EÖTVÖS LORÁND TUDOMÁNYEGYETEM
Faculty of Education and Psychology

ANDREA MÉSZÁROS

EXECUTIVE FUNCTIONS IN SPECIFIC LANGUAGE IMPAIRMENT AND DYSLEXIA

Theses of doctoral dissertation

Doctoral School of Psychology
Director: Dr. habil. Zsolt Demetrovics

Cognitive Development Program
Program coordinator: Dr. Magda Kalmár, CSc., habil., full professor

Supervisor: Dr. Kónya, Anikó, CSc., honorary (university) professor

Examination committee:
Dr. Magda Kalmár, CSc., habil., professor emerita, chair
Dr. Kata Egyed, PhD, habil., associate professor, secretary
Dr. Ádám Takács, PhD, assistant professor, reviewer
Dr. Zsanett Tárnok, PhD, psychology specialist, reviewer
Dr. S. Zita Nagy, PhD, assistant professor, member
Dr. Anna Verseghi, PhD, c. associate professor, member
Dr. Ágnes Lukács, PhD, habil., associate professor, member
Dr. Andrea Kóbor, PhD, research fellow, alternate

Budapest, 2017
1. INTRODUCTION

In the present dissertation I report a study of executive functions in two neurocognitive developmental disorders both of which affect linguistic abilities. One group of my subjects consisted of children with specific language impairment (SLI). SLI is a language disorder where problems of language acquisition are specific in that they are not attributable to hearing loss or developmental problems such as intellectual disability, neuro-motor damage, environmental deprivation, autism spectrum disorder, or emotional disturbance. The other group examined comprises children diagnosed with developmental dyslexia (DD). Developmental dyslexia is diagnosed in cases of weakness in accurate and/or fast recognition of written words that is relative to age and general level of ability; like in SLI, this weakness is not due to uncorrected sensory deficit, acquired neurological damage, intellectual disability, or poor quality of education. Within these two disorders of verbal learning a currently intensely investigated area is finding the neurocognitive core deficits that result from atypical brain development and explain the observable symptoms; in addition, describing the corresponding neurocognitive profiles based on the strengths and weaknesses. This area is the focus of the present study which, given its chosen topic, questions, and methodology, belongs to the field of clinical developmental neuropsychology, although it has psychological, psychodiagnostic, and special education aspects as well. Studying SLI and developmental dyslexia is important from both theoretical and practical point of view. Due to their high prevalence (5-8%, and 4-10% respectively), high frequency of associated disorders, and long-term effects on subjects’ lives they pose a significant challenge for professionals of special education and diagnosis. The goal of my research is to improve some examination methods and their interpretation that could become part of the psycho-diagnostic protocol of SLI and developmental dyslexia.

The present study examines control functions classified as executive functions in SLI and developmental dyslexia. Executive functions (EFs) figure primarily in tasks and situations that require mental effort; they play a key role in flexible behavioral adaptation to changing environmental demands. These control functions have a critical influence on performance at school, and they are intimately connected with linguistic functions. To examine executive functions we used procedures popular both in research and clinical practice, including verbal tests (letter fluency, category fluency; ad hoc fluency, category switching, and action verb fluency), and non-verbal ones (design fluency, and Rey Complex Figure Test). The main goal
of my research has been to identify the patterns of performance that characterize subjects with SLI and developmental dyslexia when using these test procedures. In addition to describing the performance deficits of these two clinical groups compared to the typically developing population, I strive for a better understanding of the processes that these tests measure.

At present there is no agreement, either from a theoretical or from a practical, diagnostic point of view, about the connection between SLI and developmental dyslexia. Whether these two syndromes are fundamentally distinct, or they constitute different levels within one dimension is thoroughly debated. By comparing the performances of the two groups, the present study also explores the differences between the profiles of SLI and developmental dyslexia.

2. GOALS AND QUESTIONS

The principal aim of my research is to examine whether school-aged children with SLI or developmental dyslexia exhibit any characteristic differences in executive functions compared to typically developing subjects matched in age and non-verbal intelligence. To answer this question we used the qualitative and quantitative analyses of verbal and non-verbal fluency tests, and the Rey Complex Figure Test. Our focus was to find those individual contrasts and group-level characteristics that have a discriminative role in the neuropsychological profile. Another important question is, what do these test procedures – traditional tests of executive function for the adult clinical population – uncover about these two developmental disorders that affect the language processing to differing degrees. To address the latter interpretive question we used quantified process approach in order to discover the strategies and processes underlying our subjects' performance.

The questions and choice of topic of the present research were inspired by my interest in the connections existing between clinical developmental neuropsychology and psychology of special education. Thus my aim is to synthetize the views of these two disciplines. On the one hand, SLI and developmental dyslexia are neuro-cognitive developmental disorders of verbal learning that affect the linguistic system to different degrees. On the other hand, the children who are affected need special education support (speech therapy), consequently they are classified in the public education system as subjects with special needs (in particular, as having "speech disorder", or "miscellaneous psychological developmental disorder"). Both language disorder and reading disorder have high prevalence, and they are frequently associated with other, secondary disorders; in addition, they have long-term effects. For these reasons the
eraly screening and therapeutic intervention is critical in these cases. The goal of psychological and special-needs exploration is to precisely characterize the problem and establish a diagnosis (status and differential diagnosis), and to decide on the optimal type of intervention. The individual pattern of cognitive abilities including the subject’s stronger and weaker areas plays a key role in the clinical decision process. From a practical point of view the goal of the present research is to enrich certain neuropsychological examination methods (and their interpretation) which can be integrated into the psychological evaluation protocol of SLI and developmental dyslexia.

