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Evaluation of central auditory processing in children with Specific Language Impairment

Ocena ośrodkowych procesów słuchowych u dzieci ze specyficznymi zaburzeniami rozwoju mowy i języka

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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ABSTRACT: Specific Language Impairment (SLI) affects about 7-15 % of children of school age and according to the currently accepted diagnostic criteria, it is presumed that these children do not suffer from hearing impairment. The goal of this work was to assess anomalies of central auditory processes in a group of children diagnosed with specific language impairment. Material consisted of 200 children aged 7-10 years (100 children in the study group and 100 hundred in the control group). Selected psychoacoustic tests (Frequency Pattern Test - FPT, Duration Pattern Test - DPT, Dichotic Digit Test - DDT, Time Compressed Sentence Test - CST, Gap Detection Test – GDT) were performed in all children. Results were subject to statistical analysis. It was observed that mean results obtained in individual age groups in the study group are significantly lower than in the control group. Based on the conducted studies we may conclude that children with SLI suffer from disorders of some higher auditory functions, which substantiates the diagnosis of hearing disorders according to the AHSA (American Hearing and Speech Association) guidelines. Use of sound-based, not verbal tests, eliminates the probability that observed problems with perception involve only perception of speech, therefore do not signify central hearing disorders, but problems with understanding of speech. Lack of literature data on the significance of FPT, DPT, DDT, CST and GDT tests in children with specific language impairment precludes comparison of acquired results and makes them unique.

KEYWORDS: psychoacoustic tests, developmental disorders of speech, separable hearing disorders

STRESZCZENIE: Specyficzne zaburzenia rozwoju mowy i języka (Specific Language Impairment – SLI) dotykają ok. 7–15% dzieci w wieku szkolnym. Według obecnie stosowanych kryteriów rozpoznania przyjmuje się, że grupa tych dzieci ma prawidłowy słuch.

Celem niniejszej pracy była ocena ośrodkowych procesów słuchowych pod kątem występowania nieprawidłowości wśród dzieci ze zdiagnozowanymi specyficznymi zaburzenia rozwoju mowy i języka. Badana grupa składała się z 200 dzieci w wieku 7–10 lat (100 w grupie badanej, 100 w grupie kontrolnej). U wszystkich wykonano wybrane testy psychoakustyczne (Frequency Pattern Test – FPT, Duration Pattern Test – DPT, Dichotic Digit Test – DDT, Time Compressed Sentence Test – CST, Gap Detection Test – GDT). Uzyskane wyniki poddano analizie statystycznej. Wzięto pod uwagę średnie wartości wyników w poszczególnych grupach wiekowych i zauważono, że w grupie badanej były istotnie statystycznie niższe niż w grupie kontrolnej. Na tej podstawie można sformułować wniosek, że u dzieci ze SLI występują zaburzenia niektórych wyższych funkcji słuchowych, co w oparciu o wytyczne AHSA (American Hearing and Speech Association) dotyczące diagnozowania ośrodkowych zaburzeń słuchu, upoważnia do ich rozpoznania. Zastosowanie testów opartych o materiał dźwiękowy (a nie słowny), eliminuje ryzyko, że obserwowane problemy dotyczą tylko percepcji dźwięków mowy, a zatem nie oznaczają zaburzeń ośrodkowych słuchu, a jedynie rozumienia mowy. Brak danych literaturowych dotyczących wyników testów FPT, DPT, DDT, CST i GDT u dzieci ze specyficznymi zaburzeniami rozwoju mowy uniemożliwia porównanie uzyskanych wyników i czyni je w tym zakresie wyjątkowymi.

