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COGNITIVE BACKGROUND FACTORS OF READING DISORDER IN BRAILLE READING IN THE CASE OF CHILDREN WITH SEVERE VISUAL IMPAIRMENT

THESIS SUMMARY

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2018

INTRODUCTION - PROBLEM IDENTIFICATION

Exploration of reading and reading disorder has been of particular concern to researchers for decades. There are more and more accurate models on the topic based on the results of cognitive developmental neuropsychology, cognitive neuroscience and psycholinguistics. Our knowledge of reading development, adult reading routines, reading disorder, the issues of developmental dyslexia, and their neuroscience background is growing (Csépe, 2014a, 2014b).

Studying blind people's reading ability can be traced from the 1960s. Initially, researchers studied the construction of Braille character (Nolan & Kederis, 1969), later, with the spread of imaging technologies, the attention turned to the brain background of tactile reading (Théoret et al., 2004, Reich, Szwed, Greaney and Amedi, 2011; Bedny, 2017 etc.). At the same time, more accurate results emerged about the perception functions of blind people (Collignon et al., 2013; Bedny, Richardson, Saxe, 2015, etc.). However, a model-based description of Braille reading is still awaited. There is also a small number of studies on Braille reading disorder. At present we have little knowledge about the cognitive background of tactile reading, and even less about the reading disorder and its background. No significant work has been done in our country yet. With this research, we desire to start to make up this shortfall.

THEORETICAL FRAMEWORK OF THE RESEARCH

Reading disorder can be defined as a learning disability of neurological origin, where a person has difficulty with reading even though he has average IQ, adequate education and well-functioning sensory organs. Reading itself is an extremely complex process based on existing linguistic and visual cognitive processes. The development of reading requires continuous, progressive reorganization and adaptive specialization of the brain network and behavior (Tóth & Csépe, 2009). Its complexity is demonstrated by the fact that in the development of reading the words (at least) four basic cognitive processes play a prominent role, and the existence of a well-functioning neural network ensures success in reading acquirement and reading. These cognitive factors contributing to reading – the lack of which causes the reading disorder - are *phonological awareness*, *knowledge of the letters*, rapid automatized naming (RAN) (Ziegler & Goswami, 2005), the ability of *orthographical process* and the *working memory*. Though the importance of working memory is challenged by some researchers (Oakhill, Cain, & Bryant, 2003), it has a pronounced role in the research of blind people and the interpretation of Braille reading. Also, mental rotation in present research has special significance due to the blind group. It is important that the generalization of the mirror image is not a sign of reading disorder, but this issue is often present till adolescence (or even beyond that) in case of children with dyslexia. According to Dehaene's (2005) brain re-utilization hypothesis, it is to be understood that during the learning process of reading the brain must learn to ignore the mirror image generalization (quote Csépe, 2006, p. 94).

As for cognitive markers of reading at the level of words, differences can be observed in the case of blind children. Blind children perform better than sighted children in sound-letter matching and syllable segmentation tasks, but their performance in sound segmentation tasks is very poor (Hatton, Erickson & Brostek, 2010). Blind students' RAN task results largely correlate with the speed of performing phonological awareness task. There is a tendency-like correlation between RAN and reading speed. In their case, there is a correlation between the RAN and the reading punctuality of nonwords. The reason for this is that for blind people the recall from the lexicon is not only related to the speed of reading but also to the accuracy of reading, regardless of the length or awareness of the word (Veispak et al., 2012b). Blind people show better performance in verbal short-term memory tasks (Hull & Mason, 1995; Pring, 2008), but there is no difference between the two groups regarding the performance of verbal working memory tasks (Rokem & Ahissar, 2009; Swanson & Luxemburg, 2009). The advantage of blind persons in short-term memory tasks is particularly evident in the case of serial information. Better performance in seriality is also beneficial for Braille reading, due to the succession of Braille persistence. In the case of number and nonword repetition tasks, the blind group performs better. However, if the tasks are embedded in noise, the advantage disappears and the results of the two groups are equalized (Rokem & Ahissar (2009)). Thus, the blind group's advantage in verbal memory exists only under certain conditions.

OBJECTIVE OF THE RESEARCH

This paper examines the cognitive background of Braille reading disorder by analyzing the reading performance and cognitive functions of primary school students aged 7 to 15 years. Just when examining the atypical development of reading, in the present work we are also looking for factors that can show which differences lead to the atypical reading of blind children.
During the research, we would like to explore the specificities of the reading parameters (speed, accuracy) of sighted and blind children between 7 and 15 years of age by reading words and nonwords with a various number of syllables. We look for differences in the reading of the two groups, focusing on age subgroups. During the course of the study, we also look for the tasks and tools that can be used to assess the cognitive function of both sighted and blind children quickly and accurately by diverging from executing only verbal tasks. We focus heavily on linguistic (especially phonological) and memory functions, and, in a "blind-specific" way, examination of space functions is also in the center of our research. The main purpose of the study is to explore and compare the reading features of the sighted children with and without reading impairment, and the blind children with and without reading impairment, and also to identify the characteristic cognitive background factors of the groups, taking the previously mentioned group-specific (blind-sighted) characteristics into account.

QUESTIONS OF THE RESEARCH

Due to the exploratory character of the research and the fact that in our country surveys in the subject matter have not been carried out so far, we formulate research questions instead of setting up hypotheses.

1. Concerning the reading parameters
    a. Is there a specific difference between blind and sighted children aged 7 – 15 regarding their reading speed and accuracy?
    b. Is there a change in the results of reading indicators of blind and sighted children after the grouping according to age?
2. Concerning the memory, linguistic and spatial adaptation indicators of 7 to 15-year-old blind and sighted children
    a. What are the memory, linguistic and spatial adaptation indicators that are different between blind and sighted children?

b. Are there any memory, linguistic and spatial adaptation indicators that could influence the interpretation of the results of other tests with blind or sighted children because of their group specificity?

