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ASPECTS FOR THE IDENTIFICATION AND DIFFERENTIAL DIAGNOSTICS OF READING DISORDERS

Thesis summary

Supervisor: Professor Valéria Csépe

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Introduction – problem definition

Despite the expansion of the visual communication in our modern, technology based society the written language and the reading skill represent an important factor in our whole life. For this reason some children who are unable to attain adequate reading and spelling skills despite normal intelligence, adequate educational instruction and normal sensory functioning are at a disadvantage.

In our country the special needs education, more precisely the speech therapy are in charge of the identification and intervention of reading and writing disorders. The qualification and the examination of the 'reading disorder-difficulty-delay' (SEN: Special Educational Needs versus "Social Integration Learning and Behavioural Difficulty", abbreviated BTM in Hungarian) is the responsibilty of the Local Educational Counseling Service and the Educational Supervisory Committee. Currently there is only few standard processes and tests used for performing complex diagnosis, furthermore there are only recommendations for a uniformed diagnostics protocoll (Zsoldos, 2006; Kuncz et al, 2008).

At the same time researches of the cognitive neurodevelopmental pscychology, the cognitive neuro-science and the neurolinguistics made significant progress during the last decades, as a result of which the processes and tests elaborated and standardised on the basis of theory-based researches become increasingly available in the clinic for the identification of the neurodevelopmental disorders. (Racsmány, 2007; Racsmány and Pléh, 2001)

We would like to contribute to this mainstream with our research by applying a new neuro-pscychological assessment recently introduced for researches in Hungary.

The main objective of our research was to show the patterns of cognitive ability that may contribute to different pathways in the development of reading, so in the light of our results we could offer some relevant, practical considerations regarding evidence-based diagnostic practice.

Theoretical framework of the research

Dyslexia is one of the most frequent neurodevelopmental disorder in childhood. Main components of its cognitive profile derive from the complex cognitive factors of reading development.

According to current researches (Ziegler
and Goswami, 2005; Fletcher et al, 2007; Ziegler et al, 2010; Vaessen, 2010; Landerl et al, 2013; Blomert and Csépe 2012; Tóth, 2012) three basic cognitive processes have significant role in the development and the disorder of the word-level reading.

The most important and most extensively investigated reading-related cognitive process is the phonological awareness (PA) that represents the basic implicit understanding of the segmental structure of spoken speech.

The role of the phonological awareness is strengthened by researches that proved the predictive power of the phonological awareness in the course of the reading acquisition (Bradley and Bryant, 1983; Caravolas, Volin and Hulme, 2005; Pennington, 2009), as well as by those researches that experienced adequate level of phonological awareness for good readers and inadequate level for poor readers (Goswami and Bryant, 1990; Wagner and Torgesen, 1987).

A strong reciprocal relationship was demonstrated between reading and phonological awareness: reading builds on the sound structure of words on one hand, and on the other hand it facilitates the development of phoneme-level manipulations as well (Wimmer et al, 1991, Siegel, 2006).

The fast, automatic naming of well known visual items such as letters, digits, objects and colors (RAN: Rapid Automatized Naming) represents another cognitive skill which has been frequently associated with reading skill and reading failure.
The speeded naming shows strict connection with the accuracy, fluency and comprehension of reading equally.
The speeded naming deficit experienced in young children (before school age) well predicts the risk of the later reading and particularly the reading-fluency disorder. (Wolf and Bowers, 2000; Wagner et al, 1997; Bowers and Ishaik, 2006; Norton and Wolf, 2012).
Researches that underlined the dominant role of the automate letter-speech sound correspondence in the development of reading system have been published recently (Blomert, 2011).
A qualitatively new association has to be evolved during the acquisition of letter-speech sound correspondence which will be the basis of the processing and mental and brain integration of that correspondence.
It takes many years to fully automate and integrate letter-speech sound associations in typical readers. The good readers depend on an integrated perception for which a heteromodal brain area's function is responsible. (Csépe, 2013).
Such a specific cross-modal binding deficit of letters and speech sounds in dyslexics may interfere with and/or slow down the incremental tuning of the auditory and multi-sensory cortex for the fast integration of unique audiovisual orthographic–phonological objects and negatively influence and/or delay the tuning of the fusiform cortex for the recognition of letters and words and lead on the serious reading disorders finally (Blomert and Csépe, 2012).
Beyond the above described triad the impair of the verbal working memory, independently from its domaingeneral or domainspecific character, represents a basic problem in case of reading disorder. (Swanson and Siegel, 2001; Swanson and Sachs-Lee, 2001; McCallum et al, 2006; Hulme and Snowling 1992; Catts et al, 2005).

