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Perinatal hypoxia as a risk factor for a more severe lexical-semantic deficit in children with developmental language disorder

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

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Abstract

Background/Aim. There is a small body of literature on the influence of perinatal hypoxia (PH) on language outcomes at a later age. Correspondingly, there are no studies on the influence of PH on the extent and severity of language deficits in children with developmental language disorder (DLD). The aim of this study was to examine the differences in lexical-semantic (LS) abilities in DLD children with the presence of PH (DLDph) and DLD children without any neurological risk factors (DLDwnrf). **Methods**. The study sample consisted of 96 children aged 5 to 8 years, divided into three groups: 25 children in the DLDph group, 30 children in the DLDwnrf group, and 41 typically developing (TD) peers. To compare age-related differences, an additional categorical variable was formed with two age groups – preschool and school-age children (5–6 and 7–8 years, respectively). LS abilities were investigated with specific measures for assessing the expressive vocabulary (EV) size, semantic processing (SP) skills, and lexical productivity (LPr). To assess LPr, measure for calculating lexical diversity from speech sample was applied. **Results**. Significant differences were observed between DLDph and DLDwnrf children on the SP assessment ($p < 0.05$) but not on the EV ($p = 0.350$) and LPr ($p = 0.118$) assessment. However, a detailed analysis of developmental tendencies between preschool and early school-age children showed that DLDph children progressed significantly only in the domain of EV ($p < 0.01$), while DLDwnrf children progressed significantly in the domain of EV and SP skils ($p < 0.001$). Regarding LPr developmental tendencies, no significant progress was observed in either of the DLD groups. **Conclusion**. In DLDph children, a more severe extent of LS deficit in the area of SP abilities can be related to PH. Similarly, PH can contribute to slower progress in a wider spectrum of LS abilities.

Key words:
brain; hypoxia; language disorders; risk factors.

Apstrakt

Uvod/Cilj. U literaturi postoji mali broj radova o uticaju perinatalne hipoksije (PH) na jezičke sposobnosti dece starijeg uzrasta. Takođe, ne postoje studije o uticaju PH na obim i težinu jezičkog deficita dece sa razvojnim jezičkim poremećajem (RJP). Cilj rada bio je da se ispitaju razlike u leksičko-semantičkim (LS) sposobnostima dece sa RJP i sa istorijom PH (RJPph) i dece sa RJP bez neuroloških faktora rizika (RJPbnfr). **Metode**. Uzorak je činilo 96 dece uzrasta od 5 do 8 godina, svrstanih u tri grupe: RJPph grupa (25 dece), RJPbnfr grupa (30 dece) i grupa od 41 tipično razvijene (TR) dece istog uzrasta. U cilju poređenja razlika koje zavise od uzrasta, formirane su i dve dodatne starosne grupe – deca predškolskog i deca školskog uzrasta (5–6 i 7–8 godina, redom). Za merenje LS sposobnosti primenjeni su specifični testovi za procenu obima ekspresivnog vokabulara (EV), semantičkog procesiranja (SP) i leksičke produktivnosti (LPr). Za procenu LPr primenjena je mera računanja leksičke raznovrsnosti u uzorku spontanog govora. **Rezultati**. Rezultati su pokazali statistički značajne razlike između grupa RJPph i RJPbnfr na testu procene SP ($p < 0,05$), ali ne i na testovima za procenu EV ($p = 0,350$) i LPr ($p = 0,118$). Međutim, detaljna analiza razvojnih tendencija dece predškolskog i ranog školskog uzrasta pokazala je da su deca iz grupe RJPph značajno napredovala samo u domenu EV ($p < 0,01$), dok su deca iz grupe RJPbnfr značajno napredovala u domenu EV i SP ($p < 0,001$). Što se tiče razvojnih tendencija u domenu LPr, ni u jednoj od dve grupe sa RJP nije utvrđen značajan napredak. **Zaključak**. Kod RJPph dece, teža forma LS deficita u oblasti sposobnosti SP može biti povezana sa PH. Takođe, PH može doprineti sporijem napredovanju šireg spektra LS sposobnosti.