3. Concerning the relation between reading and cognitive architecture in blind and sighted groups

Do the groups of blind children with and without reading disorder have the same cognitive pattern as the groups of sighted children with and without reading disorder have?

4. Concerning the reading models and reading disorder models

a. Which of the reading descriptive models are suitable for the explanation of reading both writing print and writing Braille?

b. Which models of reading impairment are suitable to explain the reading disorder of both writing print and writing in Braille?

STRUCTURE OF THE RESEARCH, METHOD, PERSONS INVOLVED IN TESTING

To reveal the cognitive pattern of blind good readers (Bgr) and blind children with reading disorder (Brd), and compare them to the results of the sighted good readers (Sgr) and sighted children with reading disorder (Srd), we need to know the reading indicators of the blind and the sighted groups, so we also performed a large sample reading survey. *As we do not have a set of tasks that can adequately detect cognitive indicators for blind children, we have created our own set of tasks.* The 3 dimensions of our tasks (memory, spatial processing, linguistic functions) are arranged in a similar structure for both blind and sighted groups. *The subtest of spatial processing is also our own tool with a task layout developed by ourselves.*

The sample was composed of blind and sighted students of 7-15 years with over VIQ 85. We excluded from the study all the blind students with the diagnosis of severe learning, attention or behaviour control disorder and autism spectrum disorder; or whose T-value exceeded 70 at the CBCL-Attention Problem Scale. Blind group[1]: n = 130; the sighted group: n = 141. The sighted control group was matched by gender, age, VIQ, date of birth and birth weight. As in the blind group, the proportion of examined premature children born with extremely law weight is high (61.6%), matching according to the date of birth and birth weight is relevant. Groups set up based on gestation time are: blind-low birth weight premature (BLBW) and blind-full term (BFT), sighted-low birth weight premature (SLBW) and sighted-full term (SFT). For a more detailed study, both the blind and the sighted group were organized into three age groups: Group 1: 7; 0-8;11 years, $n_{blind} = 36$, $n_{sighted} = 39$; Group 2: 9;0-10;11 years, $n_{blind} = 31$, $n_{sighted} = 33$; Group 3: 11;0-15;6 years $n_{blind} = 63$, $n_{sighted} = 69$.

We have created groups of 16 people to explore the reading specialties and the characteristic cognitive background factors of the groups of the sighted good readers (Sgr), the sighted children with reading disorder (Srd), the blind good readers (Bgr) and blind children with reading disorder (Brd).

[1] The blind sample (n=130) covered the entire Hungarian mentally healthy blind population in the given age range.

RESULTS

1. The reading speed and accuracy of blind and sighted children aged 7 to 15 years

Blind children read *less accurately* compared to their sighted companions, and the number of reading errors increases with the growing number of syllables. But the reading of *nonwords* is *less inaccurate* compared to reading words. The accuracy of reading is not significantly influenced by the number of syllables in neither group, but when reading nonwords, the growing number of syllables resulted in growing number of errors in both groups. The blind group reads the 1-syllable words less accurately than words with 2 and 3-4 syllables. There was a significant difference between the two groups in the reading accuracy of the *nonwords*. While the ***sighted*** group reads the nonwords with 1 and 2 syllables with the same accuracy, and the 3-4 syllable nonwords less accurately, the ***blind*** group makes more mistakes as word length grows. As for the *reading speed*, ***blind*** children read more slowly than their sighted companions, regardless of the type and the length of the words. Both groups read words faster than nonwords.

Reading accuracy and speed according to age groups

As for the ***sighted*** students, the results of all three age groups show the differences in the reading accuracy of words and nonwords, meaning that *in each age group* children involved in the survey *read the words more accurately than nonwords*. In case of ***blind*** students, there is no difference in reading accuracy of the two word types in the first two age groups. In the ***blind age group of 11 to 15 years***, it can be observed that Braille readers make significantly more mistakes in reading nonwords than words (Figure 1). If we take the results of the reading accuracy of the 3-4 syllables stimulus material, we can also conclude that the accuracy pattern of the 11-15 years age group equals with the word and nonword reading accuracy of sighted readers (Figure 2).

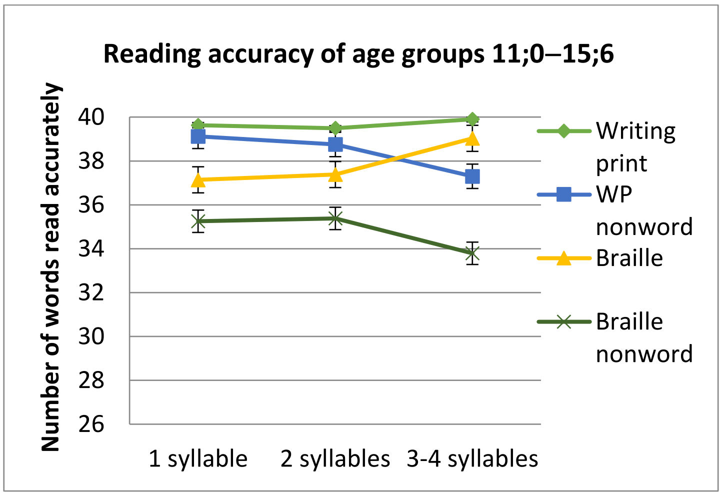

Figure 1. Reading accuracy of words and nonwords with different syllable numbers - age group no. 3.