The aim of the research:

In our research we would like to learn about the relationships between the neuropsychological characteristics and reading performance parameters (accuracy and fluency) of children with different levels of reading skills. Considering that extensive research in dyslexia has reached a strong consensus that it is a language-based disorder with a core-deficit of phonological processing (Vellutino et al. 2004, Pennington 2009, Goswami, Bryant 1990, Goswami 2008, Csépe et al. 2003), the characteristics of language functions and of memory and learning skills are particularly emphasised in our study.
In the course of research on the behavioural characteristics of reading disorders unique combinations of countless measuring tools are used, yet there is a relatively small amount of research conducted with more comprehensive test-batteries.
What makes our work novel is that it is with a profiled intelligence-test (the Wechsler Intelligence Scale for Children, WISC-IV.) and with a comprehensive development-neuropsychological procedure (NEPSY-I) permitting a more refined analysis that we are able to analyse the underlying factors of the word-level reading continuum in a wider sweep of areas.
Another novelty of our research is that on the basis of the criteria given along the word-reading continuum we formed three groups: children with reading disorders (dyslexia), poor readers and children reading well. In our work we analyse and compare the cognitive performances of these three groups.
Since our research has a strong practical basis, the common domestic use and accessibility of these procedures were important factors in them for the testing.

Explorative Questions:

As our research is of an exploratory nature we have not posed any hypotheses, but we have raised certain research questions, which we have grouped according to four topics.

1. On the relationship between cognitive factors determining intelligence and the different levels of word-level reading:

The first question will discuss whether, with the help of the WISC-IV intelligence-test constructed on basis of neuropsychological theories (Flanagan, Kaufman 2004), a unique dyslexia-specific neuropsychological profile can be set up for children with severe reading disorders, and whether this is different from the intelligence structure of less severe poor readers.

2. *Regarding the developmental neuropsychological profile:*

We would like to reveal a specific profile that specifically characterises children having average intelligence but different word level reading skill. We suppose that such difference can be found in the neurocognitive function, and NEPSY-I comprehensive neuropsychological test represents its appropriate method. We suppose that the examined groups (good readers, poor readers, dyslexics) are characterised by specific neuropsychological profile. We also suppose that this profile can be modified by the reading experience. Giving appropriate answer for this question is possible through the examination of the various school-grades.

3. *Regarding the cognitive and neurocognitive variables and word-reading relations:*

The third main question is how the cognitive factors that define intelligence, that is the neurocognitive components, explain the different reading performances in the groups demonstrating different reading abilities. We are also curious about those cognitive factors and neurocognitive components beside which fluent and accurate word-level reading can be predicted.

4. Regarding the"appropriateness"of the sample selection:

There is also an additional question as to what extent our groups set up according to the inclusion criteria (good readers, poor readers, dyslexic children) are the same as ones based on the previous question with regard to cognitive factors and neurocognitive components.

Research plan, method, test persons:

In our study we compared the cognitive psychological indicators of developmental dyslexic, poorly reading and well reading lower grade children of 8 to 10 years of age. We also set up a fourth study group of 11 to 13 year old dyslexic children, so in our study we included the data of 111children altogether, of which 29 are dyslexic, 29 are poor readers, 29 are good readers, and 24 are mostly higher grade dyslexic students.

Our further aim, beyond the scope of this research, is to conduct a follow up study of the cognitive- and reading development of the dyslexic lower primary school children in three years' time.