SŁOWA KLUCZOWE: testy psychoakustyczne, zaburzenia rozwoju mowy, ośrodkowe zaburzenia słuchu

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INTRODUCTION

Proper development of speech constitutes basis for balanced development of cognitive functions in a child. It is one of the conditions for normal social-emotional growth and its educational success. Author's area of interest includes specific language impairment (SLI). Numerous studies conducted around the world suggest that about 7-15% of school-age and pre-school children differ from their peers with regard to the speed of language acquisition and achieving language competence [1, 7, 13]. This problem more often involves boys and was often previously diagnosed in the family – in parents or siblings. It is a group of children that struggles with problems and language deficits throughout the educational period. It is not unusual for these children to persist in adulthood [18]. Specific language impairment is defined as improper acquisition of speech in children without brain damage, hearing impairment, significant learning disorders, or depraved of social contact [13]. Definition was formulated based on the exclusion criteria and the observed language difficulties cannot be explained by hearing disorders, low level of intelligence, abnormal environment or physical impairment [1]. In his book "*Children with Specific Language Impairment*" Leonard described factors that should be taken into consideration in the process of verification and diagnosis of specific language impairment [7]. He puts particular emphasis on proper hearing, but does not pertain to proper auditory processing.

Central hearing disorders are not a disease, but constitute a syndrome that might accompany a variety of diseases or appear in various healthy populations. For many years clinicians have observed a group of patients characterized by extremely poor ability to understand auditory information despite proper hearing threshold. Problems may encompass phonologic abilities, volume and sequence of auditory memory, temporal discrimination, or understanding of speech in loud surroundings [6]. Auditory Processing Disorders (APD) are defined as a deficit occurring in the process of data processing through the auditory pathway and present as dysfunction of understanding of speech in the presence of normal threshold of hearing, understanding of speech in altered/difficult acoustic conditions, and understanding of garbled speech [4]. Research on disorders of auditory perception led to formulation of a thesis that disorders in this area lead to impairment of speech and language, as well as problems with reading and writing [16, 19].

AIM

The goal of this work was to assess central processes of auditory processing disorders in children with specific speech and language impairment.

MATERIAL

Study material consisted of a group of 200 children.

Study group consisted of 100 children aged 7 to 10 years (at the time of the study), whose parents reported to consultations at the Department of Audiology and Phoniatrics of the Institute of Physiology and Pathology of Hearing between 2010 and 2011 due to the disorders of speech and language development observed in their children. Mean age of children in this group was 8.5 years. Material consisted of 72 boys (72%) and 28 girls (28%).

Control group comprised 100 children aged 7-10 years, with proper articulation, without speech and language impairment, without learning difficulties and with normal hearing – no signs of abnormalities of auditory processing. Mean age of children in this group was 8.6 years. The group included 59 girls (59%) and 41 boys (41%).

- normal results of auditory tests (tonal audiometry was performed for the following frequencies: 500Hz, 1000Hz, 2000HZ, 4000 Hz),
- no risk factors for central auditory disorders

METHOD

Among children who had reported to the Department of Audiology and Phoniatrics of the Institute of Physiology and Pathology of Hearing we selected ones who fit the criteria for diagnosis of SLI. In all selected children we conducted studies according to an established protocol that included:

- phoniatric examination with assessment of peripheral speech organ,
- hearing examination, including tonal and impedance audiometry in order to exclude hearing loss,
- psychological examination with assessment of developmental quotient,
- speech and language examination in order to assess the type of speech and language disorders - for that purpose we used the Demmel speech and language assessment questionnaire; tests for assessment of language competence in children and/or logopedic test for assessment of language competence;
- Psychoacoustic tests: **Frequency Pattern Test FPT, Duration Pattern Test DPT, Dichotic Digit Test DDT, Gap Detection Test GDT, Time – Compressed Sentence Test (CST)**