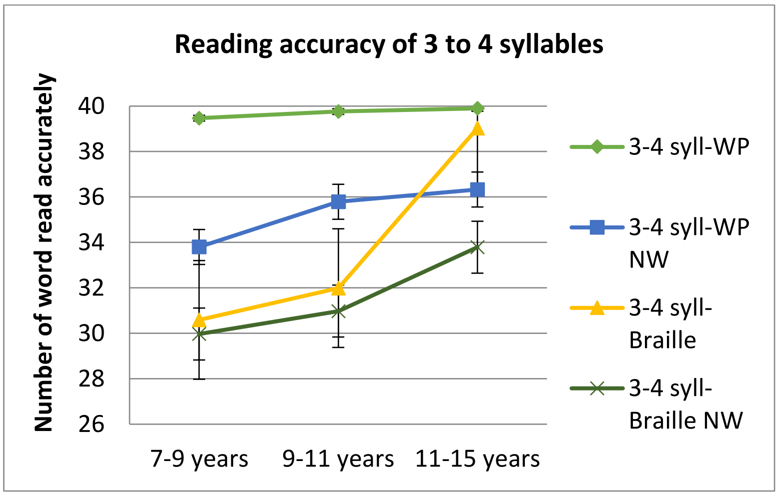

Figure 2. Reading accuracy of words and nonwords with 3 to 4 syllables

When analyzing the reading speed, we gained a significant effect *on the group* - Braille readers read slower than sighted readers; *on the age*, that is, in all groups, reading speed increases with age; and on the *word length* and *word type*, meaning that both groups read word faster than nonwords and as the number of syllables increases reading time elongates. While in case of sighted participants from the age group 7-9 and 9 - 11 the difference is measurable in the speed of word and nonword reading; this difference can be observed only in the 11 to 15-year-old age groups of blind students (Figure 4). Concerning the reading of 3 to 4 syllable words and nonwords, it can be seen that the reading speed of nonwords by blind students older than 11 years is slower than reading words. In the case of the sighted students, this difference can be discovered already in the first age group (Figure 4).

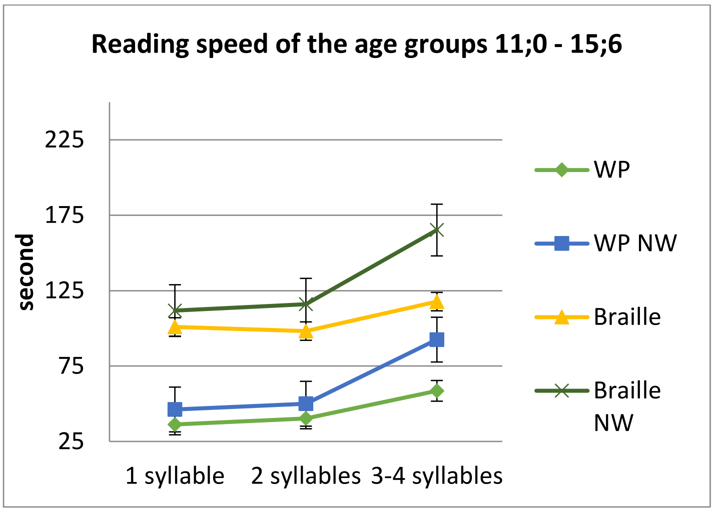

Figure 3. Reading speed of words and nonwords with different syllable numbers - age group no. 3.

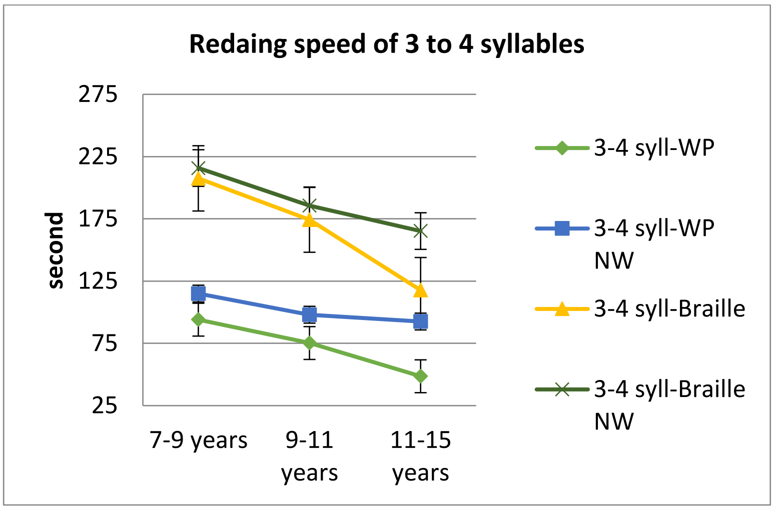

Figure 4. Reading speed of words and nonwords with 3 to 4 syllables

2. Examining mental rotation with the 'Flat Doll' mental rotation Task (FDT)

Regarding the *accuracy of rotation*, it can be said that blind children perform a larger number of errors compared to their sighted counterparts in the mental rotation task. The number of mistakes in the blind group increases with the growing angle size of rotation. Our results show that *the number of errors is influenced by the layout of the task*. In all four rotating task layouts ("A": recognition on body plane; "B": recognition in reflection; "C": naming on body plane; "D" naming in reflection) between the blind and the sighted group we can observe different error patterns after the 135 ° rotation. While the ***sighted*** group *made fewer mistakes after 135° rotation*, the *number of mistakes* in the ***blind*** group *increased with the growing size of rotation angles*. During the *tasks with the mirror* ("B" and "D"), the difference is even more pronounced, with the increase of angles the number of mistakes increases as well. *Between the performance of the two groups, we found a significant difference after 180 ° rotation.*

In all four rotation tasks layouts, BLBW children were mistaken the most often. In their case, it is most noticeable that in the reflection ("B" and "D") arrangement, the number of false answers increases compared to the answers on their own body plane.