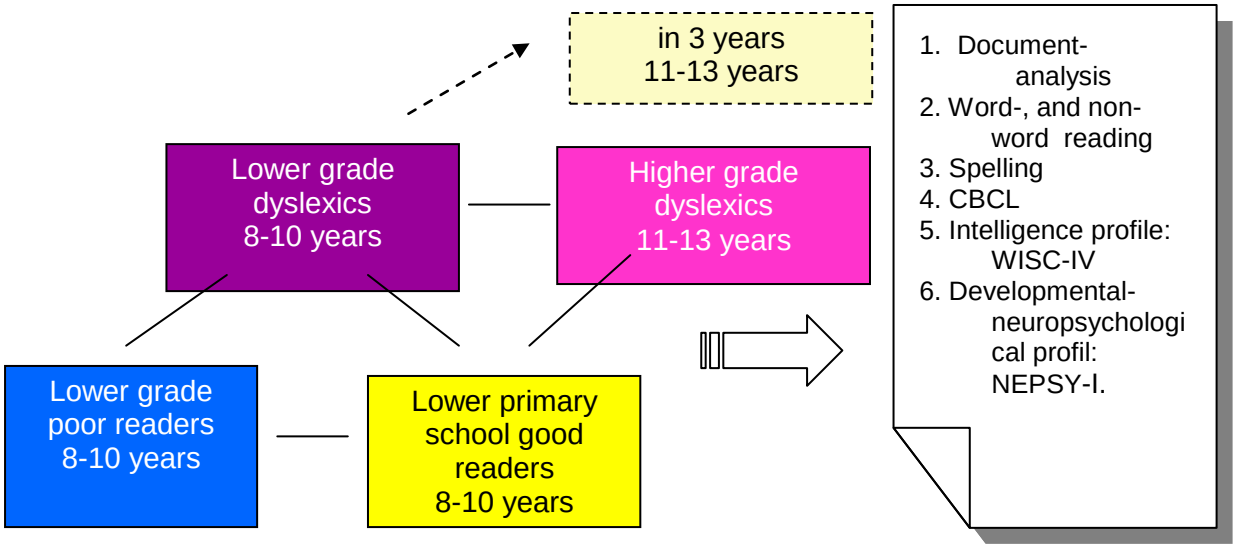


Figure 1 - Research plan

In the dyslexic group we tried to select children on whom the local Educational Counselling Service, Educational Supervisory Committee or speech therapists/educators gave opinions recommending SEN due to reading disorders or learning difficulties (BTM).
Since in our country educational services at the moment have no modern, well-established dyslexia-testing procedures for creating a"purer" dyslexic sample, and in order to be able to distinguish between the three groups along the word-reading continuum, the children were assessed with the reading and spelling parts of 3DM-H[1], which is the Hungarian version of the 3DM[2] (Dyslexia Differential Diagnosis, Maastricht) computer test. Beyond the word-level reading performance, the frequent comorbidity of dyslexia with attention deficit disorder (ADHD) was screened with the help of the parental version of the CBCL[3] (Children's Behavioural Checklist). As an exclusionary criterion, the indicators of the PRI (Perceptual Reasoning Index) and/or of the VCI (Verbal Comprehension Index) were also taken into account. In Table 1 we summarized the criteria for the inclusion or the exclusion of the sample.

Dyslexic	**Poor reader**	**Good reader**
Reading performance is significantly below the average: 3DM-H Screening**: under 32 T value** (average:50, SD:10)	Reading performance is below the average: 3DM-H Screening: **between values 34-44 T value** (average:50, SD:10)	Reading performance is average or above average: 3DM-H Screening: **between values 48-60 T value** (average:50, SD:10)
Not diagnosed with ADHD CBCL attention scale **under 70 T value**	Not diagnosed with ADHD CBCL attention scale **under value 70 T value**	Not diagnosed with ADHD CBCL attention scale **under value 70 T value**
VCI and/or PRI **above 85**	VCI and/or PRI **above 85**	VCI and/or PRI **above 85**