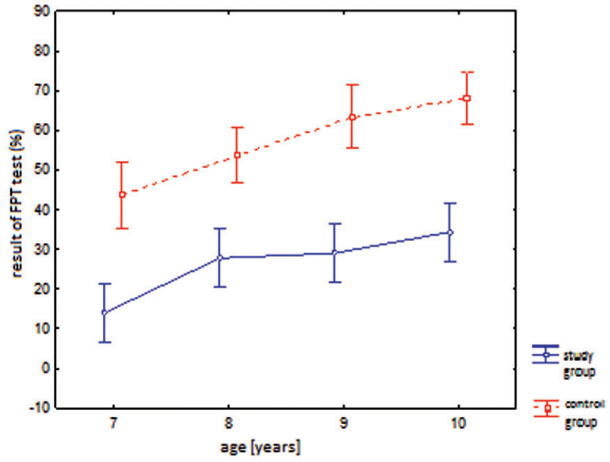

Fig. 1. Mean values with 95% confidence intervals for DPT test for the study group and the control group depending on age.

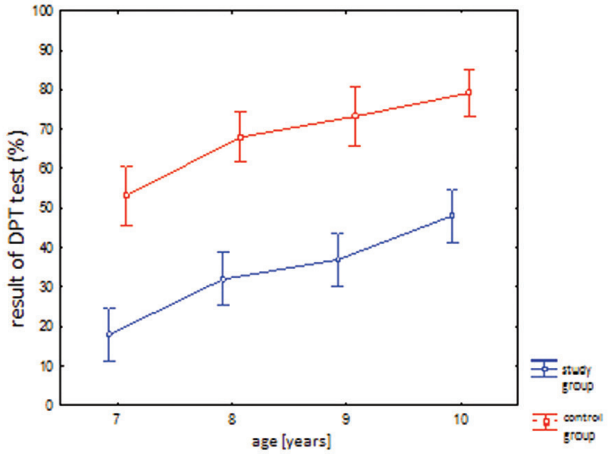

Fig. 2. Mean values with 95% confidence intervals for FPT test for the study group and the control group depending on age.

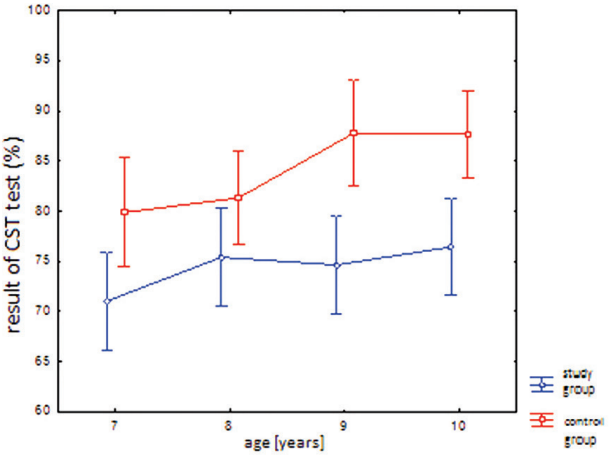

Fig. 3. Mean values with 95% confidence intervals for CST test for the study group and the control group depending on age

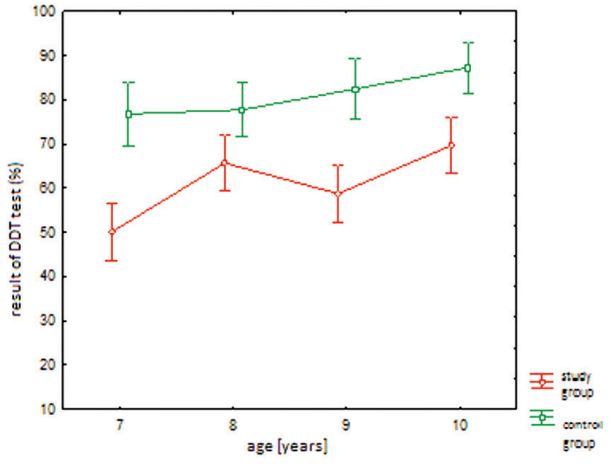

Fig. 4. Mean values with 95% confidence intervals for DDT (left ear) test for the study group and the control group depending on age.