Ključne reči:
mozak; hipoksija; jezički poremećaji; faktori rizika.

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Introduction

Developmental language disorder

According to the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (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 the 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 (LS) deficits in DLD children. In other words, these children are characterized by a significant delay in first-word acquisition [4, 5]. Some authors consider this symptom in DLD children the first key symptom of speech and language development delay [2, 3]. DLD children also have significantly underdeveloped expressive vocabulary (EV) and receptive vocabulary (RV) skills compared to their typically developing (TD) peers [6]. In accordance with poor vocabulary, these children also have word-finding difficulties [7]. Likewise, DLD children learn new words significantly slower and harder compared 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 LS organization and processing [10–12]. In addition to the above, DLD children also have significant difficulties using words in spontaneous speech. Namely, studies of lexical diversity (LD) in speech samples of DLD children showed that these children have a significantly lower usage of all types of words [13, 14] and significantly fewer content words (nouns, verbs, adjectives) [13, 15] compared to TD peers.

Although DLD is a disorder 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 LS [11, 13] and pragmatic abilities [16]. Given the importance of LS abilities for mastering academic skills, research in this population is of great importance for the academic outcomes of these children.

Perinatal hypoxia and language development

Perinatal hypoxia (PH) is a term that refers to the period 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]. Results of some studies show that these children may have average language skills measured by general batteries of tests for 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 of tests for a general assessment of cognitive abilities. The results showed that children with a history of HIE could have significant difficulties with EV skills and shorter mean length of utterance (a general measure of syntactic abilities) compared to TD peers. Additionally, data from this research showed that RV skills are quite preserved in these children. However, the results of this study showed that gender and socioeconomic status are essential predictors of EV development, while the extent and severity of brain damage are more important predictors of RV in these children. According to that, the influence of HIE on the development of expressive lexical abilities (LA) 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, LS, and phonological or pragmatic abilities.

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

Present study

Several papers in the literature have studied the possible impact of PH on children's language skills. In addition, those studies used general batteries of tests for assessing language abilities, most often as part of the general cognitive abilities assessment. These types of tests are usually not sensitive to deficits that children may have within structural aspects of language (syntactic, semantic, phonological, or pragmatic). Moreover, there are no available studies on 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 where it was not considered a separate factor. Likewise, anecdotal data from practice indicate a possible severe language deficit in DLD children who suffer from PH, even in the absence of neurological or severe cognitive deficits. Accordingly, the aim of our study was a detailed examination of the possible impact of PH on the severity of lexical deficit in DLD children, using specific tests that measure three dimensions of expressive LS abilities.

Methods

Participants

The sample consisted of 96 children aged 5 to 8 years divided into three groups. Twenty-five children were diagnosed with an expressive type of DLD and a history of PH (DLDph), and 30 children were diagnosed with an expressive type of DLD without the presence of neurological risk factors (DLDwnrf) before, during, or after birth. A control sample consisted of 41 TD children without a history of DLD or other developmental disorders and without a history of neurological or sensory impairments (Table 1). All DLD children were recruited from the Institute for Psychophysiological Disorders and Speech Pathology (IPDSP) “Prof. Dr. Cvetko Brajović” in Belgrade, Serbia. All DLD children were included in speech and language therapy for 12 to 18 months. Evidence of the presence of neurological risk factors (NRF) was obtained from medical history. All DLDph children had a history of PH, 5-min Apgar score between 5 and 7, without evidence of HIE or documented neurological or motor impairment. In the first six months of the research, 21 children with DLDph who met the criteria regarding age and treatment period were included in the sample. To increase the number of school-age children, four more children were included in the sample in the next two years. A sample of DLDwnrf 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 located in Belgrade. The inclusion criterion for all groups was an IQ above 85, within the norms of average intelligence, while one child from the DLDwnrf group with IQ above average (> 109) was excluded from the sample. Data on intelligence level were taken from psychological documentation and included the general IQ and the instrument which it was assessed with. The Wechsler Intelligence Scale for Children – Revised form, which has been normed on the Serbian population, was administered for all children [21]. Only participants whose first language is Serbian were included in the sample. The research was approved by the Ethical Board of IPDSP “Prof. Dr. Cvetko Brajović” in Belgrade, Serbia (1575/19-09-2016), and for testing all children, written consent was obtained from the parents.