Regarding its methodology this research is based on neuropsychological procedures. The three methods we have chosen have a number of favorable characteristics. First, all three of them are complex multidimensional diagnostic tools that are readily applicable with school-aged children. Second, in addition to a standard scoring-and-performance-based evaluation, these tests allow for the application of the quantified process approach. Third, combining these three procedures gives us an opportunity to bring executive functions into focus despite differences in linguistic abilities between SLI and DD. The verbal fluency tasks we used differ from one another in two important respects: (i) to what extent, and on what level they involve linguistic processing (phonological processing vs. lexicon), and (ii) what units of language they use (verbs vs. nouns). Nonverbal fluency measures productivity in the nonverbal domain, therefore it constitutes a control condition for verbal fluency. In addition, the Rey Complex Figure Test is known as a non-verbal measure of higher executive functions (planning and organizing).

We regard the present research as an exploratory one in the following respects. Results from relevant earlier studies in the literature are controversial in that the majority of them is based on analyses of quantitative measures only; moreover, the varieties of tasks they use overlap only partially with our test battery. In the area of language disorders we regard the following studies as important preliminaries: Henry, Messer & Nash (2012, 2015), Weckerly, Wulfeck & Reilly (2001), Lukács, Ladányi, Fazekas & Kemény (2015). On developmental dyslexia, Reiter, Tucha & Lange (2005), Csépe, Honbolygó & Surányi (2007), Mohai (2014), Akshoomoff, Stiles & Wulfeck (2006), Klicpera (1983) & Mati-Zissi, and Zafiropoulou (2003) served as starting points. However, in earlier research we found no example of combined use of five different verbal fluency tasks in SLI and developmental dyslexia. Earlier studies using the Rey Complex Figure Test were conducted on mixed samples involving subjects with different learning difficulties; to what extent their findings generalize to our groups is questionable. To our knowledge there exists no earlier study, using native Hungarian school-
aged subjects with SLI and developmental dyslexia (selected according to internationally accepted criteria) that uses both fluency tests (verbal and nonverbal) and the Rey Complex Figures test, and analyzes the results using qualitative and quantitative methods.

3. METHODS

3.1.1. Subjects

Study 1 – Developmental dyslexia
The first study (developmental dyslexia [hereafter DD] study) involved 38 children of whom 19 were diagnosed with DD; they were between ages 10.25-14.16 years (mean: 12.30, sd: 1.43; 6 girls, 13 boys). Children in the DD-group were selected by Katalin Mohai. Selection criteria were twofold. First, average or above-average intelligence was necessary based on the WISC-IV (Wechsler Intelligence Scale for Children, Fourth Edition; Wechsler, 2003; Nagyné Réz, Lányiné Engelmayer, Kuncz, M&záros & Mlinkó, 2008); in particular, Verbal Comprehension Index and/or Perceptual Reasoning Index must have been greater than 85, second, word reading performance was required to be significantly below average measured by the Dyslexia Differential Diagnosis, Maastricht computerized examination (Hungarian version). Children with the following conditions were excluded: attention deficit hyperactivity disorder (diagnosed by a score >70 on the Attentional problems scale of the Child Behavior Checklist (CBCL), parent version (Achenbach, 1991; Rózsa, Kő & Gádoros, 1998), in particular,; uncorrected vision problems; over three months absence from school; epilepsy or problems with behavior; and low socio-economic status. The remaining 19 children in the DD study were typically developing subjects (TD<sub>DD</sub> group) who were matched to the DD subjects one by one on age (maximal difference: eight months), and nonverbal intelligence (measured by the Raven Coloured Progressive Matrices Parallel version or Raven Progressive Matrices Parallel Version; maximum difference: nine points). Age range of the control group was 9.91 – 14.66 years (mean = 12.24, SD = 1.48); there were ninie girls and ten boys. Based on the Raven test, intelligence in both groups was average or above-average (DD group: IQ range 86 – 116, mean = 97.47, SD = 7.48; TD<sub>DD</sub> group: IQ range 88 – 119, mean = 101.32, SD = 7.48).
Study 2 – Specific language impairment

54 children participated in the second, SLI study. The SLI group consisted of 27 children (9 girls, 18 boys); in this group the age range was 7.33 – 11.66 years, mean = 9.08, SD = 1.28). The SLI group was formed from students in two classes (one in Budapest, the other from a rural area) with special curricula including speech therapy. All children had a report from the Speech Examination Expert and Rehabilitation Committee (Beszédvizsgáló Szakértői & Rehabilitációs Bizottság). Selection was based on internationally accepted diagnostic criteria (exclusive: nonverbal IQ below 85, hearing impairment, neurological damage, associated developmental disorders; inclusive: performance at least 1.25 SDs below mean on at least two out of four tests of linguistic function). Of the four faculty-of-language tests two had receptive focus (Peabody Picture Vocabulary Test (Dunn, 1959; Csányi, 1974); Test for Reception of Grammar (TROG) (Bishop, 1983; Lukács, Győri & Rózsa, 2011), and two measured expressive function (Hungarian Nonword Repetition Test [Racsmány, Lukács, Németh & Pléh, 2005], and Hungarian Sentence Repetition Test [Kas & Lukács, in press]). The typical (TDSLI) group was assembled via pairwise marching based on age (maximal difference 11 months) and nonverbal IQ on the age-appropriate version of the Raven test (maximal difference: 10 points). Thus the TDSLI group had 27 members (14 girls, 13 boys), with its age range being 7.0 – 12.0 years (mean = 9.14, SD = 1.33). The minimally required IQ level obtained in both groups (SLI group: IQ range 85–130, mean = 103.59, SD = 11.18; TDSLI group: IQ range 88 – 125, mean = 104.85, SD = 9.07).