When analyzing the *response time*, in all four task layouts, in both the blind and the sighted sample, a linear correlation can be seen between the angle between the two patterns and the time required for the decision. Significant prime effect was given to the group - blind persons involved in the test finish with the tasks slower compared to the sighted; to the birth time - in each group, premature children are working with greater response time; to the angle of rotation and the task layout - for both groups, the reaction times are higher when solving tasks "B" and "D", furthermore the reaction time increases with growing rotation angle. Also, full-term children need less reaction time to solve the task. The task of mental rotation seems to get tougher with the growth of rotation angles. It has also been proved that the reflection arrangement makes it more difficult to carry out the mental rotation. After breakdown into age groups, it can be said that the performance pattern of the blind group of 11-15 years equals the performance pattern of the sighted group.

3. Cognitive indicators of blind children aged 7 to 15

Memory function

Blind and sighted groups differ significantly only in the results of the Hungarian Nonword Repetition Test. According to the results of the four groups set up on the basis of gestation time and vision, premature children performed worse than term-born children; the **blind** groups achieved significantly better results compared to the sighted groups. Blind children begin to achieve better results in comparison with the sighted children when they become 9 years old, and this advantage will remain in the further age range. In the Digit Span Test and the Reverse Digit Span Test, the 4 groups achieved the same result. Although the result is not significant, it can be observed that blind children until the age of 9 perform the same results as sighted children, and then from the age of 9, their number span starts to get higher compared to their sighted peers. In the Listening Span Test, measuring the complex working memory, no significant deviation was found between the results of the four groups. However, after breakdown into age groups, after the age of 9, blind children achieve better results in this task as well than sighted children.

Spatial processing

The **blind** group exhibits a large lag behind the sighted control group in the field of spatial processing. The difference is more pronounced in the case of the reflection layouts. In the blind group, the outcome does not show deviation according to the time of birth, but in the (A) and (C) tasks there is a significant difference between the SLWB children and the SFT children. The two tasks are carried out in parallel with their own body, which is rarely encountered by sighted children, so this task, which is not „overlearned”, seems discriminatory between the two groups.

Language function

The indicators of blind and sighted groups only differ significantly in the task called *Phonemic verbal fluency*. Here, the unique "blind specific" word-seeking strategy of the children born with blindness can be observed. This is confirmed by the fact that there is no difference between the results of the BLBW and BFT group. During the task, the worst performance was achieved by the SFT group.

4. Cognitive background factors in the case of blind children aged 7 to 15

   a. Reading test

Concerning *reading accuracy*, children with reading disorder read less accurately than their peers without impairment, regardless of their condition of sight. The number of reading errors increases with syllables in groups with reading disturbances, again, regardless of their sight condition. The word length has no effect on the good reading groups. There was a ceiling effect in the sighted good reader (Sgr) group, while the blind good reader (Bgr) group also had a ceiling effect for the 3-4 syllable words. The worst results were achieved by the sighted children with reading disorder (Srd) when reading the 3-4 syllable words (Figure 5).

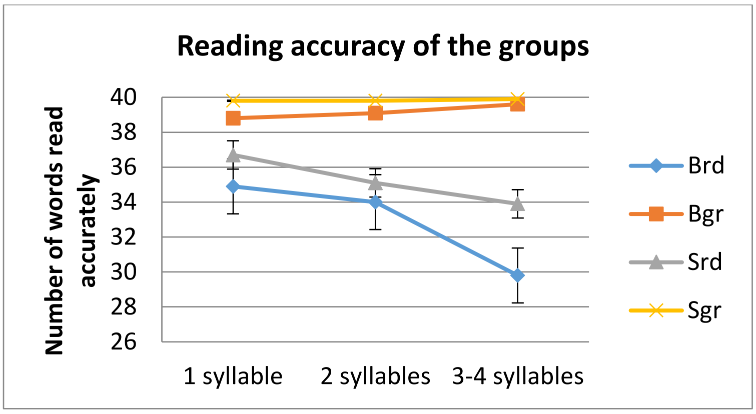

Figure 5. Reading accuracy of the four groups when reading words with different syllable numbers

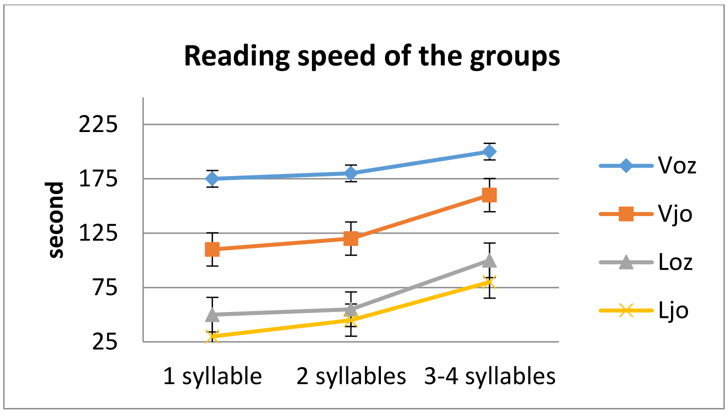

Figure 6. Reading speed of the four groups when reading words with different syllable numbers

During the examination of the reading speed, we gained a significant prime effect on the sight - Braille readers read more slowly than writing print readers, irrespective of reading (reading disorder/good reading) and word length; on the reading – good readers involved in the study read faster, regardless of sight conditions (Figure 6).

b. Cognitive indicators of blind children with reading disorder aged 7-15

- *Comparison of groups along cognitive functions*

Memory Function (Figure 7)

In the *Hungarian Nonword Repetition Test*, the significantly better results of the ***blind*** examined children retained according to the previous study. The prime effect of sight and reading is significant, as well as the interaction of the two variables. The best result was achieved by the Bgr group, the worst by the Srd group.

