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Perinatalna hipoksija kao faktor rizika od težine leksičko-semantičkog deficita dece sa razvojnim jezičkim poremećajem

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Perinatal hypoxia as a risk factor of severity of lexical-semantic deficit in children with developmental language disorder

Perinatalna hipoksija kao faktor rizika od težine leksičko-semantičkog deficita dece sa razvojnim jezičkim poremećajem

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Abstract

Background/Aim. There are a small body of the literature on the influence of perinatal hypoxia (PH) on language outcome at later age and there are no studies on the influence of PH on the extent and severity of language deficit in children with developmental language disorder (DLD). Therefore, the aim of this study was to examine the differences in lexical-semantic abilities in DLD children with a presence of PH (DLDhpx) and DLD children without any neurological risk factors (DLDwrf). **Methods**. The sample consisted of 96 children aged 5 to 8, divided into 3 groups, 25 children in DLDhpx, 30 children in DLDwrf and 41 typically developing (TD) peers. For the purpose of comparing age differences, additional categorical variable was formed with two age groups, preschool and school-age children (5-6 and 7-8 years). Lexical-semantic abilities were investigated by specific tests for assessing the expressive vocabulary size, semantic processing, and lexical productivity in continuous speech. **Results**. The significant differences were observed between DLDhpx and DLDwrf children on the semantic processing assessment test ($p < 0.05$), but not on the vocabulary size ($p = 0.350$) and lexical productivity ($p = 0.118$) assessment tests. However, a detailed analysis of developmental tendencies between preschool and early school-age children showed that DLDhpx children progress significantly only in a domain of expressive vocabulary skills ($p < 0.01$), while DLDwrf children progress significantly in a domain of expressive vocabulary and semantic processing skills ($p < 0.001$). Regarding lexical diversity developmental tendencies, significant progress was not observed in both DLD groups. **Conclusion**. PH in DLD children can be related to a more severe extent of lexical-semantic deficit in the area of semantic processing abilities. Also, PH can contribute to slower progress in a wider spectrum of lexical-semantic abilities. Some of the possible explanations for the obtained results are the possible comorbidity with a specific cognitive deficit, but also that PH can contribute to significantly slower maturation of the brain and neural networks that underlie language abilities.

Key words:

developmental language disorder; perinatal hypoxia; lexical-semantic abilities; neurological risk factor.

Apstrakt

Uvod/Cilj. U literaturi je prisutan mali broj radova o uticaju perinatalne hipoksije (PH) na jezičke sposobnosti dece na starijem uzrastu i ne postoje studije o uticaju PH na obim i težinu jezičkog deficita kod dece sa razvojnim jezičkim poremećajem (RJP). Cilj rada je bio da se ispitaju razlike u leksičko-semantičkim sposobnostima kod dece sa RJP i istorijom PH (RJPhpx grupa) i dece sa RJP bez neuroloških faktora rizika (RJPbfr grupa). **Metode**. Uzorak je činilo 96 dece uzrasta od 5 do 8 godina, podeljenih u 3 grupe, 25 dece sa RJPhpx, 30 dece sa RJPbfr i 41 tipično razvijene dece (TR) istog uzrasta. U svrhu poređenja uzrasnih razlika uzorak je naknadno podeljen u dve starosne grupe– decu predškolskog i decu školskog uzrasta (5-6 i 7-8 godina, redom). Leksičko-semantičke sposobnosti ispitivane su specifičnim testovima za procenu obima eskpresivnog vokabulara, semantičkog procesiranja i leksičke produktivnosti u kontinuiranom govoru. **Rezultati**. Uočene su statistički značajne razlike između grupa RJPhpx i RJPbfr na testu procene semantičkog procesiranja ($p < 0,05$), ali ne i na testovima procene eskpresivnog vokabulara ($p = 0,350$) i leksičke raznovrsnosti ($p = 0,118$). Međutim, detaljna analiza razvojnih tendencija između dece predškolskog i ranog školskog uzrasta pokazala je da deca sa RJP i PH značajno napreduju samo u domenu ekspresivnog vokabulara ($p < 0,01$), dok deca sa RJP, bez neuroloških faktora rizika, značajno napreduju u domenu ekspresivnog rečnika i semantičkog procesiranja ($p < 0,001$). Što se tiče razvojnih tendencija u domenu leksičke raznovrsnosti, značajan napredak nije utvrđen ni u jednoj od dve RJP grupe. **Zaključak.** Kod dece sa RJP PH može biti povezana sa težom formom leksičko-semantičkog deficita u oblasti sposobnosti semantičkog procesiranja. Takođe, PH može biti povezana sa sporijim napredovanjem u širem spektru leksičko-semantičkih sposobnosti. Neka od mogućih objašnjenja dobijenih rezultata odnose se na potencijalno prisustvo komorbiditeta sa deficitom specifičnih kognitivnih sposobnosti, ali i da PH može dovesti do značajno sporijeg sazrevanja mozga i neuronskih mreža, koje leže u osnovi jezičkih sposobnosti.