3.2. Test procedures

1. To measure verbal fluency we used five tasks (letter fluency, category fluency; ad hoc, fluency, category switching, and action verb fluency). All of these require verbal responses; subjects need to produce their responses (the maximum number of words they can recall) to the cue within 60 seconds in each task.

2. Non-verbal fluency was measured using the D-KEFS „Design Fluency” test (Delis, Kaplan & Kramer, 2001; hereafter design fluency, or DF). Solving the design fluency tasks requires certain basic or elementary capacities (visual attention, speed of motor responses, visual perception and construction) plus higher order executive functions
(problem solving; fluent production of visual patterns; creative drawing of new shapes and patterns; simultaneous application of rules and constraints during drawing; inhibiting earlier responses). The test consists of three related tasks that tax executive functions to different extent in increasing order (Filled Dots; Empty Dots Only; Switching), it is regarded as one of the most complex measurement procedure for nonverbal fluency.

3. Responses to the copying, immediate recall, and delayed recall tasks of the Rey-Osterrieth Complex Figure (ROCF) were evaluated according to the following three systems: Rey Complex Figure Test and Recognition Trial, RCFT, Meyers & Meyers, 1995); Developmental Scoring System for the Rey-Osterrieth Complex Figure, DSS-ROCF (Bernstein & Waber, 1996); and the Boston Qualitative Scoring System, BQSS (Stern & mtai, 1999).

4. Answers to the questions

4.1. Answers to questions about developmental dyslexia

We propose the following answers to our research questions concerning developmental dyslexia:

1. Is there a difference between the DD group, and the control group matched in age and nonverbal intelligence in quantitative indices of verbal fluency?

The DD group produced a smaller number of correct responses than the controls on the animal and supermarket trials, and also on category fluency, and category switching in general. In the animal task, the DD group was behind the control group in the total number of uttered words as well. Regarding category switching, we found a significant difference in the number of all responses, and that of correct category switches. The relation between the latter two indices is also evidenced by the fact that there was no difference between groups in the accuracy of switching, that is, the ratio of correct switches per all switches. In other words, children with dyslexia made fewer category switches, but did not err more frequently than typical subjects. The two groups did not differ in letter fluency and action verb fluency (total number of responses). Solving verbal fluency tests the two groups made the same number of errors; they repeated earlier responses with the same frequency, and produced the same number of self-corrections.

The absence of a between-group difference contradicts to the majority of earlier data (e.g., Kelly, Best & Kirk, 1989; Menghini et al., 2010; Varvara, Varuzza, Sorrentino, Vicari &
Menghini, 2014; Reiter, Tucha & Lange, 2005; Csépe, 2005), however, they are in accordance with the results obtained by Mohai (2014) who examined children with developmental dyslexia, and weak readers, comparing both groups to typically developing children (with all Ss being in the 8-10 years age range) The lag in the category fluency test together with intact letter fluency performance is the exact opposite of the pattern reported by Frith, Landerl & Frith (1995), according to which first-phoneme-based word finding is difficult, whereas meaning-based word finding is easy for subjects with dyslexia.

2. **Do the two groups differ in the qualitative indicators of verbal fluency?**

Comparing temporal changes in correct responses, children with developmental dyslexia gave less correct responses than the controls (i) to the letter fluency, category fluency, ad hoc fluency, and category switching questions in the first 15 seconds; (ii) to the action verb fluency question in the second quarter (secs. 15-30), and (iii) to the category fluency in the third quarter (secs. 30-45). None of the tests used showed a significant difference in the last quarter (secs. 45-60). The overall weaker performance of the DD group in the category fluency test is due to the animal task in the first and third quarters, and to the fruit task in the first quarter.

On the level of strategic operations the DD group, compared to the controls, gave less responses and used less semantic categories in the animal task; the latter was true throughout the entire category fluency test. Operation indices relative to response numbers did not differ between the groups, that is, the relative frequency of the strategies seems unrelated to clinical status. In the animal task the absolute size of the clusters did not differ, however, relative to the total number of responses the DD group formed larger clusters. Our results indicate that children with developmental dyslexia use the same strategies as typically developing children in the verbal fluency test. In the most automatized category-based task automatic and controlled lexical search and recall, plus semantic clustering and switching appear responsible for the lower production index.

In the DD group, automatic retrieval of easily activated words from the lexicon is affected, which is in accordance with our findings on quantitative indices (see the first question above), and and with the "rapid naming deficit" view (Wolf & Bowers, 1999; Mather & Wendling, 2011). In the verbal fluency test this phenomenon was observed globally, while the strategy-linked deviations occurred specifically in the category fluency task. The pattern we obtained shows important commonalities with findings by Takács, Kóbor, Tárnok & Csépe (2017) obtained from 8-12-year-old children diagnosed with ADHD; these authors analyzed strategy and temporal data from letter and category fluency tasks.
3. Is there a difference between the groups in the subtests, and in the overall score, of the nonverbal fluency tests?