There were no significant differences between groups regarding age (Tables 1 and 2). Given the numerous data in

Table 1

Demographic characteristics of study participants

Variable	Groups		
	DLDph n = 25	DLDwnrf n = 30	TD n = 41
Age (months), mean ± SD	69.6 ± 9.5	73.9 ± 12.4	71.8 ± 11.6
Gender, n (%)			
girls	7 (28)	13 (43.3)	20 (48.8)
boys	18 (72)	17 (56.7)	21 (51.2)
Maternal education, n (%)			
secondary	16 (64)	13 (43.3)	22 (53.7)
tertiary	9 (36)	17 (56.7)	19 (46.3)

DLDph – developmental language disorder with perinatal hypoxia; DLDwnrf – developmental language disorder without neurological risk factors; TD – typically developing children; SD – standard deviation.

Table 2

Comparison of groups according to sociodemographic variables

Variable	Groups		Mean diff./χ^2	SE/df	*p*-value
Age	DLDph	DLDwnrf	4.227	3.070	0.391
	DLDph	TD	2.189	2.877	0.749
	DLDwnrf	TD	2.037	2.724	0.757
Gender	DLDph	DLDwnrf	0.802	1	0.370
	DLDph	TD	1.981	1	0.159
	DLDwnrf	TD	0.046	1	0.831
Maternal education	DLDph	DLDwnrf	1.581	1	0.209
	DLDph	TD	0.322	1	0.570
	DLDwnrf	TD	0.384	1	0.536

diff. – difference; χ^2 – Chi squared; SE – standard error; df – degree of freedom. For abbreviations of other terms see Table 1.

the literature that indicate the possible influence of gender [6, 22, 23] and maternal education [24–26] on children's LA, we compared groups regarding mentioned demographic variables. However, no significant differences were found between these groups of children (Table 2). To compare age differences, an additional categorical variable was formed with two age groups, preschool and school-age children (5–6 and 7–8 years, respectively). Data on the distribution of participants through age groups are given in Table 3. Comparison analysis of the participants by age groups showed that there was no statistically significant difference between all groups (DLDph vs. DLDwnrf: $\chi^2 = 0.000$, df = 1, $p = 1.000$; DLDph vs.TD: $\chi^2 = 0.000$, df = 1, $p = 1.000$; DLDwnrf vs. TD: $\chi^2 = 0.000$, df = 1, $p = 1.000$).

Instruments

To assess vocabulary size (VS), Boston Naming Test (BNT) [27] was used. The test consists of 60 black-and-white drawings of objects and assesses the ability of 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 the Serbian language but is not standardized. The 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.

To assess LS processing skills (PS), Word Association Task (WAT) was used. Eighty words were selected from Kent and Rosanof [30] list with the addition of ten verbs in order to equalize word classes. The association test based on this list is the best studied in a linguistical manner of all available in the literature within the Birkbeck Vocabulary Project [31] in the 1980s. All words were selected to be early acquired, as highly imageable as possible depending on the word class, and high and medium frequencies according to the Children's frequency dictionary [32]. Moreover, variants of association tests are commonly used for assessing semantic processing in children with language disorders and LS organization of bilingual children [12, 33, 34]. Furthermore, 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 are paradigmatic and syntagmatic responses, which are the indicators of a 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. These types of associations are indicators of an underdeveloped semantic network [11]. The score of mature type of associations was used for statistical analysis.