Table 1 - Criteria of the sample selection

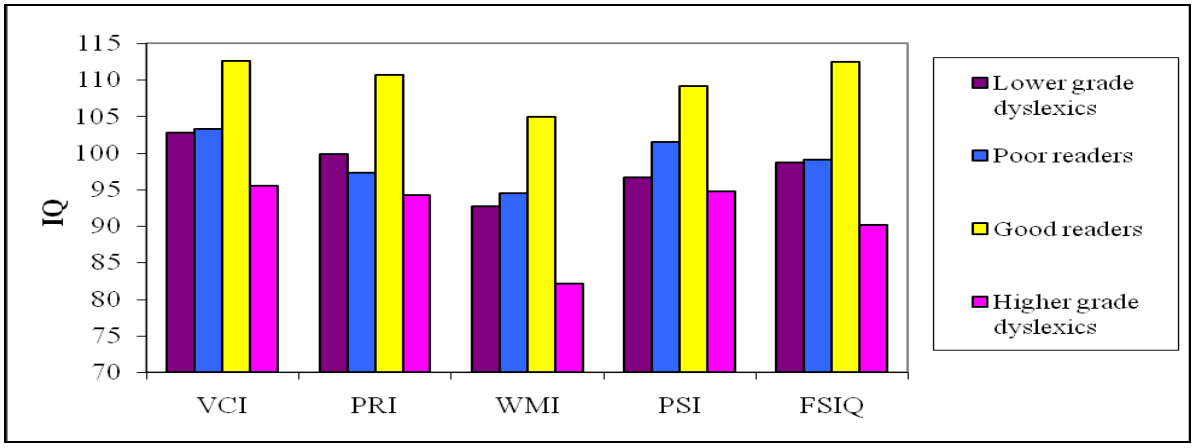
[1] Hungarian version: Copyright Csépe V., Tóth D., Vaessen A., Blomert L., 2009. The adaptation of the test is currently under procedure.
[2] The original version was developed by Leo Blomert and Anniek Vaessen.
[3] The original version of the Children's Behaviour Check List was developed by Achenbach – Hungarian version: Rózsa et al., 1998.

We tried to match the children based on their age, degree of class, gender, and SES (mother's education). However, the control group does not match the target groups regarding a potentially important variable. With regard to the intelligence indicators, we drew a value boundary of VCI or PRI at above 85 for all three groups, yet the groups do not match the Full Scale Intelligence Quotient (FSIQ). The effects of global intelligence were therefore controlled statistically, this FSIQ variable appearing as covariate in the analyses.

Results, answers to the research questions:

1. Regarding relationship between the cognitive factors determining intelligence and the different levels of word-level reading:

Between our groups, two striking phenomena are observed in terms of the intelligence indicators. First, although the intelligence indicators of all four groups fell into the normal region, the control group of children reading well obtained better results in all areas, and had higher average values. On the other hand the older dyslexic group showed the weakest results in all intelligence indexes.



VCI: Verbal Comprehension Index; PRI: Perceptual Reasoning Index; WMI: Working Memory Index; PSI: Processing Speed Index; FSIQ: Full Scale IQ

Figure 2 - Comparison of the groups by index indicators

Based on the intelligence indicators of our samples it seems obvious that there is a relationship between reading and intelligence, but the question which arises, however, is the nature and direction of this relationship. For the phenomenon experienced in our sample , which goes against the latest research trends (Gustafson, Samuelsson 2002, Siegel, 1989, Hoskyn, Swanson 2000, Stuebing et al. 2002) the most obvious explanation could be that intelligence plays an important part in developing the reading level of the group.

In order to provide a more distinct interpretation of our research results we originate from the mutual dynamic relationship of reading and cognitive development. Several researches (Siegel, 2006; Ferrer & McArdle, 2004; Stanovich, 1998; Cotton & Crewther, 2009) highlight the symbiosis of reading and cognitive development. Such symbiosis is characterised by the fact that after a while all processes influence the other. In case of dyslexics the positive reciprocal feedback effect could not be proved, though it appears in case of typical reading development. This led to a conclusion that such relationship between reading and intelligence could be disconnected in their case (Ferrer & mtsai, 2004, 2007). In accordance with all the above several researches established an increasingly stronger dissociation between cognitive skills and reading regarding the dyslexic population (Stanovich, 1988, 1991; Lyon, Shaywitz & Shaywitz; 2003; Ferrer et al, 2010).