In the Filled Dots condition of the D-KEFS test's design fluency task we found a significant between-group difference in the number of correct responses; however, no such difference was found in the number of errors, or that of repeated responses. This pattern suggests that lower productivity in children with dyslexia is not due to improper understanding of the task. It is the Empty Dots Only condition in which subjects in the clinical group differed most from typical subjects; here a lower number of correct responses was associated with a higher number of errors. In this condition the rules learned in the Filled Dots condition need to be applied to new stimuli, ignoring the earlier targets. This interference did not lower the number of responses in either group; however, children with dyslexia made more erroneous designs, while at the same time they did not differ from the controls in their number of repetitions and self-corrections. The between-group difference in the Empty Dots Only condition indicates weaker response inhibition in the DD group. According to the results by Menghini et al. (2010) the neurocognitive profile of children with developmental dyslexia often shows a disorder of attention and/or executive functions in addition to a phonological deficit. In the switching condition, which is the most complex of the three, there was only a marginal difference between the groups. Combining the three subtests of the design fluency test we found that the number of correct responses was significantly lower in the DD group. Performance graphs by children with dyslexia had a similar overall shape to those of typical children, but their curves representing number of correct responses were significantly lower in the Filled Dots and Empty Dots Only condition, and marginally lower in the Switching condition. In light of these data impairment in cognitive flexibility does not appear characteristic of developmental dyslexia. Comparing the Design Fluency profiles our impression is that children with developmental dyslexia have a difficulty with rapid learning in the task situation involving the fluent application of rules. This cautious suggestion leads us toward Nicolson & Fawcett’s (2007) procedural deficit hypothesis to justify which further studies are needed.

4. How do performance indicators of verbal and non-verbal fluency relate to each other within the two groups?

We analyzed the connection between the different fluency indicators separately in the two groups. Within the clinical group, the five verbal fluency indicators derived from the number of correct responses were unrelated, whereas in the control group correct responses in three
semantic tasks (Category Fluency, Category Switching, and Action Fluency) were significantly correlated. Thus within the age range examined developmental dyslexia is characterized by a heterogeneous performance profile on verbal fluency tasks. Apparently the types of tasks applied are not equivalent; more importantly, differences between the tasks are more expressed in the clinical than in the control group.

Design fluency showed a similar pattern of relations within the two groups. The Filled Dots and the Empty Dots conditions were highly correlated in the DD group, and marginally correlated in the control group. Scores of the switching task were independent of the other two conditions in both groups. In accordance with the analysis by Suchy, Kraybill & Larson (2010) with old adult subjects, this pattern reinforces the idea that the Switching task is independent of, therefore it needs to be interpreted separately from, the Filled Dots and the Empty Dots Only conditions.

In neither of the groups did we find a correlation between correct responses in the verbal vs. nonverbal fluency tasks. Category switching exhibited a marginally significant, still intermediate-level correlation with the total number of correct responses in the Design Fluency test. In addition, Category Switching marginally correlated with performance in the Filled Dots condition in the DD group, and with the Empty Dots Only condition in the control group. Another marginally significant correlation in the control group was obtained between Letter Fluency and number of correct responses in the Switching task. Our results suggest that verbal and nonverbal fluency tasks are not equivalent, or near-equivalent versions of one another. Within our test battery the most obvious relation obtained between category switching and the Design Fluency Test as a whole. Expected correlations based on principles of construction of our tests were found mostly in the typical group (Letter Fluency and the Switching condition of Design Fluency; Category Switching and Switching in Design Fluency); however, even these were only marginally significant.

5. Does the DD group differ from controls on quantitative indices of the Rey Complex Figure Test?

According to the Rey Complex Figure Test and Recognition Trial (RCFT) evaluation procedure children with developmental dyslexia performed worse than controls on accuracy and location of the parts in the copying and immediate recall tasks, whereas in delayed recall the two groups did not differ. The RCFT performance profiles suggested that the disadvantage of the DD group stems from problems of information coding (during copying), which in turn affects memory recall. Mati-Zissi & Zafiropoulou (2003) report results obtained with younger
native Greek subjects with reading disorder. These authors did not use the delayed recall probe. Our data confirm the conclusions by Waber, Bernstein & Merola (1989) and Waber (2003) according to which developmental switches in ROCF solutions, or lack thereof, are primarily connected to processes of the coding phase.

6. Comparing the groups by qualitative data from the Rey Complex Figure Test

According to most accuracy indicators of the Developmental Scoring System for the Rey-Osterrieth Complex Figure, DSS-ROCF the DD group did not differ from the control group; the only exception was immediate recall where children in the clinical group remembered less detail. The key factor in accuracy for the clinical group was the type of task: they copied significantly more structural detail that what they recalled. In the control group copying and recall did not differ in terms of the number of reproduced structural elements; it remained high throughout. In copying the figure, children with dyslexia represented its structure at a simpler level (as reflected in their Basal Organization Level, Organization Score); this difference, however, was no longer present in immediate and delayed recall. The distribution of styles (Part-oriented, Intermediate, Configurational) was identical in the two groups. Drawings by children with dyslexia contained more malformations in all three task situations, while errors increased at the same rate in the two groups. An important difference was, however, that typically developing children copied precisely, and malformations occurred only in recall. In the DD group there was a tendency for (i) more frequent rotations during copying; (ii) misplacements along the vertical axis during immediate recall, finally, (i) perseveration and conflation during delayed recall. Our results concerning the organization, accuracy, and error scores of ROCF solutions correspond to the data by Waber & Bernstein (1995) obtained from children between 7-14 years of age with heterogeneous background of learning disorders, with the exception that we did not find a between-group difference in categories of Style.