Ključne reči:

razvojni jezički poremećaj; perinatalna hipoksija; leksičko-semantičke sposobnosti; neurološki faktori rizika.

Introduction

Developmental language disorder

According to the DSM-5 criteria, developmental language disorder (DLD) is a neurodevelopmental disorder characterized by difficulties in vocabulary, syntactic abilities and discourse skills, which can be manifested in expressive and/or receptive language and through several modalities, and can significantly impair communicative, social, academic and professional functioning [1]. DLD is characterized by a delay or abnormality in expressive and/or receptive language abilities in the absence of general cognitive deficits, autism, hearing impairment, social and emotional disorders, and severe environmental deprivation [2].

There is a well-founded viewpoint that underlying mechanism in neurodevelopmental disorders is an atypical pattern during intrauterine brain development, and that relatively mild abnormalities affecting limited brain regions can lead to difficulties in developing higher cognitive functions [3].

Data from the literature indicate the presence of various lexical-semantic deficits in DLD children. Namely, these children are characterized by a significant delay in first word acquisition [4 5]. This symptom in DLD children is considered by some authors to be the first key symptom of speech and language development delay [2,3]. DLD children also have a significantly underdeveloped expressive and receptive vocabulary skills, comparing to their typically developing (TD) peers [6].

In accordance with poor vocabulary, these children also have word finding difficulties [7]. Also, DLD children learn new words significantly slower and harder comparing to TD children [8, 9]. However, word finding difficulties in these children are not only due to retrieval difficulties, but also to poor semantic representations and deficits in lexical-semantic organization and processing [10-12].

In addition to the above, DLD children also have significant difficulties in using words in spontaneous speech. Namely, studies of lexical diversity (LD) in speech samples of DLD children showed that these children use significantly less of all types of words [13,14] and significantly less content words (nouns, verbs, adjectives) [13,15], comparing to TD peers.

Although DLD is a disorder that is usually diagnosed at an early preschool age with a good language outcome at a later age [1], numerous data from the literature indicate that these children can have significant difficulties at school age. Difficulties that these children

have at school age are mostly manifested within lexical-semantic [11, 13] and pragmatic abilities [16]. Given the importance of lexical-semantic abilities for mastering academic skills, research in this population is of great importance for the academic outcomes of these children.