In shaping the intelligence indicators of dyslexic students it can also be important that the intelligence-tests also measure the crystallized capacities, beyond the fluid capacities, so in the results the tested person's vocabulary, verbal memory and specific knowledge would also count as well. With dyslexics the underperformance of exactly these skills can be observed (Siegel 1989, 2006). It is not a coincidence that several authors (Prifitera et al. 1998, Berninger, O'Donnell 2005) claim that in the case of dyslexia instead of a FSIQ the intelligence indicators VCI or PRI can better predict the development of educational skills. It is not a coincidence that now several researchers (Fletcher et al. 2002, 2007, Lyon et al. 2001, 2003, Mather, Wendling 2012, Reynolds, Shaywitz 2009), mention that in the case of dyslexia, intelligence and reading disorder are two independent factors and in the diagnostic procedure the IQ-achievement discrepancy-based classification applied for several decades has now been abandoned.

Our further analysis confirms the above scenarios. Controlling the over-representation of the good readers' sample (groups are compared with the standard norm-score of the indexes) in the dyslexic and the poor reader groups, a significant difference appeared only in the Working Memory Index and within this in the Letter-Number Sequencing subtest. Their nonverbal fluid intelligence (Perceptual Reasoning Index) is within the norm values. The same was observed when the global intelligence factor was introduced as a covariance in the analysis. The comparison of our group intelligence profiles gave us the result that the intelligence profile of the primary school dyslexic group is shown by the marked dysfunction of the verbal working memory.

In the poor readers' intelligence profile, if compared with the norm values, the marked weakness of the working memory (Letter-Number Sequencing) also appears, at the same time in their case our attention was brought to a more general linguistic weakness by their relative underperformance in the Vocabulary subtest (we covariated the FSIQ).

