Congenital	11	2.64	3.17
Adventitious	10	4.60	3.37
Level of education			
Primary	11	3.91	3.51
Secondary	10	3.20	3.29
Subscale 2			
Gender			
Male	10	1.90	2.03
Female	11	5.00	4.20
Age at loss of vision			
Congenital	11	3.45	3.14
Adventitious	10	3.60	4.27
Level of education			
Primary	11	4.64	3.67
Secondary	10	2.30	3.36
Subscale 3			
Gender			
Male	10	1.30	1.25
Female	11	1.91	2.07
Age at loss of vision			
Congenital	11	1.45	1.81
Adventitious	10	1.80	1.69
Level of education			
Primary	11	2.27	1.35
Secondary	10	0.90	1.85
Gender			
Male	10	6.10	4.33
Female	11	11.09	9.88
Age at loss of vision			
Congenital	11	7.55	7.69
Adventitious	10	10.00	8.52
Level of education			
Primary	11	10.82	7.95
Secondary	10	6.40	7.76

in subscale 1 and fewer in subscale 3. Finally, female participants who were adventitiously blind and were in primary educational settings (special or mainstream) made more errors on average in all subscales. However, *t*-tests showed no significant differences in performance.

As can be seen in Table 3, the average number of errors in the three subscales correlated very highly with each other, signifying that performance in the three subscales was very similar.

Research aim 2

The second aim of the research was to describe potential correlations among error categories on the basis of gender, age at loss of vision, and level of education. A classification system was used to categorize the participants' errors (see Methods). Table 4 includes all types of errors the participants made ($N_{errors} = 19$). The most common type of error was observed for "replacement" and the least miscues were observed for the type "addition."

Positive correlation was found between "replacement" and "subtraction" types of errors ($p < .05$) as well as between "replacement" and "recognition" ($p < .001$). Also, the total number of errors was correlated with "replacement" ($p < .001$), "subtraction" ($p = .001$), and "recognition," respectively ($p < .001$). Table 5 shows the number of errors for the categories of gender, age at loss of vision, and grade, respectively.

In total, Table 5 shows that female students made more errors on average compared to their male classmates; that students who were adventitiously blind made more errors on average compared to students who were congenitally blind; and that elementary school students made more errors on average compared to secondary students. To delve more deeply into the quality of error that students made as they were going through the subscales,

Table 3
Correlations among the three subscales.

	Subscale 1	Subscale 2	Subscale 3
Subscale 1			
R	1	.762*	.694*
Sig. (2-tailed)		.000	.000
N	21	21	21
Subscale 2			
R		1	.812*
Sig. (2-tailed)			.000
N		21	21
Subscale 3			
R			1
Sig. (2-tailed)			
N			21

*Correlation is significant at the 0.01 level (2-tailed).

error-type categories were analyzed, using the classification system (see Methods). Thus, participants who were congenitally blind made significantly more errors in the "addition" category compared to those who were adventitiously blind, whereas the latter made significantly more errors in the categories "replacement," "subtraction," and "recognition" compared to the former. Also, elementary school students made significantly more errors in all categories except for the category "subtraction" compared to those in secondary education.

The most common error among the male participants (or those who were congenitally blind) was observed for the "subtraction" category, whereas the number of miscues regarding the performance of the female participants (or those who were adventitiously blind) was reported to be highest for the "replacement" category. Finally, elementary school students made more "replacement" type errors in contrast to secondary students, who made more errors in the "subtraction" category.

Table 6 shows the results of *t*–tests performed for all variables (gender, age at loss of vision, and level of education). A brief description of Table 6 leads to the following inferences: female participants made more errors in "replacement": $t(19) = 2.09$, $p \cong .05$; participants in secondary education made significantly fewer errors in "recognition": $t(19) = 2.49$, $p < .05$; and participants who were

Table 4
Descriptives for types of error in the three exercises.

Type of error	*n*	Minimum	Maximum	Mean	*SD*
Addition	21	0	3	.71	1.007
Replacement	21	0	19	3.43	4.760
Subtraction	21	0	10	2.81	2.562
Recognition	21	0	8	1.71	2.194
Other	21	0	2	.38	.669
Total	21	2	30	9.05	8.36

Table 5
Means for number of errors per type of error and in total for gender, age at loss of vision, and school grade.