PH and language development

PH is a term that refers to the period of time before, during and after birth in which a fetus or child is exposed to a reduced amount of oxygen in cells and tissues, which can lead to serious brain damage. The development of language and other cognitive abilities has been most studied in children who have developed hypoxic-ischemic encephalopathy (HIE) due to a severe form of PH. Data from some of these studies have shown that children with a history of HIE may have underdeveloped speech and language abilities at school age, including reading and writing difficulties, even in the absence of more severe cognitive or motor difficulties [17]. On the other hand, the results of some studies show that these children may have average language skills measured by general batteries for the cognitive abilities assessment [18]. In a recent study, Chin et al. [19] investigated the language abilities of preschool children with a history of moderate and severe HIE at birth. The authors assessed language abilities with batteries for a general assessment of cognitive abilities. The results showed that children with a history of HIE can have significant difficulties of expressive vocabulary skills and shorter mean length of utterance (general measure of syntactic abilities), comparing to typically developing peers. On the other hand, data from this research showed that the receptive vocabulary skills are quite preserved in these children. However, the results of this study showed that gender and socioeconomic status are important predictors of expressive vocabulary development, while the extent and severity of brain damage is a higher predictor of receptive vocabulary skills in these children. According to that, influence of HIE on developing of expressive lexical abilities is not entirely clear.

On the other hand, there are no available data on the language abilities in children with a history of mild PH without sequelae in the form of HIE or some other form of brain damage. In addition, existing studies have used general assessment instruments for investigating language skills (verbal **intelligence quotient** -IQ, cognitive battery assessment subscales), which do not assess the structural aspects of language in detail, such

as specific tests for assessing morphosyntactic, lexical-semantic, phonological or pragmatic abilities.

Only available data about possible influence of mild form of PH on specific language abilities comes from one larger study of lexical abilities in DLD children showing that DLD children with a presence of slower neural maturation risk factors have poorer performance than DLD children without the presence of risk factors [20]. The results of this study showed that this subtype of DLD children have significantly worse performance in the domain of lexical processing and diversity. Additionally, DLD risk children progressed more slowly within all observed lexical abilities, including naming objects and activities [20]. However, this study included children with PH and children with nonspecific encephalographic changes in the group of DLD risk group, so the effect of PH was not investigated as individual factor.

Present study

There are few papers in the literature that have studied the possible impact of PH on children's language skills. In addition, those researches used general batteries for assessing language abilities, most often as part of the general cognitive abilities assessment. These types of tests usually are not sensitive to deficits that children may have within structural aspects of language (syntactic, semantic, phonological or pragmatic). Moreover, there are no available studies of the possible impact of PH on the severity of language deficit in DLD children, especially where PH was not severe and did not cause significant motor and cognitive disorders, or PH was not considered as a separate factor. Also, anecdotal data from practice indicate a possible severe language deficit in DLD children who suffered from PH, even in the absence of neurological or severe cognitive deficits.

Accordingly, the aim of our study is a detailed examination of the possible impact of PH on the severity of lexical deficit in DLD children, by using specific tests that measure three dimensions of expressive lexical-semantic abilities.

Methods

Participants

The sample consisted of 96 children aged 5 to 8, divided into 3 groups. 25 children were diagnosed with expressive type of DLD and a history of PH (DLDhpx), 30 children were diagnosed with expressive type of DLD without the presence of neurological risk factors before, during or after birth (DLDwrf), while a control sample of typically developing children consisted of 41 participants without a history of DLD or other developmental disorders, as well as without a history of neurological or sensory impairments (Table 1). All DLD children were recruited from Institute for Psychophysiological Disorders and Speech Pathology "Prof. Dr Cvetko Brajovic" (IPDSP) in Belgrade, Serbia. IPDSP is a specialized health institution that deals with prevention, diagnosis, habilitation and rehabilitation of children and adults with various difficulties in psychophysiological and speech and language functioning. Also, IPDSP is the only state institution of this type in Serbia where children are included in interdisciplinary assessment and rehabilitation. All DLD children were included in the speech and language therapy for 12 to 18 months. Evidence of presence of neurological risk factors was obtained from medical history. All DLDhpx children had a history of PH, 5-min Apgar score between 5 and 7, without evidence of HIE and without documented neurological or motor impairment. In the first six months of the research, 21 children with DLDhpx who were in IPDSP and met the criteria regarding age and treatment period were included in the sample. For the purpose of increasing the number of school-age children, the remaining four children were included in the sample for the next two years. A sample of DLDwrf children who met the criteria regarding age and treatment period was formed in the first six months of the study. TD group consisted of children who were recruited from local preschools and schools, also in Belgrade. Inclusion criterion for all groups was an IQ above 85 and within the norms of average intelligence, while one child from DLDwrf group with IQ above average ($>$ 109) was excluded from sample. Data about intelligence level were taken from psychological documentation and included the general IQ and the instrument with which it was assessed. All children were administered with the Wechsler Intelligence Scale for Children Revised that has been normed on the Serbian population [21]. Only participants whose first language is Serbian were included in the sample.