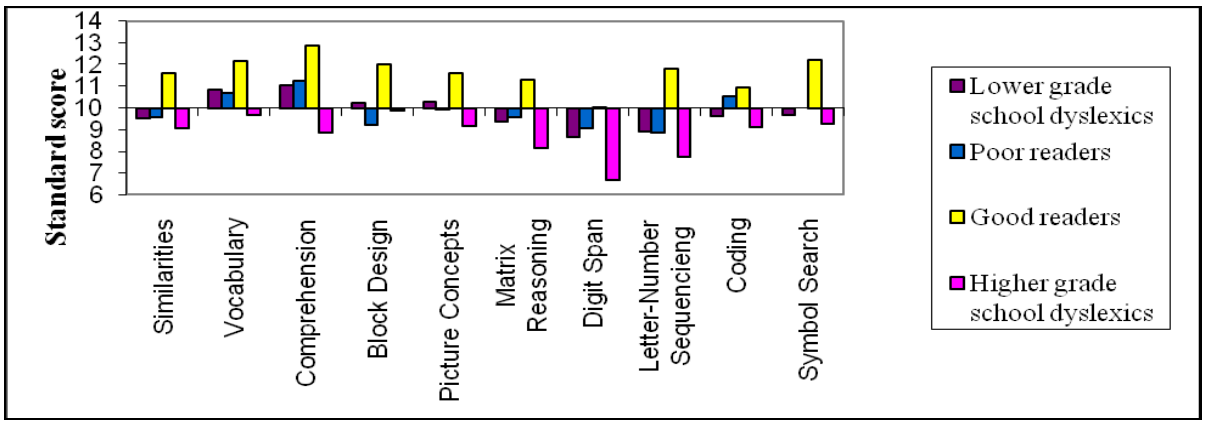


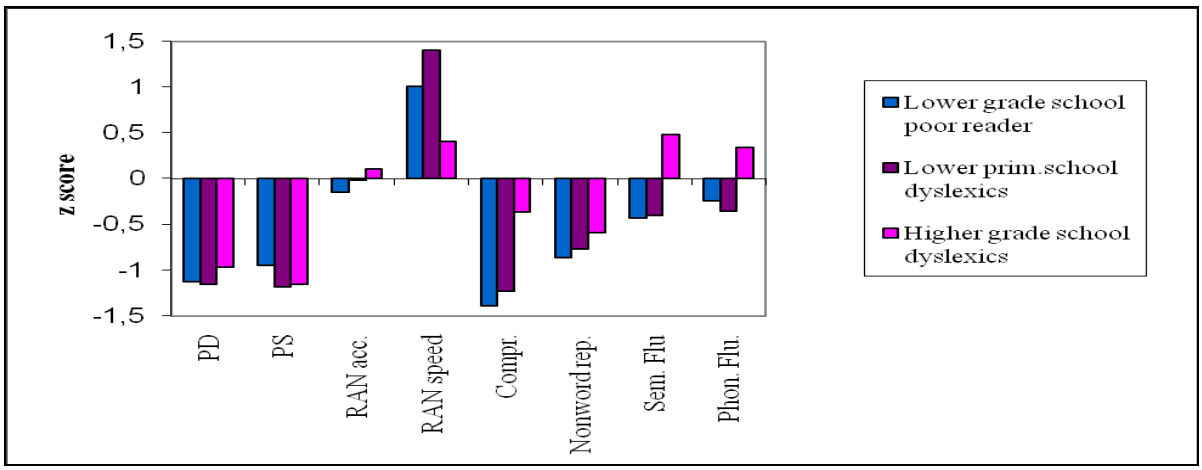
Figure 3 - WISC-profiles based on standard norm scores (M:10, SD:3)

The profile dyslexic group of the higher grade school differed from that of the lower grade school groups. In their case, as in that of the poor readers, underlying the reading difficulties the children's underachievement beyond the Comprehension, Digit Span and Letter-Number Sequencing tasks, in one of the strongest indicators of fluid intelligence (Wechsler, 2008), in the Matrix Reasoning as well as in the Similarities subtest, which requires abstract, verbal categorical thinking all indicate a more comprehensive ability disorder. In addition, the speed of information processing is also affected, which is shown in the significant difference in the Symbol search and in the tendency level difference in the Coding task.

To sum up our results, we can conclude that such cognitive factors as speech processing or working memory have a direct effect on the development of skills at school, while intelligence has a less direct impact, yet nevertheless it correlates with the cognitive factors determining reading acquisition. (Shapiro, Hurry, Masterson, Wydell, & Doctor, 2009)**. In response to our question concerning the specific intelligence profiles, - in line with previous research** (Alloway & Gathercole, 2006; Swanson & Sachse-Lee, 2001, Vellutino et al., 2004, Smith-Spark, Fisk 2007), **we can conclude that the dyslexic students' comprehensive skill profile is determined by the striking deficit of verbal, complex working memory. For practical diagnostic purposes our results reveal that for such language based disorders as dyslexia, the measurement of verbal working memory plays a relevant diagnostic role** (Németh et al. 2000)**.**

2. *Regarding the developmental neuropsychological profile*

Comparing the neuropsychological profiles of the test groups we found that in both the lower primary school and the higher primary school dyslexic groups the function area of language processing showed the most differences.



PD: Phoneme Deletion; PS: Phoneme Substitution; RAN acc.: Speeded Naming Accurate; RAN speed: Speeded Nnaming Time; Compr.: Comprehension of Instruction; Nonword rep.: Repetition of Nonsense Words; Sem.flu: Semantic Verbal fluency; Phon. Flu: Phonemic Verbal fluency

Figure 4 - Comparisons of the groups along the z-scores of Language functions

In the language field, we would like to mention the visible under-operation of two language tests, namely the Phoneme substitution subtest for phoneme awareness, which is based on very complex phoneme-manipulation, and the rapid automatic naming RAN task. In the latter task, unlike the control group they were able to gain access to the known lexical labels significantly more slowly. The marked deviation experienced in the two language fields might be interpreted in the so-called double deficit theoretical framework (Wolf and Bowers, 1999), according to which, phonological awareness and rapid naming play an equally important role in the dyslexic reading disorder independently of each other.

Our results closely match the results of dyslexia research to date (Vaessen et al. 2010, Goswami, Ziegler 2005, Vellutino et al. 2004, Caravolas et al. 2005, Csépe et al 2003), that dyslexic reading is a language-based developmental disorder that results in undifferentiated phoneme representation, phoneme perception and phoneme awareness, as well as in the inadequate working of the phonological loop.