According to the Boston Qualitative Scoring System (BQSS), dyslexic children copied clusters less precisely; for configural constituents this difference was only marginal. In all three tasks there was a significant connection between the structural importance of the constituents, and the frequency of their occurrence in the drawings. When copying, the DD group preferred configural elements compared to filling in the details; in the control group this shift did not occur due to an overall ceiling effect extending to all types of elements. In the DD group, the structural role of elements did not influence their accuracy, and location within a given drawing. The typical group copied clusters more accurately than configural elements; copying the localization of details was also better than that of clusters. These differences disappeared in
recall. Dyslexic children were better at copying than recalling configural constituents. Within the clinical group the precision of reproducing clusters decreased between copying and delayed recall; in the control group it decreased from copying to both types of recall. In BQSS score designed to measure executive functioning (Fragmentation, Planning, Neatness, Perseveration, Confabulation) and in Organization Summary Score the two groups did not differ significantly. Copying of the complex figure by dyslexic children was characterized by weaker line quality and neatness (a tendency-level difference from controls); in addition, perseveration was more frequent in their delayed recall drawings. Placement scales (Vertical and Horizontal Expansion, Reduction, Rotation, Asymmetry) indicated no group difference. In the DD group the BQSS summary scores Presence and Accuracy were significantly lower in Immediate Retention, and marginally lower in copying. The two groups did not differ on scores of short or long-term visuo-spatial memory capacity.

4.2. Answers to questions about specific language impairment

We found the following answers to our questions concerning SLI:

1. Is there a difference between the SLI group, and the control group matched in age and nonverbal intelligence in quantitative indices of verbal fluency?

Children with SLI differed significantly from controls in the number of correct responses in the Letter Fluency and Action fluency tests, and in the total number of responses as well. This reduction in the number of total responses may be related to the motor component of faster speech production (speech rate and continuity) and/or to problems with the tempo of recall. However, low response number in the clinical group was observed only in these two types of tasks, which suggests that that it is explained by letter/phoneme-based word recall and specific factors activated by verb generation. The majority of earlier studies using letter and categories fluency tasks found that SLI is characterized by a global deficit of verbal fluency tasks (Rodríguez, Santana & Expósito, 2017; Henry, Messer & Nash 2015; Weckerly, Wulfeck & Reilly, 2001). Similarly to our results, Coelho, Albuquerque & Simões (2013) demonstrated a dissociation between the two types of task with native Portuguese-speaking children, however, the direction of difference was the exact opposite of what we found. Contrary to the results of Lukács, Ladányi, Fazekas & Kemény (2015), the group difference in letter and action fluency scores was unrelated to verbal short-term memory measured by a simple digit span task. A
possible explanation for this difference is that Lukács et al. used the summary score of verb fluency, the supermarket task, and the k-task, and in their analysis they did not separate these varieties of tasks.

2. Do children with SLI differ from typically developing children in the qualitative indicators of verbal fluency tests?

Comparing correct responses as a function of time, children in the SLI group exhibited a delay on the letter fluency test that was comprehensive, that is, present in all four temporal quarters. Concerning the verb generation task, the two groups performed similarly in the first quarter; they differed significantly in the second and fourth quarters, and marginally significantly in the third quarter. Based on this the delay by the clinical group in letter fluency is attributable to difficulties with starting and maintaining the verbal response, and a joint disorder of automatic plus controlled, conscious effort-driven processes of recall, whereas the lower action fluency is explained by access to the extended mental lexicon, non-automatic recall, and maintaining the verbal response. Looking at the role of time we did not identify any further between-group effect; response numbers marginally differed between the groups in the second quarter of ad hoc fluency, and in the fourth quarter of category switching. In the category fluency test response numbers in all four quarters were the same between groups.

Analyzing the strategic operations, the clinical group produced fewer phonological clusters in the letter-, category-, and ad hoc fluency tasks than the controls. With respect to the number or semantic categories the groups did not differ on any of the tests. Children with SLI formed less cluster than the controls in letter fluency, category fluency, and ad hoc fluency. Unlike Weckerly, Wulfeck & Reilly (2001), we found that the smaller number of clusters formed within category fluency and ad hoc fluency persisted even when it was calculated relative to the total number of responses. Between-group difference in the number of categories formed in the category fluency and ad hoc fluency tasks persisted even after taking into account the total number of responses. In the Letter Fluency test children with SLI formed the same number of phonological and semantic clusters, whereas in the control group phonological clusters consistent with task rules were predominant. Average cluster size in absolute terms did not differ between groups in either of the tasks, but relative to the total number of responses children with SLI formed larger clusters in the ad hoc fluency test, and in action fluency test as well (but the latter difference was only marginally significant). Children with SLI performed below control level on cluster switching, hard switching, and total switching in the letter fluency test; on total switching in category fluency; finally, on hard switching and total switching in ad
hoc fluency. Between-group differences of response indicators are due to absolute response numbers; when relativized to the total number of responses, these differences disappear. The two groups do not differ in the pattern of action fluency switches.