Research was approved by Ethical Board of IPDSP "Prof. Dr Cvetko Brajovic" in Belgrade, Serbia (1575/19-09-2016), and for the purpose of testing of all children written consent was obtained from the parents.

There were no significant differences between groups regarding age (Table 1). Given the numerous data in the literature that indicate the possible influence of gender [6,22,23]. and maternal education [24-26] on children's lexical abilities, we compared groups regarding mentioned demographic variables. No significant differences were found between the groups of children regarding gender and the maternal education also (Table 1).

For the purpose of comparing age differences, additional categorical variable was formed with two age groups, preschool and school-age children (5-6 and 7-8 years). Data about distribution of participants through age groups are given in Table 2. Comparison analysis of the participants distribution by age groups showed that there was no statistically significant difference between all groups (DLDhpx *vs* DLDwrf: $\chi 2 = 0.000$; df = 1; $p = 1.000$; DLDhpx *vs* TD: $\chi 2 = 0.000$; df = 1; $p = 1.000$; DLDwrf *vs* TD: $\chi 2 = 0.000$; df = 1; $p = 1.000$).

Instruments

For the purpose of assessing vocabulary size, Boston Naming Test (BNT) [27] was used. The test consists of 60 black-and-white drawings of objects and assesses the ability to confrontational naming (visually evoked naming). Images of objects are sorted by usage frequency in the language, from more to less frequent concepts. The test is used to assess naming in children and adults, with and without developmental and acquired speech and language impairments. BNT is adapted for Serbian language but not standardized. Serbian version of BNT has been used in several studies with Serbian speaking children and adults with speech and language disorders [20,28,29]. Scores of correct answers were used for statistical analysis.

For the purpose of assessing lexical processing skills, Word Association Task (WAT) was used. 80 words were selected from Kent-Rosanof list [30] with the addition of 10 verbs, in order to equalize word classes. The association test based on this list is the best studied in linguistical manner of all available in the literature, within the Birkbeck Vocabulary Project in the 1980s [31]. All words were selected to be early acquired, highly imageable as possible depending on the word class, high and medium frequencies

according to Children's frequency dictionary [32]. Moreover, variants of association test are commonly used for assessing semantic processing in children with language disorders and lexical-semantic organisation of bilingual children [12,33,34]. Also, the same test has been already used in a study with a larger sample of DLD children in the Serbian population [11]. Associations were coded into two categories: mature and immature associations. Mature associations (MA) are paradigmatic and syntagmatic responses, which are the indicators of more mature and better organized semantic network resembling the one of a typical adult speaker [35]. Immature associations are phonological, unrelated and echolalic responses, as well as omissions. This type of associations are indicators of underdeveloped semantic network [11]. Score of mature type of associations was used for statistical analysis.

Measure of lexical diversity was used for the purpose of assessing lexical productivity. Lexical diversity (LD) was assessed by analysis of the spontaneous speech sample. A sample of spontaneous speech was obtained by retelling a story, and the fairy tale "Cinderella" was used as a stimulus task. Book "Cinderella" with pictorial material (without words) that illustrates the content was given to the children, with a request to review the picture book for as long as they need to recall the fairy tale. After that, the book was removed and children were asked to tell an illustrated fairy tale. It is a common method of assessing lexical diversity in people with language disorders [36,37]. A speech samples were recorded and then transcribed according to the rules of phonological transcription of the Serbian language. From the total sample, a segment of the first 150 words was analysed. This measure also represents the shortest speech sample of the participants included in the sample. This way of segmentation has been recommended in some of the studies that have analysed lexical diversity of children with language disorders [38,39]. The score of lexical diversity was calculated with the ratio of different and the total number of words in a given discourse (Type Token Ratio – TTR) [40, 41].