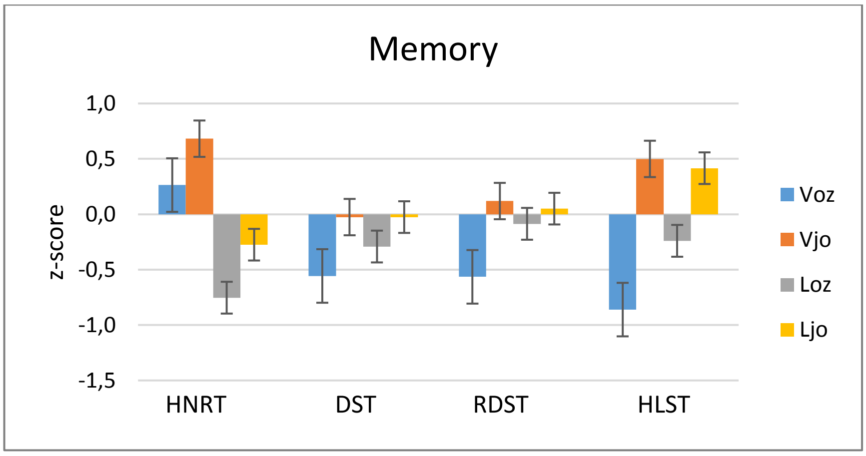

Figure 7.

Comparison of verbal working memory tasks along z-values in the four groups. (HNRT: Hungarian Nonword Repetition Test, DST: Digit Span Test, RDT: Reverse Digit Span Test, HLST: Hungarian Listening Span Test, Brd: group of blind children with reading disorder, Bgr: blind group of the good readers, Srd: group of the sighted with reading disorder, Sgr: good reader sighted group. The y error lanes indicate the standard error.)

In the *Digit Span Test*, groups with reading disorder performed worse, regardless of the sight conditions. In the *Reverse Digit Span Test*, the performance of the two groups of blind good readers and blind with reading disorder (Brd and Bgr) differs significantly. The *Hungarian Listening Span Test* does not show a significant prime effect on vision, but the interaction between reading and the two variables is significant. The group of blind children with reading disorder (Brd) performed the worst. The performance of blind good readers (Bgr) and sighted good readers (Sgr) is equal, but the performance of the blind group of reading disorder and the group of blind good readers (Brd - Bgr) is significantly different.

Spatial processing (Figure 8)
Blind groups, regardless of reading, show a great deal of backlog in the tasks of spatial processing compared to the sighted groups. For each task, it can be said that irrespective of vision, the groups of children with reading disorder perform worse. The worst is the performance of the blind children with the reading disorder, the best was that of the group of sighted good readers.

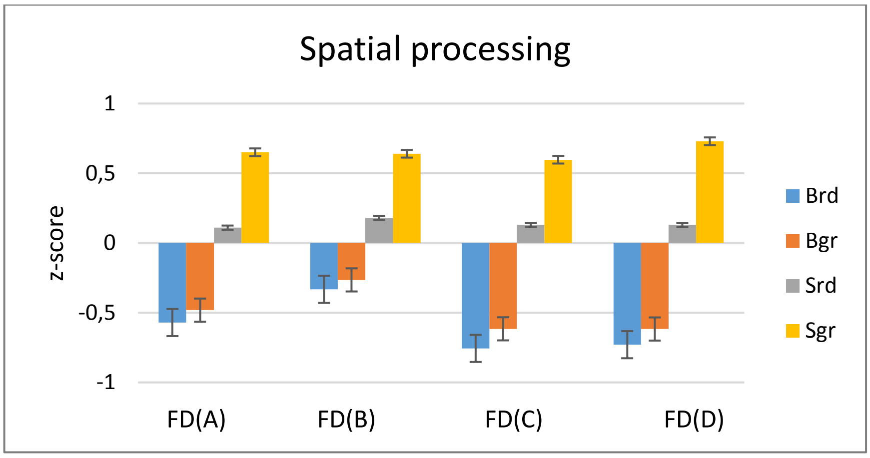

Figure 8.
Comparison of spatial processing tasks along z-values in the four groups(FD(A) (B) (C) (D): Flat-Doll mentak rotation tasks, Brd: group of blind children with reading disorder, Bgr: blind group of the good readers, Srd: group of the sighted with reading disorder, Sgr: good reader sighted group. The y error lanes indicate the standard error.)

In each task, the group of the sighted persons with the reading disorder (Srd) performed significantly worse than the group of sighted good readers (Sgr).

Language function (Figure 9)
During the RAN task, good readers achieved significantly better results compared to groups of students with a reading disorder. The result of the blind group of with the reading disorder (Brd) was far behind the results of the other groups.