3. Is there a difference between the groups in the subtests, and in the total score, of the nonverbal fluency tests?
In the D-KEFS Design Fluency test the two groups did not differ in the Filled Dots condition, which means they understood and applied the rules of the task equally well. In the Empty Dots Only condition, where visual attention is needed to cope with interference, children with SLI performed less accurately than controls, and less productively than they did in the Filled Dots condition. Within the control group the Filled Dots and Empty Dots Only conditions did not differ in difficulty. Regardless of clinical status subjects produced the smallest number of correct figures in the Switching condition, which requires creativity and flexibility. In addition, the SLI group, compared to controls, produced a smaller number of correct drawings, which were also less accurate. This pattern suggests that children with SLI had more difficulty than their typically developing companions in flexibly using rules mastered earlier in new circumstances, monitoring their responses, and inhibiting incorrect solutions. In the Design Fluency test as a whole the clinical group produced less correct solutions, and they also produced twice as many erroneous ones on average, therefore their percentage of correct solutions (65%) was below that of controls (85%). Regarding the number of figures finished within one minute, the two groups did not differ in either the individual tasks or at the level of the entire test; this suggests that the differences found do not result from swiftness of the motor system or graphomotor skills. Comparing patterns of performance revealed two important differences. First, while children with SLI made less and less drawings in each subsequent task, for controls the number of responses reduced only in the last task. Second, typical children were equally accurate in all three tasks, that is, they reacted with lowered response numbers to increased cognitive demand, which was not accompanied by an increased error rate. In the clinical group the number of correct responses was smaller in the Empty Dots Only condition than in the Filled Dots one, still the error rate was not reduced.

4. How do performance indicators of verbal and non-verbal fluency relate to each other within the two groups?
The pattern of relations between the the five types of verbal fluency tests differed in the two groups. Within the clinical group we found a looser correlation between the summed correct
responses of the tasks. Only the correlation between ad hoc fluency, and action fluency was significant; the remaining semantically-based tasks showed a few marginally significant correlations. Performance on the letter fluency test was independent of all other tasks. In the control group, Letter Fluency score correlated with Action Fluency, Category Fluency, and Category Switching; its correlation with ad hoc fluency was marginally significant. Category Switching and Action Fluency also exhibited a tendency-level correlation.

Within Design Fluency the pattern of correlations was similar in the two groups. The correlation between the Filled Dots and Empty Dots conditions was significant in both groups, and the Switching condition was independent of the other two. Summed correct responses of the Design Fluency test correlated significantly with all three subtests in the typical group, whereas in the clinical group its correlation with the Switching Task did not reach significance.

In the SLI group correct responses to the verbal vs. non-verbal fluency tests did not correlate significantly; there was only a marginally significant connection between Category Switching and the Switching Task in the Design Fluency test. In the control group, Letter Fluency significantly correlated with the Switching Task, and exhibited a correlation tendency with the Design Fluency Test as a whole. Finally, we found marginally significant connections between (i) Switching and Action Fluency, and (ii) the Design Fluency Test score on the one hand, and both Ad Hoc Fluency and Action Fluency scores on the other.

5. Does the SLI group differ from controls on quantitative indices of the Rey Complex Figure Test?

According to the Rey Complex Figure Test and Recognition Trial (RCFT) children with SLI had significantly lower copying scores than controls; in immediate and delayed recall the between-group difference was marginally significant. This marginally significant difference in memory tasks probably stems from the copying task since the two groups did not differ in the information loss between the three task situations. RCFT performance profiles did not differ in the two groups, that is, there was no task-group interaction.

6. Comparing the groups by qualitative data from the Rey Complex Figure Test

According to the Developmental Scoring System for the Rey-Osterrieth Complex Figure (DSS-ROCF), children in the SLI group copied significantly fewer line elements than typically developing children. In copying by the SLI group the ratio of Incidental Elements and that of Structural elements was the same, that is, these children did not differentiate between the elements on the basis of their role in the structure (important vs. unimportant) during
information coding. In copying by the typical group, Structural Elements were predominant. In memory-based drawings this processing difference disappeared. Copy organization performance by children with SLI was marginally lower than that of controls, and these children also reproduced the structure of the complex figure at a lower level. The two groups did not differ in memory-based solutions. Frequency of the categories within Style did not differ in the two groups; in copying the majority of children used Part-oriented or Intermediate style, whereas in memory-based drawings Configurational approach dominated. Based on the four categories of error analysis in DSS (Rotation, Perseveration, Misplacement, Conflation), specific language impairment was characterized by significantly higher error rate, but only in copying; the extended analysis using 10 further error categories revealed higher error rates in all three tasks. Within the studied age range typically developing children solved the copying task with one error on average, whereas children with SLI made an average of four errors. Our own results suggest that for children with SLI error analysis needs to take into account overshoots of line formation in copying, and confabulations in recall tasks. The remaining types of distortions that characterized our clinical group (horizontal and vertical misplacement, rotation, duplications) are readily covered by the DSS category system.