The measure of LD was used to assess lexical productivity (LPr). LD was measured 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. The 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 needed 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 LD in people with language disorders [36, 37]. 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 analyzed. This measure also represents the shortest speech sample of the participants. This way of segmentation has been recommended in some of the studies that have analyzed the LD of children with language disorders [38, 39]. The score of LD was calculated with the ratio of the different and total number of words in a given discourse (Type Token Ratio – TTR) [40, 41]. The lexical assessment was performed by two highly qualified speech and language therapists.

Statistical analysis

The χ^2 test was used for comparing groups of children regarding categorical variables, gender, maternal education, and age groups. Analysis of variance (ANOVA) was used for comparing groups regarding age, including differences in LA 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 in individual variables. Multiple comparisons between three groups regarding their LA were investigated with *post-hoc* analysis, Tamhane's T2 method, when the equality of variance is not assumed. Two-way ANOVA was used to investigate developmental trends in LA. SPSS software (version 26.0) was used for data analysis.

Table 3

Distribution of participants through age groups

Age (years)	Groups			Total
	DLDph	DLDwnrf	TD	
5–6	15 (60.0)	18 (60.0)	25 (61.0)	58 (60.4)
7–8	10 (40.0)	12 (40.0)	16 (39.0)	38 (39.6)
Total	25 (100.0)	30 (100.0)	41 (100.0)	96 (100.0)

Results are shown as numbers (percentages) of the participants. For abbreviations see Table 1.

Results

The results of ANOVA indicate statistically significant differences in achieving the VS, PS, and LPr tasks between DLDph, DLDwnrf, and TD children. A detailed analysis using the *post-hoc* Tamhane's T2 reveals a pattern of difference between the groups on all tasks (Table 4). Data showed that DLDph children have statistically significantly lower scores compared to DLDwnrf children on assessing PS tasks ($p < 0.05$). On the other hand, the two DLD groups do not differ significantly on VS and LPr tests, although children with DLDph have a lower average achievement (VS = 39.47 vs. 44.33; LPr = 0.29 vs. 0.34). Both DLD groups have statistically significantly lower scores compared to TD children on all tests ($p < 0.01$) (Table 4).

Further, we wanted to examine whether differences in developmental patterns between the observed groups existed. Using a two-factor ANOVA, we examined whether there are differences in developmental tendencies between preschool and school-age children in the examined groups of children. Two-way ANOVA showed specific developmental patterns in DLDph, DLDwnrf, and TD children on tasks assessing VS, PS, and LPr (Table 5).

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

In the case of WAT achievement (for PS assessment), a statistically significant interaction was observed between groups and age ($F_{5; 95} = 26.595$, $p \leq 0.000$) (Table 5). Group explains about 51% of results variability ($F_1 = 47.442$, $p \leq 0.000$, part η2 = 0.513), while age explains about 20% of results variability ($F_1 = 22.898$, $p \leq 0.000$, part η2 = 0.203). The observed pattern shows that PS 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 LPr ($F_{5; 95} = 2.239$, $p = 0.113$). All three groups of children show a similar developmental trend regarding LPr, with the difference of starting from different developmental levels (Table 5).

However, upon 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 DLDph population, a statistically significant improvement was found only on the VS task ($F_{1; 23} = 9.884$, $p = 0.005$). On the other hand, no statistically significant differences were found between the two age groups on the PS and LPr tasks (PS – $F_{1; 23} = 1.629$, $p = 0.215$; LPr – $F_{1; 23} = 0.001$, $p = 0.980$).