Lexical assessment was performed by two highly qualified speech and language therapists.

Statistical analysis

Chi-square test was used for comparing groups of children regarding categorial variables, sex, maternal education and age groups. Analysis of variance (ANOVA) was used for comparing groups regarding age, as well for comparing differences in lexical abilities between age groups. In cases where the equivalence of variance assumption is

violated, Welch's approximate method of analysis of variance was used to verify the significance of subpopulation differences in achievements on individual variables. Multiple comparison between three groups regarding their lexical abilities was investigated with *post-hoc* analysis when equality of variance is not assumed, Tamhane's T2 method. Two-way ANOVA was used for the purpose of investigating developmental trends in lexical abilities. SPSS software (version 26.0) was used for data analysis.

Results

The results of the analysis of variance (ANOVA) indicate statistically significant differences in achievement in the tasks of naming assessment, semantic processing and lexical diversity between DLDhpx, DLDwrf and TD children. A detailed analysis using the post-hoc Tamhane's T2 reveals a pattern of difference between the groups on all tasks (Tables 3 and 4).

Data showed that DLDhpx children have statistically significantly lower scores comparing to children DLDwrf on tasks assessing semantic processing ($p < 0.05$). On the other hand, two DLD groups do not differ significantly on vocabulary size and lexical diversity tests, although children with DLDhpx have lower average achievement (BNT = 39.47 vs. 44.33; LD = 0.29 vs. 0.34). Both DLD groups have statistically significantly lower scores comparing to TD children on all tests ($p < 0.01$) (Table 3).

Further, we wanted to examine whether there are differences in developmental patterns between the observed groups. Using a two-factor analysis of variance, we examined whether there are differences in developmental tendencies between children of preschool and school-age in the examined groups of children. Two-way ANOVA showed specific developmental patterns in DLDhpx, DLDwrf and TD children on tasks assessing vocabulary size, semantic processing and lexical diversity (Table 4).

No interaction was observed between groups of children and age on the BNT test ($F_{(5;95)} = 2.565$; $p = 0.083$). All three groups of children show a similar developmental trend in the vocabulary growth, with the difference of starting from different developmental levels (Table 4).

In a case of WAT achievement, a statistically significant interaction was observed between groups and age ($F_{(5;95)} = 26.595$; $p \leq 0.000$) (Table 4). Group explains about 51% of results variability ($F_{(1)} = 47.442$; $p \leq 0.000$; part $\eta 2 = 0.513$), while age explains about

20% of results variability ($F_{(1)} = 22.898$; $p \leq 0.000$; part $\eta 2 = 0.203$). The observed pattern shows that semantic processing improves with age, but also that there are significant differences in progress between groups of children.

No interaction was observed between groups of children and age regarding LD ($F_{(5;95)} = 2.239$; $p = 0.113$). All three groups of children show a similar developmental trend regarding lexical productivity, with the difference of starting from different developmental levels (Table 4).

However, observing the age differences at the subpopulation level, different developmental patterns were identified in three groups of children. Using the ANOVA test, the differences between preschool and school-age children in all three groups were compared on all three lexical tasks. Comparing the two age groups within the DLDhpx population, a statistically significant improvement was found only on the BNT test ($F_{(1;\ 23)} = 9.884$; $p = 0.005$). On the other hand, no statistically significant differences were found between the two age groups on the semantic processing and lexical diversity tasks (WAT – $F_{(1;\ 23)} = 1.629$; $p = 0.215$; LD – $F_{(1;\ 23)} = 0.001$; $p = 0.980$). Within the DLDwrf group, statistically significantly better achievements of school-age children were observed on vocabulary size and semantic processing assessment (BNT – $F_{(1;\ 28)} = 19.991$; $p \leq 0.000$; WAT – Welch $F_{(1;\ 28)} = 20.386$; $p \leq 0.000$), while statistically significant differences between preschoolers and schoolers were not found on the lexical diversity assessment ($F_{(1;\ 23)} = 0.045$; $p = 0.833$). In the TD group, statistically significantly better achievements of school-age children were observed on all three lexical tasks (BNT – $F_{(1;\ 39)} = 9.110$; $p = 0.004$; WAT – $F_{(1;\ 39)} = 8.938$; $p = 0.005$; LD – Welch $F_{(1;\ 16.182)} = 7.016$; $p = 0.017$).