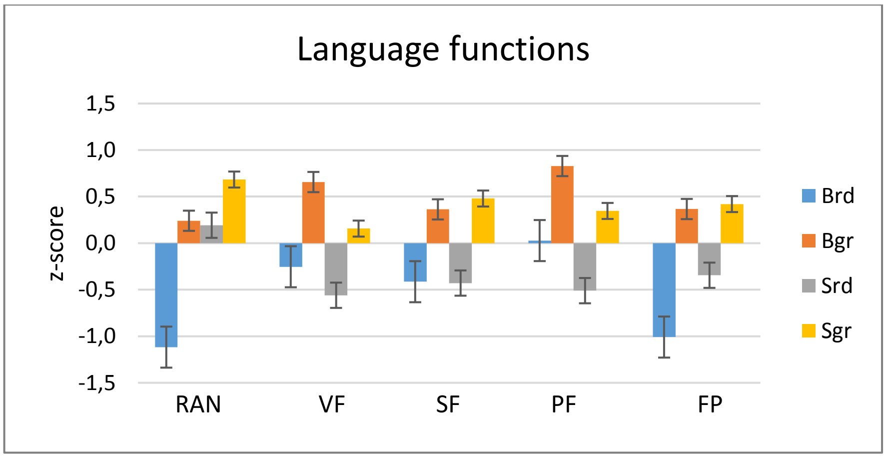

Figure 9.
Comparison of linguistic functions along z-values in the four groups (RAN: Rapid naming, VF: Verbal fluency, SF: Semantic fluency, PF: Phonemic fluency, FP: Phonological processing, Brd: group of blind children with reading disorder, Bgr: blind group of the good readers, Srd: group of the sighted with reading disorder, Sgr: good reader sighted group. The y error lanes indicate the standard error.)

In a *verbal fluency* test, groups with reading disorder performed more poorly compared to their good reader companions, regardless of sight. In the *semantic fluency* task, children with the reading disorder in both the blind and the sighted groups performed worse. In the *phonemic fluency* task, the performance of the blind groups of reading disorder and good readers (Brd-Bgr), the blind and the sighted group of reading disorder (Brd-Srd), the group of blind and sighted good readers (Bgr-Sgr) are significantly different. The *phonological processing* task was performed worse by the subgroup of reading disorder in both blind and sighted groups. Here, too, we can observe that the group of blind children with the reading disorder is immensely lagging behind the other groups.

The relationship between word-level reading and the cognitive functions of reading

In case of the ***blind group with reading disorder***, Reverse Digit Span test, Hungarian Listening Span Test, as well as the indicators of Flat-Doll C, Flat-Doll D, rapid naming and phonemic awareness showed a relation with *reading accuracy*. With *reading fluency,* Flat-Doll C, Flat-Doll D, language functions, rapid naming, and phonemic awareness showed a strong positive relationship.

In the ***blind group of good readers***, Hungarian Learning Span Test, rapid naming task, as well as Flat-Doll C, Flat-Doll D tasks showed a moderate relationship with *reading accuracy*. With *reading fluency*, phonemic awareness and the rapid naming tasks, Flat-Doll C, Flat-Doll D tasks measuring the spatial processing indicated a significant relationship.

In the case of the ***sighted group with a reading disorder***, with the *accuracy of reading*, the Hungarian Nonword Repetition Test, the Flat-Doll C, D, and the rapid naming task indicated a connection. Flats-Doll C, D, and the rapid naming indicators indicated a strong positive relationship with r*eading fluency.*

In the ***sighted good reader*** group, with the *accuracy of reading*, the Hungarian Listening Span Test and phonological processing task showed a moderately strong relationship. With *fluency in reading*, rapid naming task and phonemic awareness indicator showed relation.

Cognitive indicators of word-level reading

In the ***blind group***, significant predictors of the word reading accuracy are the phonological processing and spatial processing tasks accounting for 49% of the variance of reading accuracy. Rapid naming, phonological processing, and spatial processing tasks are responsible for 47% of the reading fluency variance. In the sighted group, phonological processing is responsible for 41% of the reading accuracy, while rapid naming and phonological processing are responsible for 46% of the reading fluency variance. **Phonological processing, rapid naming, and spatial processing tasks are responsible for the variance of reading performance in the two groups.**

In the next step of the analysis, we are looking for those independent variables that *significantly discriminate* between the good reader and the reading disorder subgroups within the groups. According to the results of the discriminant analysis, in the ***blind group***, the tasks measuring rapid naming and phonological awareness proved to be significant discriminators. If we predicted by the two variables whether a blind child is a good reader or has a reading disorder, there would be 74.2% chance to get the correct result, i.e. 24 of 32 blind children in the sample could be placed in the appropriate group. However, if we included the Listening Span Test variable in the function, knowing the **three variables – rapid naming, phonological processing, Hungarian Listening Span task - we could correctly classify 86.4% of the blind children**, that is, in the case of our sample, we could place 27-28 children out of 32 in the appropriate group. As for the sighted group, also the **rapid naming and the phonological processing tasks** proved to be the significant discriminators. If we predicted by the two variables whether a sighted child is a good reader or has a reading disorder, there would be 61.1% chance to get the correct result, i.e. 19-20 of 32 sighted children in the sample could be placed in the appropriate group. However, if we included either of the spatial processing **Flat-Doll C or D task** in the function, knowing the two variables **we could correctly classify 89.2% of the sighted children in the appropriate group**. This means 28-29 out of the 32 sighted children.

DISCUSSION AND RESPONSE TO RESEARCH QUESTIONS

1. Concerning the reading parameters

Blind persons' *reading speed* increases with the number of syllables in the same proportion whether it is a word or a nonword. As for sighted persons, however, the increase in the number of syllables only influences the reading speed of the nonwords in a significant way, which can be explained by the choice of the grapho-phonological reading path, i.e. the reading with phonological decoding.

In case of the words, *reading accuracy* is not significantly influenced by the syllable number, neither in the blind nor in the sighted sample. However, in both groups, nonword reading is performed with a higher error number when the number of syllables is increased. In the case of nonwords read by sighted persons, the increase in the syllable number leads to a faster decrease in reading accuracy.