Table 4

***Post-hoc* Tamhane's T2 multiple comparisons of lexical abilities between the studied groups**

Lexical abilities	Groups		Mean diff.	SE	*p*-value
Vocabulary size	DLDph	DLDwnrf	-4.867	3.2	0.350
	DLDph	TD	-28.378	2.5	**0.000**
	DLDwnrf	TD	-23.511	2.7	**0.000**
Processing skills	DLDph	DLDwnrf	-25.296	8.2	**0.010**
	DLDph	TD	-54.382	5.9	**0.000**
	DLDwnrf	TD	-29.086	6.3	**0.000**
Lexical productivity	DLDph	DLDwnrf	-0.048	0.0	0.118
	DLDph	TD	-0.205	0.2	**0.000**
	DLDwnrf	TD	-0.157	0.0	**0.000**

diff. – difference; SE – standard error. For abbreviations of other terms see Table 1. Boston naming test, mature associations, and lexical diversity were used to determine vocabulary size, processing skills, and lexical productivity, respectively.
Statistically significant values are bolded.

Table 5

Two-way ANOVA analysis of lexical abilities of the studied groups in preschool and school-age children

Lexical abilities	Age (years)	Groups			df	MS	F	*p*-value	part η^2
		DLDph	DLDwnrf	TD					
Vocabulary size	5–6	34.8 ± 8.4	37.6 ± 11.2	65.1 ± 6.1	5	196.608	2.565	0.083	0.054
	7–8	46.5 ± 10.1	54.4 ± 8	72.2 ± 9.1					
Processing skills	5–6	17.4 ± 27.5	32.0 ± 30.0	73.4 ± 11.3	5	2,094.300	26.595	**0.000**	0.596
	7–8	31.7 ± 19.0	72.9 ± 19.6	83.9 ± 10.7					
Lexical productivity	5–6	0.3 ± 0.1	0.3 ± 0.1	0.5 ± 0.0	5	0.017	2.239	0.113	0.055
	7–8	0.3 ± 0.1	0.3 ± 0.1	0.6 ± 0.1					

df – degree of freedom; MS – means squares; F – statistic value for analysis of variance (ANOVA); η^2 – squared Eta. For abbreviations of other terms see Table 1. Results are shown as mean ± standard deviation.
Boston naming test, mature associations, and lexical diversity were used to determine vocabulary size, processing skills, and lexical productivity, respectively. Statistically significant value is bolded.

Within the DLDwnrf group, statistically significantly better achievements of school-age children were observed on VS and PS assessment (VS – $F_{1; 28} = 19.991$, $p \leq 0.000$; PS – Welch $F_{1; 28} = 20.386$, $p \leq 0.000$), while statistically significant differences between preschoolers and schoolers were not found on the LPr 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 (VS – $F_{1; 39} = 9.110$, $p = 0.004$; PS – $F_{1; 39} = 8.938$, $p = 0.005$; LPr – Welch $F_{1; 16.182} = 7.016$, $p = 0.017$).

Discussion

In this study, we examined three dimensions of expressive LS abilities by applying specific tests of EV assessment, PS, and the LPr in continuous speech. The results showed that both groups of DLD children differed significantly from their TD peers in all three dimensions of LS abilities. Regardless of the presence of NRF, DLD children have significantly poorer EV, sparse semantic networks, and difficulties in PS, and they use significantly fewer words in spontaneous speech compared to TD peers. A significantly lower number of correct answers on the naming test indicates a smaller volume of DLD children's vocabulary. Several previous studies have identified difficulties in naming in DLD children [42–44]. DLD children may even have a level of EV similar to children with autism spectrum disorder [45]. In terms of PS, our results show that all DLD children have significantly lower results compared to TD peers. Namely, a significantly lower number of mature associations shows that DLD children have deficits in organization and sparse LS networks. Our results confirm the results of several previous studies that examined PS in DLD children [12, 34, 46]. Additionally, both DLD groups have lower achievements compared to TD children in the domain of LPr, regardless of the presence of NRF. These results confirm the results of several previous studies of LPr in DLD children [13, 14, 47, 48].