Variable	Addition	Replacement	Subtraction	Recognition	Other	Total errors
Gender						
Male						
Mean	.50	1.40	2.90	1.10	.30	6.20
SD	.972	1.506	2.558	1.287	.483	4.541
Female						
Mean	.91	5.27	2.73	2.27	.45	11.64
SD	1.044	5.951	2.687	2.724	.820	10.289
Age at loss of vision						
Congenital						
Mean	1.09	2.18	2.73	1.36	.55	7.91
SD	1.14	3.76	2.94	1.86	.69	8.23
Adventitious						
Mean	.30	4.80	2.90	2.10	.20	10.30
SD	.68	5.53	2.23	2.56	.63	8.77
Level of education						
Primary						
Mean	1.00	4.18	2.64	2.73	.55	11.09
SD	1.18	5.53	2.54	2.24	.82	8.23
Secondary						
Mean	.40	2.60	3.00	.60	.20	6.80
SD	.69	3.86	2.71	1.58	.42	8.34

congenitally blind made significantly more errors regarding the error type "addition": $t(19) = 1.96$, $p \cong .05$.

Finally, a 2-way ANOVA (see Figure 1) showed that there was significant interaction effect between grade and age at loss of vision—$F(3/17) = 3.09$, $p = .05$—regarding the "recognition" type of error. Specifically, elementary school students who were adventitiously blind made more errors in "recognition" type, compared to their peers who were enrolled in secondary education and were also adventitiously blind.

Discussion

It seemed that according to the findings of this study, female participants (gender), students who were adventitiously blind (age at loss of vision) and elementary school students (grade level) made more errors on average in all subscales. Nevertheless, the average number of errors correlated very highly with each other,

Table 6
Results of *t*-tests for number or errors per type of error and in total for gender, age at loss of vision, and school grade.

Variable	Addition	Replacement	Subtraction	Recognition	Other	Total number of errors
Gender	*ns*	≅.05	*ns*	*ns*	*ns*	*ns*
Age at loss of vision	≅.05	*ns*	*ns*	*ns*	*ns*	*ns*
Level of education	*ns*	*ns*	*ns*	< .05	*ns*	*ns*

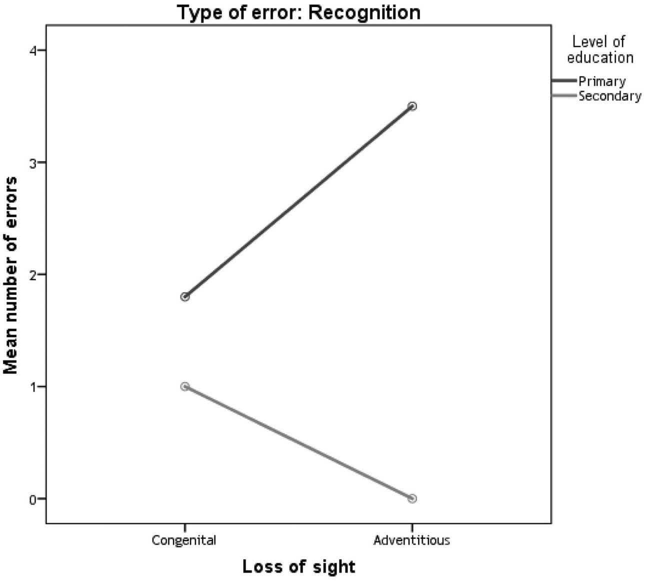

Figure 1. Mean number of errors of recognition per age at loss of vision and level of education.

signifying that performance in all three subscales was very similar. It seems that these findings do not support the contention that braille readers have demonstrated that they read meaningful words more accurately than pseudowords (Millar, 1997). The braille readers in the present study did not benefit exceptionally from semantic information. It may be that the many suffixes in the Greek language, in conjunction with the mixed meaningful and nonmeaningful words in subscale 3, made braille readers more cautious and caused them to prefer to adopt the "reading the entire word" strategy (see the significant correlation between performance and grade in the third subscale, Table 3).