Discussion

In our study, we examined three dimensions of expressive lexical-semantic abilities by applying specific tests of expressive vocabulary assessment, semantic processing, and the lexical productivity in continuous speech. The results showed that both groups of DLD children differed significantly from their TD peers in all three dimensions of lexical-semantic abilities. Regardless of the presence of neurological risk factors, DLD children have significantly poorer expressive vocabulary, have a sparse semantic network and difficulties in semantic processing, as well as use significantly fewer words in spontaneous speech compared to TD peers. A significantly smaller number of correct answers on the

naming test indicates a smaller volume of DLD children's vocabulary. Difficulties in naming in DLD children have been identified in several previous studies [42-44]. DLD children may even have a level of expressive vocabulary similar to children with autism spectrum disorder [45]. In terms of semantic processing, our results show that all DLD children have significantly lower results comparing to TD peers. Namely, a significantly smaller number of mature associations shows that DLD children have deficits in organization and sparse lexical-semantic network. Our results confirm results of several previous studies that examined semantic processing in DLD children [12,34,45]. Additionally, both DLD groups have lower achievements compared to TD children in the domain of lexical productivity, regardless of the presence of neurological risk factors. These results confirm the results of several previous studies of lexical diversity in DLD children [13,14, 47,48].

The comparison analysis within the group of DLD children indicated certain specifics. Namely, children with DLD and PH have significantly lower scores comparing to DLD children without neurological risk factors on semantic processing task, but not on naming and lexical diversity assessment. These results indicate a potential effect of perinatal hypoxia, even in mild form, on the severity of deficits in semantic network organization, but not on vocabulary size and lexical productivity in continuous speech. There are no researches in the literature that have studied the impact of PH on the severity of language deficit in DLD children for direct comparison, but there are several that studied the impact of perinatal risk factors on language outcome in the population of typically developing children. The influence of risk factors on the language abilities of preschoolers with speech and language disorders was studied in the research of Tomblin et al. [49]. The results of this study showed that children who experienced some of the prenatal or perinatal risk factors (infections, low birth weight, hypoxia) have lower scores at general language assessment, comparing to children without pre/perinatal risk factors. Furthermore, Fox et al. [50] stated that, of the several risk factors studied, prenatal and perinatal risk factors are most associated with speech and language difficulties at a later age. One of the few studies that has examined the impact of prenatal and perinatal risk factors on children's achievement on specific language tests is a study of Duncan et al. [51], which confirmed a link between the presence of risk factors and poor performance on specific language assessment tests. Namely, the mentioned study compared the achievements of prematurely

born children (without the presence of cognitive deficits, sensory and intellectual disabilities), aged four to seven, with children without occurred perinatal complications. The results of this study showed a significant and negative impact of risk factors on the mean length of utterance, syntactic complexity and short-term memory. Significantly lower achievements of semantic processing in DLDhpx children can be explained by the possible presence of cognitive deficits. Namely, cognitive deficits that are often observed in these children at a later age, without more pervasive cognitive impairment and with or without history of HIE. Of the various cognitive deficits, more pronounced memory deficits are the most common [52,53]. On the other hand, semantic processing is lexical-semantic highly related to different dimensions of memory, including short-term memory, working memory and cognitive processing speed [54,55]. However, for reliable conclusions and as implication for future research, the sample should be expanded and tests for the assessment of specific cognitive abilities should be added.