According to the Boston Qualitative Scoring System (BQSS) children with SLI copied the details less accurately and placed their clusters less well (these were marginally significant differences from controls); in Immediate Retention they remembered less clusters and did so less accurately; in Delayed Retention they reproduced less detail. There was no difference between the groups on Organization scales. The number of elements in the drawings in all three situations, and both groups, was significantly connected with their structural role, namely, configural elements and clusters were more frequent than the details. Comparisons within and between points of measurement showed that, in light of Presence, Accuracy, and Placement, children with SLI processed the complex figure similarly to controls. The two groups did not differ on the BQSS score of executive functioning (Fragmentation, Planning, Neatness, Perseveration, and Confabulation) nor on the Organization Summary score of copying. In Delayed Retention children with SLI exhibited a tendency toward less well organized drawings as characterized by neatness and line quality; they were also prone to perseveration. In both copying and memory recall children with SLI obtained scores identical to those of controls on Vertical Expansion, Horizontal Expansion, Reduction, Rotation, and Asymmetry scales. Summary scores of Presence and Accuracy were significantly lower in the SLI group compared to controls in copying and immediate recall, and marginally lower in delayed recall. The groups did not differ on Immediate Retention and Delayed Retention scores.
Regarding the coding phase, DSS-ROCF (accuracy in terms of number of line elements), and the deviations in the Presence and Accuracy indices of BQSS point toward a more general processing deficit, in accordance with the results by Akshoomoff, Stiles & Wulfeck (2006).

5. PRACTICAL RELEVANCE OF THE PRESENT WORK

In the present research we used performance-based neuropsychological tests that can readily be included in the assessment battery for children with neuro-cognitive developmental disorders. Our results support the conclusion that verbal and nonverbal fluency tests and the Rey Complex Figure Test are useful in distinguishing typical from atypical development, thereby helping diagnosis as parts of a complex examination methodology. Within our samples of typically developing children and children with developmental dyslexia clinical status was predicted with 90% accuracy by the combination of (i) the number of correct patterns produced in the Design Fluency test, and (ii) that of correct responses in the first 15 seconds of the category fluency test. The sensitivity of the model constructed out of the verbal and nonverbal fluency indicators was high (94.7%), while its specificity was acceptable (78.9%). The combination of these same fluency tests in our SLI study produced the best match to antecedent clinical classification. Based on the number of correct responses in the letter fluency test, and summed accuracy score of the Design Fluency Test correct classifications reached 87% with a high sensitivity (96.3%), and a moderate specificity (77.8%).

Using the quantified process approach we can obtain a precise picture of the factors behind performance deficits. The combination of quantitative and qualitative approaches offers a better understanding of the nature of the studied disorders, and it also serves as a starting point for planning intervention in particular cases. We think that these methods must become available in domestic clinical practice in legal, standardized forms, to support up-to-date neuropsychological diagnosis; at the same time, postgraduate training programs should support the acquisition and application of process-oriented diagnostic approaches.
6. FUTURE PERSPECTIVES AND LIMITS

There exist certain limits to the generalizability of our results. First, sample sizes were small in both studies. The reason for this was that in forming the special groups, it was of utmost importance to use selection criteria according to international standards. This principle narrowed the range of available child subjects, since diagnoses by the expert committees could only serve as starting points. It may also seem objectionable that outliers were not removed from the analyses. One motivation for this was small sample sizes; however, more important was that the developmental disorders in the focus of our study are characterized by a heterogeneity of symptoms, therefore inclusion of outliers could have increased the validity of our results. Also important for statistical analyses and interpretation is the fact that the majority of the variables used were not normally distributed. As a result, in analyzing connections we could only rely on correlations between test indices; uncovering causal relationships was only possible in a few cases.

The question may arise why the two clinical groups do not come from the same age range. The explanation is that establishing reading disorders is possible only after a minimum of two years of learning to read (that is, from 8-9 years of age), whereas the methods for diagnosing specific language impairment are most sensitive to disorders of linguistic ability in kindergarten age. Another critical note may be that the test methods used in the two studies are not exactly the same, which limits the comparisons between the two sets of results (in addition to differences in age). Of the two studies presented here the one about developmental dyslexia was conducted first, and it helped us to refine the methodology used to examine the SLI group.

It may also be viewed as a shortcoming that we did not use controls matched in language-level. The explanation is that the primary focus of our study was on executive functions. In the control (TDSLI) group the methods of our study were only partially applicable because these children were kindergarten-age, that is, younger than those in the clinical group. Another question is, what linguistic indicators should be used for sample matching? At present there is no comprehensive standardized test of linguistic ability in Hungary to be used for this purpose. To resolve this, receptive vocabulary, or WISC-IV Verbal Comprehension Index may be considered. We think a further study is in order to supplement our results by this comparison.

In the present research we did not address the question how the differences found in our clinical groups are related to the relevant linguistic dysfunctions. Our result so far suggest that it is important to clarify these causal relations in a further study.
Nor has it been clarified what underlying cognitive factors determine performance in the tests we used. Most studies touching upon this issue targeted adult populations. It is important to investigate this question in a developmental approach in the future.

7. CONCLUSIONS

Using verbal and nonverbal fluency tests and quantitative plus qualitative data analyses from the Rey Complex Figure Test, we identified a number of differences between children with developmental dyslexia on the one hand, and children with SLI on the other, compared to typically developing groups matched in age and nonverbal intelligence. Using process analysis we clarified the nature of certain factors underlying performance differences between groups. Understanding background processes and operations is important non only for diagnostic decision making, but also for planning individual intervention strategies.

Indirect comparison of our two clinical groups based on the results from the two studies supports the view that SLI and developmental dyslexia are two distinct syndromes. Profiles from the fluency tests and the Rey Complex Figure Test in the two target groups overlap to some extent, still they contain characteristic differences. In interpreting these differences, however, we must take into account the fact that children in our SLI group were younger than those in the DD group (lower bounds and means are 7.33 and 9.08 years [SLI], versus 10.25 and 12.30 years [DD]). Executive control functions change substantially between these two age ranges, therefore the contrasts identified may be partly due to developmental changes. We characterized the atypical features of our clinical groups in terms of their differences from the typical course of development, still it is likely that the two specific neurocognitive disorders studied add extra modulating factors to developmental changes.