The role of age

In the case of sighted examined persons, the difference in the speed of reading words and nonwords can be measured between the age group 7-9 and the age group 9 - 11, but in the blind sample, this difference can be observed only in the age group 11 to 15 years. During the 3-4 syllable word and nonword reading, nonword reading speed of a blind student is slower than the reading of words after the age of 11. For sighted students, this difference can be discovered already in the group of students aged 7 -9.

As for the sighted students, the differences can be observed in the results of all three age groups in reading accuracy of words and nonwords, meaning that test people read the words more accurately than nonwords in each age group. When it comes to blind students, the reading accuracy of the two word types does not show any difference in the age groups 7-9 and 9-11. In the blind age group of 11 to 15 years, it can be observed they read the nonwords with a significantly greater error rate than words. Concerning the reading accuracy of the 3-4 syllable stimulus materials, we can state that, again, the reading accuracy pattern of the age group 11 - 15 is equivalent to the word and nonword reading accuracy of the sighted students.

Compared to the 7-9 year old and the 9-11 year old group, the reading speed of the nonwords is more influenced by the word length in the age group of 11-15, i.e. in the *group of 11-15 years* the word length effect is more pronounced when reading nonwords, the same result as what we experienced in reading print writing. *In this range of age, a clear difference occurs in case of both sighted and blind examinees in the strategy between reading words or nonwords. In both groups, it can be observed that while the reading of nonwords the speed and accuracy improves only slightly, the reading of words is significantly faster and more accurate. The reason for this is that in the case of words, the decreasing word length effect is a sign of the*

formation of word-form-based reading. Developments in the reading of nonwords alone indicate a more efficient development of decoding. Our results can be matched to classical network models and confirm the existence of semantic and phonological pathways described in dual-route reading theories.

While *in the case of nonwords, in the blind group of 11-15-year-old students we encounter with phonological decoding, the reading of words is increasingly based on automatic word recognition,* that is, contrary to what Pring (1982, 1984, 1994) or Hughes (2011) claims, *blind people do not stick at letter reading, they do also develop the global word form*.
In the blind group of aged 11 - 15 years we only found a significant difference in the case of nonwords, the same we found in the sighted group.

2. Concerning the indicators of memory, linguistic and spatial processing for blind and sighted children between the age of 7 - 15

Based on the results of the tasks analyzing the *memory functions* we can say that between the blind and the sighted groups we found a significant difference only between the results of the Hungarian Nonword Repetition Test. **In using the phonological loop component of the memory, the blind group achieved significantly better results, however, this significant benefit appears only after the age of 9.** The result has not been novel in the light of previous study data, as children born with blindness achieve better results in tasks related to verbal memory than their sighted peers, visually impaired and those whose blindness is not congenital (Dekker, 1989). The reason for better memory performance is that blind people encode auditive verbal information more effectively (Röder, Rösler, & Neville, 2001), although according to Rokem and Ahissar (2009) there is no difference between the performance of blind and sighted groups regarding verbal working memory tasks.
Therefore, it can be said, that if a blind child achieves a significantly better result than the sighted examined persons in the Hungarian Nonword Repetition Test, it is possible that this advantage is not a personal ability but a "blind specific" advantage. It is also important that the worse performance of a blind-low birth weight premature child is not a unique feature, either, but a deviation in the performance characteristic of the premature blind group.

During the mental rotation tasks measuring *spatial processing*, the blind group exhibits a significant backlog compared to the sighted group. According to Ungar, Blades, and Spencer (1995), the underlying difficulty in the mental rotation for blind people is the ineffective or less effective mode of spatial coding, which can be blamed not on the success or failure of tactile perception, but the effectiveness or success/failure of handling the mental representation. It is a fact, however, that during mental rotation, the same activity can be observed in both the sighted and the blind persons' left superior parietal cortex next to the intraparietal sulcus. Previously, Röder, Rösler, and Hennighausen (1997) demonstrated that the posterior parietal cortex is active during tactile mental rotation as well as during visual rotation (Alivisatos & Petrides, 1997).
Impact of premature birth in the spatial processing function
Although there is a deviation in the results of premature and term-born blind children, **significant differences were observed in the performance of the two subgroups of the sighted group: premature children involved in the test performed much more poorly**. The fact of premature

birth may delay the recognition of spatial conditions and the formation of spatial representation, which disadvantage is even present at the school age (Györkő, Lábadi, & Beke, 2012).

In the case of *linguistic functions,* **the blind and sighted group differ significantly from each other in the results of the Phoneme fluency test. The advantage of the blind group points to a "blind specific" word-seeking strategy that provides verbal fluency without the use of semantics. The present test result optimizes and realizes the interpretation of the results of the blind groups in other phonemic fluency tasks.**

3. The correlation between reading and cognitive architecture in the blind and sighted groups

Within the *memory function* area, the blind group has retained its advantage in the Hungarian Nonword Repetition Test, but the performance of the blind group with the reading disorder (Brd) is significantly worse compared to the bling group of good readers (Bgr). According to Swanson and Luxenberg (2009), in the background of the weakness of the phonological loop component of the memory is the weakness of the phonological processing, which may hinder the processing.

It is typical of spatial processing that performance is sharply divided along the dimension of vision. **The blind group performs significantly worse than the sighted group in each mental rotation task**. However, while there was no significant difference between the results of the blind group, **the performance of the sighted group with reading disorder differed significantly from the results of the sighted good readers**. The explanation for the worse performance of the group with the reading disorder may be the dysfunction of the parietal cortex or the anomaly of cerebellar functions (Rüsseler, Scholz, Jordan & Quaiser-Pohl, 2005) or the dysfunction of the posterior parietal area (Shaywitz, 1998).