Taking into account the results of the present study, it can be argued that students who are visually impaired may adopt an effective decoding mechanism quite early and may make good use of this skill throughout all school years (Veispak et al., 2012). Nonetheless, it seems that vocabulary enrichment via reading experience and maturity are essential, so that secondary education students can distinguish meaningful words.

Vakali and Evans (2007) also indicated that the prevalent error type in their research was "repetition," whereas in the present study the most common error type was that of "replacement." A positive correlation was found between "replacement" and "subtraction" types of error; "replacement" and "recognition"; and total number of errors with "replacement," "subtraction," and "recognition," respectively. Errors of "replacement" probably indicate that visually impaired students are likely to be confused by either symmetrical characters (mirrorings), the density of braille dots, or the position of the braille dots. For example, Greek braille character "*ι = iota*" (dots: 2, 4) is often confused with the symmetrical character "*ε = epsilon*" (dots: 1, 5). Additionally, character "*ν = ni*" (dots: 1, 3, 4, 5) was often replaced by the character "*τ = taf*" (dots: 2, 3, 4, 5). This finding indicates that misperceptions of the position of, for example, one braille dot may lead to a “replacement” error. It also seems that letter subtractions may be related to the position of braille dots that form a braille character. For instance, braille characters that include braille dots 3 or 6 are more likely to be omitted. Recognition errors may be attributed to the position and density of braille dots (Nolan & Kederis, 1969); to ineffective reading scanning; to vocabulary deficiencies (Pring, 1984); or to the tendency of braille readers to predict the suffix of the word instead of decoding it (Millar, 1997).

Finally, this study indicated correlations among error categories and gender, age at loss of vision, and level of education. Participants in secondary education made significantly fewer errors of “recognition,” which may be attributed to the enrichment of their vocabulary as well as to their increased reading experience. It is also noteworthy that in the “recognition” type of error, there was a significant interaction effect between grade and age at loss of vision. In fact, elementary school students who were adventitiously blind made more errors of the “recognition” type, compared to their peers with adventitious blindness who were enrolled in secondary education. This finding may imply that initially students who were adventitiously blind confronted decoding difficulties during primary education, which may be attributed either to nonincorporated reading strategies or to inexperience, since the braille code might not have been their initial reading medium.

The results of the present research may affect aspects of braille reading that have potential implications for instruction. This study subscribes to the argument that literacy instruction should focus primarily on basic reading skills such as decoding, so that students who are blind can develop reading skills at an appropriate rate and can keep up with their sighted peers (Wall Emerson et al., 2009). The strategy of “reading the entire word” should be regarded as the most effective decoding strategy for braille readers, and it also ultimately promotes braille reading accuracy (in reading either meaningful or nonmeaningful words). Moreover, it would be beneficial to encourage students with visual impairments to enrich their vocabulary and “reading readiness” by reading literature (Pring, 1984; Wall Emerson et al., 2009). In sum, when reading instruction and braille instruction are offered consistently within a structured format, students who are visually impaired are more likely to accomplish higher literacy performance (Wall Emerson, Sitar, Erin, Wormsley, & Herlich, 2009). The affects, if any, of gender will not be addressed in this article because of the small sample.

Limitations and future research

The present study has several limitations that do not allow many causal associations to be drawn. Initially, the sample was small. It is critical to conduct the same research study in a larger sample in order to reaffirm and generalize the findings and to include gender as well. Such replication would lead to more systematic research in the area of braille reading accuracy, including more quantitative and qualitative aspects. Furthermore, in relation to the students’ proficiency in braille, it must be remembered that no instruments were used; rather, the authors adopted the teachers’ assessments and the input of the Ministry of Education. Also, correlations between educational settings (specialized and mainstream) and the performance of participants were not conducted due to the small sample. In a large-scale study it would be interesting to correlate students' performance in relation to educational settings. Finally, future research could also focus not only on semantic recognition of words in isolation but also on context, to see if there are differences related to the same variables (particularly age of learning braille and grade).

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