On the other hand, a detailed analysis of the achievements in preschool and school-age children indicated specific developmental tendencies in all three dimensions of lexical and semantic abilities. Namely, age proved to be a significant factor of improvement in DLDwrf and TD children regarding semantic processing. However, the comparison analysis of preschool and early school-age children′s achievements showed that DLDhpx children progress only within expressive vocabulary skills, while DLDwrf children progress significantly within expressive vocabulary and semantic processing skills. On the other hand, a significant improvement in all assessed lexical abilities was observed in TD children. This means that DLD children without any of the neurological risk factors progress significantly more than DLD children with PH within general lexical ability.

Given that both groups of DLD children have been covered with a treatment in a specialized institution for a long period of time, we can assume that PH may pose a significant risk for more severe lexical deficits in DLD children, that may be quite resistant to conventional rehabilitation approaches used in treatment. There are two possible explanations for this. One is that even a milder form of hypoxia in DLD children can lead to comorbidity with specific cognitive deficits which cannot be detected with standard and general cognitive assessment. Assessing of specific cognitive abilities that are highly related to lexical-semantic abilities, such as working memory or cognitive processing speed, usually is not a part of general cognitive assessment. Another explanation is related

to the influence of PH on the development of the brain in newborns. The other explanation is that PH may affect timing of programmed synaptic death, or synaptic pruning, most of which occurs postnatally. Synaptic pruning is an important part of the neural networks formation that underlie speech and language abilities[56]. Given that very complex and widely distributed neural networks connected to different regions of the brain underlie lexical-semantic abilities, it is possible that inadequate synapse formation causes difficulties in developing some of many aspects of this complex ability, or causes a more severe semantic deficit in children who have underdeveloped speech and language skills.

The result that indicates that both groups of DLD children do not progress with age in the domain of lexical productivity in spontaneous speech can be explained by several difficulties of particular aspects of language that these children have. Namely, lexical diversity is an ability that lies at the syntactic-semantic crossroads, and, to some extent, depends on syntactic abilities. As syntactic deficit is often a dominant symptom in DLD children [2], it is possible that it significantly contributes to the non-progression of both DLD groups. Reliable measurement of the semantic dimension of lexical productivity in continuous speech should include measuring the lexical diversity of only content words, such as nouns, adjectives, and verbs. This is one of the shortcomings of this study and implications for future research.

Finally, we would like to state the biggest limitation of the study. In general, DLD is a very heterogeneous disorder [2], which in such small clinical subgroups leads to frequent violations of the rules of sample homogeneity and normality of distribution, which limits the application of statistical measures with high reliability of the obtained results. A significantly higher number of children in subgroups would allow for more reliable conclusions, which is one of the implications for future research.

Conclusion

PH in DLD children can lead to a more severe degree of lexical-semantic deficit that these children otherwise have. This is manifested by a more severe deficit of semantic processing, which indicates a weaker organization and sparse lexical-semantic network, which is otherwise underdeveloped in DLD children. However, a more extensive problem is that the PH presence in DLD children can cause significantly slower progress in all observed dimensions of lexical-semantic abilities, even with a language therapy. Slower

progress was observed in the area of expressive vocabulary size, semantic processing and lexical productivity in continuous speech. It is possible that PH is a significant factor of the slower maturation of the central nervous system. Given the great importance of lexical and semantic abilities in the process of mastering academic skills, these children may have significantly more difficulties in this domain compared to DLD children without the presence of any of the neurological risk factors.

In order for better understanding the neurological risk factors influence on the language outcome in DLD children, more research with language specific tests is needed, which would include also phonological and syntactic abilities. Also, future research should include tests for assessing specific cognitive abilities and their relationship with language skills.