The phonological processing, however, is only one aspect of the phenomenon; according to our results other fields are also affected. Among the sensorimotor tasks in the Manual Motor Sequences test we found that dyslexic children have increased difficulty in learning and automatising motor sequence rhythms.

Beyond the weakness of sensorimotor functions that was highlighted by a number of studies on learning disorder (Korkman 1988, Semrud-Clikeman 2005, Berninger & Rutberg, 1992, cit. Schmitt, Wodrich 2004), several alternative explanations are possible. The Manual Motor Sequences, in particular the under functioning of the executive system motor planning function in the smooth implementation of asymmetric motion sequences of the two hands, also play a role. All of this is confirmed by the specific skills pattern of the dyslexic group. Their results were also poor in the Route finding test included in the Visuospatial processing tasks. The complexity of the test, namely the development and transfer of a visuospatial representation, also show that the executive system is affected.
In the further analysis of the neurocognitive pattern of the dyslexic group it is striking that the problem of access to verbal items (in the RAN task) correlates with the tendency-level difference of Memory for Names, which also requires the acquisition and retrieval of verbal items in paired associate learning tasks. According to Korkman et al. (1998), to learn and recall names requires phonological processing, and similarly to phoneme awareness, Memory for Names also highly correlates with successful reading.
The common underlying weakness of the Memory for Names, Manual Motor Sequences and Repetition of Nonsense Words tests is thought to be a result of both memory and executive dysfunctions.
Similarly to the dyslexic clinical team, the poor reader group also achieved significantly lower results in the Phoneme substitution subtest and the Manual Motor Sequences task.
Their neuropsychological profile, however, differs in two important points from the profile of the dyslexic children. Neither their RAN task accuracy nor their speed indicator differ from those of the control group, but the Comprehension of instruction task showed a weaker result.
Two consequences can be drawn from this. On the one hand **those dyslexic students who have a double deficit (phonological awareness and rapid naming together), display much more severe symptoms in reading than in either isolated phoneme awareness or isolated naming deficit** (Wolf and Bowers, 1999, Norton and Wolf 2012). On the other hand**, the comparison of neurocognitive and intelligence profiles of poor readers suggests that their case is not merely about a phonological processing disorder, but about a more general language weakness**. This is supported by the fact that the poor reading and the dyslexic children produced some differences in the Arrows spatial-visual tasks and in WISC-IV Block design test, the poor reading group performing significantly worse. Their visualization and construction of spatial relationships may be more severely affected.
The comparison of the neurocognitive profiles classified by class-age further strengthened our results in that **the poor readers may have more diffused, diversified skill differences. They are less likely to have a selective impairment of phonological processing, although this is also affected, and it seems that it is part of a broader dysfunction** (Stanovich 1988).

3. *Regarding the cognitive and neurocognitive variables and word-level reading relations:*
So far, our results have been further strengthened by the cognitive and neurocognitive variables and the correlation measurements regarding the connection of reading parameters.
In the good readers' group, it was primarily learning and memory tasks, the various variables of associative learning (name learning) and list learning that showed a strong positive correlation with the accuracy of word-level reading. The Phoneme delete task of Phonological processing was associated with fluent reading and the WISC-IV Coding task. This is not

surprising, since the Coding subtest is a timed task requiring abilities similar to orthographic coding (Wechsler 2008). Fluent word-level reading is significantly determined by the advanced state of word-specific orthographic representation (Share, 1999, Tóth, 2012). **The positive correlation between learning and memory areas suggests a basically positive learning potential in the case of good readers.**

In the case of the lower primary school students with dyslexia reading accuracy strongly correlates with the WISC-IV complex working memory task, the Letter-Number Sequencing task, while the fluency of reading correlates with a sensorimotor variable of the Finger Tapping and Route Finding tasks. It is very difficult to give a satisfactory explanation for ability-correlations regarding fluency although it is perhaps not surprising that the reading speed parameter was found to correlate with a sensorimotor task that is also based on speed measurement at both the good reading and the dyslexic groups. The relationship regarding the role of working memory in the case of dyslexic reading strengthens our conclusions so far.