In the SLI group the verbal fluency tests provided evidence for a distinctive role of the productivity indices of letter fluency and action fluency, which was accompanied by a marginally significantly elevated error level in the phonological condition. As an underlying factor for this, analysis of the temporal distribution of responses identified controlled processes of word recall responsible for maintaining the continuity of verbal response generation. These processes show a deficiency specifically linked to letter and action fluency; in the other tasks we only found tendency-level differences. Regarding strategic operations, SLI is characterized by a lower level of phonological cluster formation and a smaller number of groups, which occurs in category and ad hoc fluency tasks independently of response numbers. A role of switching
was also found in the background of lower productivity, but this only affected total response numbers. In the DD group the animal and supermarket tasks, plus lower productivity indices in Category Fluency, and Category Switching separated the groups. Analyzing temporal distributions revealed problems with starting verbal responses, and a deficit in early automatic processes of lexical recall which affected all tasks. Differences in using strategies manifested in an isolated fashion in the category fluency task only, that is, children with developmental dyslexia applied the operations of grouping and switching similarly to control group members. Analysis of temporal patterns in SLI revealed alterations in task-dependent, later stages of processing, whereas in developmental dyslexia it showed a more general deficit linked to earlier stages of the recall process. Strategy indices in SLI showed deviations independent of response numbers, while in dyslexia the lower efficiency of operations was observed only in specific task situations.

In the nonverbal D-KEFS Design Fluency test both groups were characterized by a lower total score, however, difference patterns of performance were identified in the background. Children with SLI did not differ from controls in the Filled Dots condition, whereas in the Empty Doty Only and Switching conditions they lagged behind controls in both productivity and accuracy. They made more errors as the complexity of the tasks increased, therefore the accuracy index showing the ratio of correct versus incorrect responses was the most informative in their case. Children with developmental dyslexia gave less correct responses in the Filled Dots condition, and made more errors in the Empty Dots Only condition, however, in the most complex Switching task they differed only marginally from controls. For children with developmental dyslexia the Empty Dots Only condition has proven to possess diagnostic force; taking into account error rates did not impart further information. The Filled Dots and Empty Dots Only conditions resulted in performance different from that in the Switching task in both clinical groups.

Based on the quantitative profiles of the Rey Complex Figure Test the two clinical groups were very similar. According to the Rey Complex Figure Test and Recognition Trial, (RCFT) both groups solved the copying task relatively poorly, whereas the quality of delayed recall was identical to that of controls. Immediate, short-term recall was marginally weaker than controls’ performance in SLI; the same difference was significant in dyslexia. Our analyses suggest that the copying task has a key role in separating our clinical groups from controls; at the same time, contrasts between SLI and developmental dyslexia are found in memory performance. Behind the copying deficit as a surface symptom we found similar causes in the two groups using process analysis; these factors were related to organization ability and error
patterns. The clinical groups did not distinguish between parts of the figure according to their structural role (important vs. unimportant), and they grasped the overall structure less well than their typically developing peers. In the DD groups this was accompanied by a significant delay in Basal Organization Level; the same difference was only marginal in the SLI group. We also found differences between the two clinical groups in processes of memory consolidation. For children with SLI forgetting mainly affected incidental elements, whereas the retention of structural elements was able to stabilize. In children with dyslexia this selectivity was not observed, as the recollection rate of both structural and incidental elements reduced with time. In accordance with the results of Waber & Bernstein (1995), our observations support the central role for error analysis. Both clinical groups made errors in copying which is very rare with typically developing children. In the SLI group copying was characterized by marginally more frequent misplacements and line overshoots; immediate recall contained more rotations, horizontal misplacements, and confabulation; finally, delayed recalls exhibited more frequent confabulation and doubling of lines with the same function. In the DD group marginally significantly more frequent features were rotation during copying, vertical misplacement during immediate recall, and perseveration plus reduction during delayed recall.

The BQSS score designed to measure executive functioning did not distinguish the examined groups. Based on data from earlier studies with developmental emphasis (Akshoomoff & Stiles, 1995; Ogino et al., 2009), and in light of group differences on the DSS-ROCF indices a possible explanation for this is that within the age range we studied these indices are not sufficiently sensitive to developmental shifts and individual differences. Our results suggest that in the specific groups we studied the most useful evaluation system is DSS-ROCF, which is easily supplemented by the traditional quantitative approach for purposes of screening.

We can summarize the differences between the two verbal learning disorders by concluding that in SLI the range of distinctive features is broader and more comprehensive than in developmental dyslexia. According to our empirical results the use of multifactor models in both SLI and developmentsl dyslexia is recommended, and the different phenomena are reasonably viewed as a syndrome. In these verbal learning disorders linguistic deficits play a key role, however, all by themselves these deficits cannot explain the whole picture of symptoms. In the present study we did not investigate how the neuro-cognitive dysfunctions described contribute to symptoms in spoken of written language. Still it is obvious that in these specific developmental disorders, even with the strict criteria of sample selection used, deviations are not limited to the verbal domain.
List of the author’s own publications related to the thesis


References


Ogino, T., Watanabe, K., Nakano, K., Kado, Y., Morooka, T., Takeuchi, A., ... & Ohtuska, Y. (2009). Predicting executive function task scores with the Rey-Osterrieth Complex Figure. Brain and Development, 31(1), 52-57.