Table 1

Description of the sample according to demographic variables

		DLDhpx	DLDwrf	TD			Mean Diff. / $\chi 2$	SE / df	*p*
Age	N	25	30	41	Age	DLDhpx	DLDwrf	4.227	3.070	0.391
	Mean	69.64	73.87	71.83			TD	2.189	2.877	0.749
	SD	9.51	12.39	11.55		DLDwrf	TD	2.037	2.724	0.757
Gender	Girls N(%)	7(28)	13(43.3)	20(48.8)	Gender		DLDwrf	0.802	1	0.370
						DLDhpx	TD	1.981	1	0.159
	Boys N(%)	18(72)	17(56.7)	21(51.2)		DLDwrf	TD	0.046	1	0.831
Maternal education	Secondary N(%)	16(64)	13(43.3)	22(53.7)	Maternal education	DLDhpx	DLDwrf	1.581	1	0.209
							TD	0.322	1	0.570
	Tertiary N(%)	9(36)	17(56.7)	19(46.3)		DLDwrf	TD	0.384	1	0.536

DLDhpx – Developmental Language Disorder with hypoxia; DLDwrf - Developmental Language Disorder without neurological risk factors; TD – Typically Developing children;

SD-standard deviation; SE-standard error; Diff.- difference.

Table 2

Distribution of participants through age groups

Group		Age (years) 5-6	Age (years) 7 -8	Total
DLDhpx	N	15	10	25
	%	60.0	40.0	100.0
DLDwrf	N	18	12	30
	%	60.00	40.00	100.00
TD	N	25	16	41
	%	61.00	39.00	100.00
Total	N	58	38	96
	%	60.42	39.58	100.00

DLDhpx – Developmental Language Disorder with hypoxia; DLDwrf - Developmental Language Disorder without neurological risk factors; TD – Typically Developing children.

Table 3

Post-hoc Tamhane's T2 multiple comparasion of lexical abilities between DLDhpx, DLDwrf and TD children

			Mean difference	SE	*p*
BNT	DLDhpx	DLDwrf	-4.867	3.195	0.350
		TD	-28.378	2.482	**0.000**
	DLDwrf	TD	-23.511	2.689	**0.000**
MA	DLDhpx	DLDwrf	-25.296	8.222	**0.010**
		TD	-54.382	5.899	**0.000**
	DLDwrf	TD	-29.086	6.321	**0.000**
LD	DLDhpx	DLDwrf	-0.048	0.022	0.118
		TD	-0.205	0.234	**0.000**
	DLDwrf	TD	-0.157	0.018	**0.000**

BNT – Boston Naming Test; MA – Mature Associations; LD – Lexical Diversity; DLDhpx – Developmental Language Disorder with hypoxia; DLDwrf - Developmental Language Disorder without neurological risk factors; TD – Typically Developing children.

SE-standard error.

Table 4

Two-way ANOVA age * group model

	Group	Age (yrs.)	Mean	SD	df	MS	F	*p*	part η2
BNT	DLDhpx	5-6	34.777	8.425	5	196.608	2.565	0.083	0.054
		7-8	46.499	10.137					
	DLDwrf	5-6	37.593	11.248					
		7-8	54.444	8.050					
	TD	5-6	65.066	6.075					
		7-8	72.187	9.062					
MA	DLDhpx	5-6	17.374	27.477	5	2094.300	26.595	**0.000**	0.596
		7-8	31.745	19.015					
	DLDwrf	5-6	32.037	30.030					
		7-8	72.992	19.649					
	TD	5-6	73.374	11.276					
		7-8	83.959	10.702					
LD	DLDhpx	5-6	0.292	0.088	5	0.017	2.239	0.113	0.055
		7-8	0.291	0.113					
	DLDwrf	5-6	0.338	0.062					
		7-8	0.343	0.080					
	TD	5-6	0.468	0.041					
		7-8	0.548	0.114					

BNT – Boston Naming Test; MA – Mature Associations; LD – Lexical Diversity; DLDhpx – Developmental Language Disorder with hypoxia; DLDwrf - Developmental Language Disorder without neurological risk factors; TD – Typically Developing children.

SD-standard deviation.

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