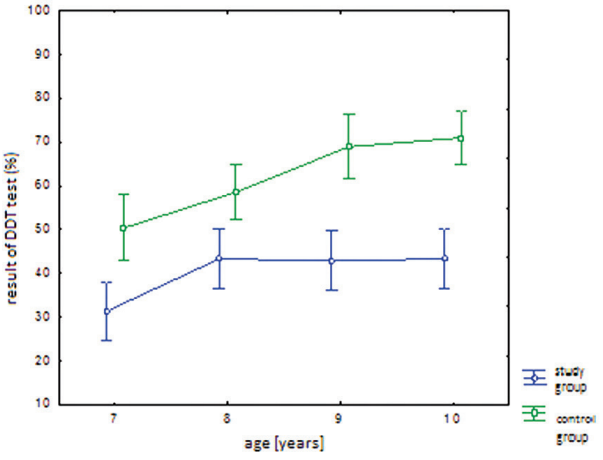

Fig. 5. Mean values with 95% confidence intervals for DDT (right ear) test for the study group and the control group depending on age.

RESULTS

Table 1 presents mean values and standard deviations for the results of psychoacoustic tests for particular age groups in the study group and the control group.

Analysis of DPT and FPT results

Statistical analysis of acquired results showed that values for DPT and FPT obtained in the study group amounted to about a half of those observed in the control group regardless of child's age.

Analysis of CST test results

Mean values of CST do not differ significantly for children of various ages. Statistical analyses revealed that CST values obtained in children from the study group aged 7, 9 and 10 years are significantly lower than values acquired in the control group. In the group of 8-year-olds values were lower, but these differences were not statistically significant. Mean results of CST in the control group demonstrated statistically significant differences for two subgroups: children aged 7-8 years and 9-10 years. Therefore, there is an apparent increase in mean CST values depending on the age.

Analysis of DDT test results

Statistical analysis revealed that mean value of DDT test in the right ear differ significantly as a function of age, while in the left ear independently of age – these differences were not statistically significant. Values of DDT test obtained in children from the study group, both in the left as well as the right ear, were significantly lower than the values acquired in the control group regardless of child's age.

Analysis of GDT results

A significant proportion of children (41%) failed to perform the GDT test properly. In the group of seven-year-olds the proportion reached 64%, while in the remaining age groups a similar number (31% on average) of children failed to perform the task. Among those who completed the task mean value of GDT equaled 7.7 ms for 7-year-olds, 6.8 ms for 8-year-olds, 6.6 ms for 9-year-olds, and 5.28 ms for 10-year-olds. Significant interpersonal dispersion in all groups and a large proportion of improperly performed examinations did not allow proper statistical evaluation. Thus, it seems that at the moment the value of this examination in everyday clinical practice for children aged 7-10 years is rather poor.