The weak reading and the dyslexic upper primary school groups show similar results. Their word-level reading development is more closely connected to the uneven development of intellectual capabilities, and perhaps the more comprehensive disorder of cognitive skills leads to a lower degree of word-level reading.

With further analysis of the relationship between cognitive skills defining reading accuracy and fluency, we wondered which aspects of the cognitive structure contribute most to predicting certain reading indicators. Through regression analysis, we were able to set aside five subtests, which are responsible for the variance of reading achievements in our groups, these are Letter-Number Sequencing, Phoneme Substitution, Manual Motor Sequences, Arrows and Speeded Naming tests.

Our results were also confirmed by the discrimination analysis in the light of these five variables, with 60% of the children being classified correctly.

This further reinforces our results for the cognitive determinants of word-level reading so far, in that in the development of **word-level reading the child's verbal working memory, phoneme awareness, speeded naming**, **visuospatial processing as well as automation processes play an equally significant role. Behind all this is the interactive specialization** of the **extensive neural network operating reading** (Csépe, Tóth 2009).

4. Regarding the"appropriateness"of sample selection:

Our results so far also show that dyslexia and poor reading on the level of behaviour is a phenomenon that is very hard to distinguish solely along the continuum of reading. Although very controversial reviews have been published on the dimensional and distinct nature of dyslexia (Hulme, Snowling 1992, Siegel 2006, Stanovich 1998, Ellis 2004, Pennington 2009, Ferrer et al. 2010, Elliott, Gibbs 2008, Rice, Brooks 2004), we still wanted to know whether it was possible to separate even "cleaner" subgroups along the continuum of reading than the ones we had originally created. For clarification of the question two types of cluster analyses were performed. The "sample-controlled" cluster analysis was conducted based on the variables of the regression equation. Beside the variables of the Letter-Number Sequencing, Phoneme Substitution, Manual Motor Sequences, Arrows and RAN tests we managed to identify two clusters within which the different levels of reading are easily distinguishable. The other cluster analysis was performed with a 'theory-based' approach, employing the two strongest cognitive predictors of developmental dyslexia, Phoneme Delete and Phoneme Substitution, which are the strong tests of phoneme awareness as well as the two RAN variables, accuracy and speed indicators.

When comparing the group differences that resulted from the two clusters it was found that in both atypical clusters certain functions of the following areas, Language domain, Learning-memory and certain Sensorimotor skills, are equally affected.
A significant difference between the two kinds of analysis was not seen, yet it was noticeable that in the case of **both 'atypical' clusters poor reading performance was significantly determined by phoneme awareness, speeded naming as well as by the differing state of development in the functions of verbal working memory.**
However, the cluster analyses reveal new information in that **the more extreme the move towards the negative range of reading performance is, the more pronounced atypical pattern language processing has.**

To summarize our analyses in a nutshell, it seems that the difficulty in processing visuospatial stimuli, sensorimotor integration and the weakness in learning and memory may cause the problem of academic acquisition of reading for poor readers, while in the case of dyslexia, the isolated function disorder specifically affecting the phonological processing of the language module is of key importance. However, we should be careful with the generalization of our former statement, as one of the results of the cluster analysis, according to which the atypical development of reading can be easily separated based on the neurocognitive indicators, crystallized in our analysis (Letter-Number Sequencing, Phoneme Substitution, Speeded naming, Manual Motor Sequences and Arrows), while at the same time the tests do not have a sufficient degree of discriminating power regarding the degree of the severity of reading.

The practical relevance of the research:
Looking at the practical relevance of our research from a *narrower test-usage approach*, we can say that both the WISC-IV, and the NEPSY-I have proved to be sensitive procedures for the detection of the specific skill pattern of learning disorders, but from different aspects.
The overall practical relevance of our research *from a broader perspective* is that it seems worth studying the diagnostics of learning disorders with a different kind of paradigm in which a dynamic assessment and a Response to Intervention approach can provide a suitable basis for an evidence-based diagnostic and therapeutic practice.
In the last chapter of the thesis, we offer a possible alternative to this.

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