Examination of spatial work has not been done with blind people with reading disorder so we can not present here any other results, neither their interpretation. There is no data either on what cortical-level processes can be observed during mental rotation of blind people with a reading disorder. Based on this study, we can say that **in the blind group of 7 to 15 years, the spatial processing ability is so low, probably because of the lack of vision, that in case of the blind group of good readers, better spatial functions expected on the basis of the sighted group's results can not be displayed.**

During the examination of the *language functions,* consistently with the results of dyslexia research, we found that the linguistic processing function showed the most significant dysfunction in the groups showing reading disorder, regardless of sight. **We found significant differences in the results of the rapid naming, the fluency tasks, as well as the phonological processing task in both (blind and sighted) groups, while the group with reading disorder falls short.** The performance of the blind group with reading disorder (Brd) is significantly the worst in the RAN and phonological processing tasks. **When examining the blind and the sighted groups, we found that in the blind group the outstandingly good results of the phonemic fluency task as part of the fluency tasks lead us to think of a "blind-specific" word-seeking strategy as an explanation**. There is also a significant difference between the performance of the blind group with reading disorder (Brd) and the blind good readers (Bgr) with the benefit of the good reader group.

The explanation for the bad achievement of the phonological awareness and rapid automatic naming tasks is (or maybe) the problem of phonological processing, phonological awareness, and processing speed or the weakness in recall the phonological code from the memory. As we notice a marked difference between the two linguistic areas, the result can be interpreted in the framework of the double-deficit model. According to the theory, two distinct sources of dyslexia are possible, the phonological deficit and the lack of general processing speed.

According to our results, irrespective of modality, rapid automatic naming and phonological processing are the abilities that are the most decisive functions of word-level reading for both sighted and blind groups.

Based on the results of the tasks measuring cognitive functions, we consider that in the present sample, in the age group of 7 to 15 years, no identical cognitive pattern of the sighted and blind subgroups with reading disorder can be found. The same can be said of the comparison of the cognitive function in the blind and sighted groups of good readers.

When comparing the performance of the groups with reading disorder (Brd-Srd) and good readers (Bgr-Sgr), the previously described specific performance characterizes the blindness is displayed: better performance in the Hungarian Nonword Repetition Test and the phonemic fluency task, and huge arrears in the spatial processing function. This means that there is a different cognitive pattern between the blind children with reading disorder and blind good readers. A different cognitive pattern can be detected also in the sighted groups of reading disorder and good readers.

3. Concerning the reading models and reading disorder models

An important result of this study is that *a clear and unambiguous difference is taking shape between the reading strategies of words and nonwords in the age group of 11-15, both in the blind and in the sighted groups.* In both groups, it can be observed that while the reading of nonwords is faster and more accurate only slightly, the reading of words is significantly faster and more accurate. The reason for this is that in the case of words, the decreasing word length effect is a sign of the formation of word-form-based reading. Development in the reading of nonwords alone indicates a more efficient development of decoding. **Our results can be matched to classical network models *and confirm the existence of semantic and phonological pathways described in dual-route reading theories*. It can also be emphasized that in our study we can observe an effective and automatic word recognition, which is reflected in the speed and accuracy of reading the words. While phonological decoding occurs in the case of nonwords in this age group as well, the reading of words is increasingly based on the automatic word recognition. If the existence of the direct reading pathway was clearly proved in reading Braille, it would basically transform thinking about Braille reading.**

The role of the visual word form area (VWFA) related to sighted readers is becoming growingly emphasized in Braille reading as well. Reich and his colleagues (2011), similarly to what was found after examining sighted people, assessed left-wing activity of VWFA when they examined the reading of blind persons without visual experience, demonstrating that VWFA is not just a visual word form recognition system but a metamodal area specialized on reading. The VWFA area is a part of the network responsible for reading that improves significantly between the age of 7 and 12, according to the study carried out by Ben-Shachar, Dougherty, Deutsch, and Wandell (2011). This fact supports also the double-deficit model, so it is more and more likely that in the case of Braille reading, there is indeed a direct and an indirect path with different brain processing circles. **Our own test result can also be linked to the above, i.e. while in the case of nonwords, in the blind group of 11-15-year-old students we encounter with phonological decoding, the reading of words is increasingly based on automatic word recognition. If in the case of Braille reading, the central role was played by VWFA in the operation of direct reading, then the direct pathway of reading in both modalities can be explained by the neural recycling hypothesis (Dehaene & Cohen, 2007).**

There has been no model to describe the Braille reading disorder yet. However, the findings so far (Greaney & Reason, 2000; Veispak & Ghesquière, 2010; Veispak et al., 2012b; Veispak et al., 2013) can be incorporated into one of the "sighted" models. These are mostly single-factor reading models: the phonological deficit hypothesis model, the temporal processing deficit hypothesis, or the specific auditory deficit model.

The practical relevance of the research

By using our "blind specific" results, not only the diagnostics can be made more accurately, but also the existing pedagogical methodology and toolbox. In teaching the Braille character structure, devices of decreasing size are used currently in our country suitable for both local and numerical naming of the Braille characters. According to Millar's theory (199), blind children interpret characters as structures and not as global forms, furthermore, the most typical feature of a character is the dot density of the cell instead of the position of the dots in the cell. Blind children learn the letters based on the number of dots, in parallel with their positional naming, which contradicts the results of Millar (1997). It is also necessary to reconsider that the cause of reading errors is often explained in everyday practice by tactile difficulties. Based on the results of Veispak et al. (2013), it can be stated that the quality of tactility indeed influences the accuracy and the speed of reading, but this is (or this can be) relevant only during the learning period of reading. **According to our results, in the case of blind children with reading disorder, the most important task is improving the rapid naming, the phonological awareness, the central executive function of memory processes, the semantic processing, coding and recall, i.e. the parallel operational load.**

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