The comparison analysis within the group of DLD children indicated certain specifics. In other words, DLDph children have significantly lower scores compared to DLDwnrf children on PS tasks but not on naming and LPr assessment. These results indicate a potential effect of PH, even in a mild form, on the severity of deficits in semantic network organization but not on VS and LPr in continuous speech. There are no studies in the literature that have analyzed the impact of PH on the severity of language deficit in DLD children for direct comparison, but there are a few that have examined the impact of perinatal RF on language outcome in the population of TD children. The influence of RF on the language abilities of preschoolers with speech and language disorders was analyzed in the study by Tomblin et al. [49]. The results of this study showed that children who experienced some of the prenatal or perinatal RF (infections, low birth weight, hypoxia) have lower scores at general language assessment, compared to children without pre/perinatal RF. Furthermore, Fox et al. [50] stated that, of the several RF studied, prenatal and perinatal RF are most associated with speech and language difficulties at a later age. One of the few studies that have examined the impact of prenatal and perinatal RF on children's achievement on specific language tests is a study by Duncan et al. [51], which confirmed a link between the presence of RF and poor performance on specific language assessment tests. Particularly, the mentioned study compared the achievements of prematurely born children (without the presence of cognitive deficits, sensory and intellectual disabilities) 4 to 7 years old to children without any perinatal complications. The results of this study showed a significant and negative impact of RF on the mean length of utterance, syntactic complexity, and short-term memory. Significantly lower achievements of PS in DLDph children can be explained by the possible presence of cognitive deficits. Namely, cognitive deficits are often observed in these children at a later age, without more pervasive cognitive impairment and with or without a history of HIE. Of the various cognitive deficits, pronounced memory deficits are the most common [52, 53]. On the other hand, PS is a domain of LS that is highly related to different dimensions of memory, including short-term memory, working memory, and cognitive processing speed [54, 55]. However, for reliable conclusions and implications for future research, the sample should be expanded, and tests for assessing specific cognitive abilities added.

A detailed analysis of the achievements in preschool and school-age children indicated specific developmental tendencies in all three dimensions of LA and semantic abilities. In other words, age proved to be a significant factor of improvement in DLDwnrf and TD children regarding PS. However, the comparison analysis of preschool and early school-age children's achievements showed that DLDph children progress only within EV skills, while DLDwnrf children progress significantly within EV and PS. On the other hand, a significant improvement in all assessed LA was observed in TD children. That means that DLDwnrf children progress significantly more than DLDph children within general LA. Given that both groups of DLD children have been covered with 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, which 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 that cannot be detected with standard and general cognitive assessment. Assessing specific cognitive abilities that are highly related to LS abilities, such as working memory or cognitive processing speed, is not usually a part of general cognitive assessment. The obtained results may be explained by the possible comorbidities with a specific cognitive deficit but also by the fact that PH can contribute to significantly slower maturation of the brain and neural networks that underlie language abilities. Synaptic pruning is an important part of neural network formation that underlies speech and language abilities [56].

Namely, LPr 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 may significantly contribute to the nonprogression of both DLD groups. Reliable measurement of the semantic dimension of LPr in continuous speech should include measuring the LPr of only content words, such as nouns, adjectives, and verbs. That is one of the shortcomings of this study and its implications for future research.

Finally, we would like to state the most major 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.

In order to better understand the NRF influence on the language outcome in DLD children, more research with language-specific tests is needed, which would also include phonological and syntactic abilities. Furthermore, future research should include tests for assessing specific cognitive abilities and their relationship with language skills.

Conclusion

PH in DLD children can lead to a more severe degree of LS deficit than these children would otherwise have. That is manifested with a more severe deficit of PS, which indicates a weaker organization and sparse LS network, 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 LS abilities, even with language therapy. Slower progress was observed in the area of EV skils, semantic PS, and LPr in continuous speech. Given the immense importance of LS abilities in mastering academic skills, the DLDph children may have significantly more difficulties in that domain than DLDwnrf children.

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