DISCUSSION

As reported by various authors, specific language impairment (SLI) involves a few to several dozen percent of the population [1, 13, 18]. It is assumed that, according to American researchers, prevalence reaches 7% [7]. Literature lacks data on the frequency of its occurrence in Poland, but the information gathered to date suggest that this problem involves a similar number of subjects [17]. Nature of this problem had not been completely explained. The only feature common for all people with SLI is such that they are characterized by inadequate language skills, while all other criteria, such as proper hearing or lack of neurological damage to the central nervous system, are preserved. Therefore, further studies aimed at establishing potential causes and coexisting abnormalities are a priority for the professionals involved in speech and language therapy. Authors became interested in dysfunction of auditory processing as one of possible causes of SLI or one of the associated abnormalities. The goal of this work was to assess central auditory processes in this group of children based on psychoacoustic tests developed for the diagnostics of Central Auditory Processing Disorders (CAPD) and used at the Institute of Physiology and Pathology of Hearing. Previously published research on specific language impairment (SLI) and central auditory processing disorders (CAPD) lacks reports on application of above-mentioned psychoacoustic tests in the diagnostics of children with such type of language disorders. Until now, researchers interested in this topic raised a problem of abnormalities of auditory perception as one of possible causes of language impairment, but the tests they had used were never included in everyday practice. Psychoacoustic tests for the diagnosis of such anomalies were developed throughout the years of research on central auditory disorders. However, no reference values have been created. Difficulties in development of such reference values may be related to cultural, educational and language differences. Musiek, a distinguished investigator of central hearing impairment emphasizes the need for creation of control groups for the purpose of research involving use of psychoacoustic tests [9]. Thus, a significant part of this work involved analyses aimed at development of normative values, i.e. creation of our own control group. Results we have acquired in the control group for the Frequency Pattern Test (FPT) and Duration Pattern Test (DPT) as well as the observed trend for increase in values with child's age are concordant with the results obtained by other researchers [4, 10]. Increase in FPT and DPT with age was also demonstrated in the study group, which allows for formulation of hypothesis that the auditory systems of those children develops in a similar manner as those of healthy children, but with some delay. The Dichotic Digit Test (DDT) was performed separately for each ear ac-

Tab. I. Mean values of psychoacoustic tests in particular age groups in the study group and the control group

PSYCHOACOUSTIC TESTS	GROUPS	AGE							
		7		8		9		10	
		MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
FPT (mean value)	Study group	14.1	11.5	27.8	19.3	29.1	18.8	34.4	14.5
	Control group	43.6	24.3	53.8	22.3	63.5	21.0	68.1	15.7
DPT (mean value)	Study group	17.9	12.3	32.0	13.4	36.9	18.8	48.0	17.9
	Control group	53.1	21.4	67.9	20.6	73.2	17.7	79.2	13.4
DDT right ear	Study group	50.0	19.7	65.7	17.2	58.7	21.9	69.6	18.3
	Control group	76.8	13.9	77.7	15.8	82.4	10.3	87.3	7.6
DDT left ear	Study group	31.4	19.6	43.3	14.7	42.9	20.6	43.4	18.0
	Control group	50.4	19.0	58.6	17.4	68.9	14.9	71.0	11.8
CST	Study group	71.0	12.6	75.4	14.2	74.6	17.7	76.4	15.1
	Control group	79.9	8.4	81.3	10.8	81.8	7.7	87.7	8.0

cording to Musiek's recommendations. Results registered in the control group were similar to those obtained by Musiek [10]. A similar concordance was observed in the results of Speech Compressed Test (CST) [2]. In this group we were not able to acquire stable and repeatable tests results of the Gap Detection Test (GST), as a large proportion of children in the study group (mean: 32%) as well as the control group (20%), failed to complete the examination. Significant interpersonal dispersion was observed among those who completed the test. Lowe and Campbell [8] studied how children with SLI and healthy children deal with detection of two clear, identical tones occurring one after another within a short interval. In such cases some of the subjects fail to notice the intermission and report it as one tone. In order for a child with SLI to notice the two separate sounds the interval between them had to be on average twice as long as that for children in the control group. In the second study sounds had different pitches, which raised the level of difficulty. On average, children with SLI needed a six times longer interval between the tones in order to properly complete the task. McCroskey and Kinder [9] obtained similar results. Detection of intermissions between the sounds is a test based on the same principles as the gap detection test (GDT) we used in our work. However, it seems that due to the hum used as sound material, this test is too difficult to perform for children in early school age – both the children with language impairment, as well as for the healthy children who constituted a control group. It is corroborated by the studies described above – use of tones that different in frequency led to significant worsening of acquired results. Subsequent studies were based on verbal material. Rosenthal presented a study, in which he had used [ts] and [s], consonants characterized by different temporal characteristics, as sound material [15]. In this study, children with SLI were never able to achieve results as good as those of healthy children regardless of the interval between presented sounds. When presented separately, the consonants were not hard to identify, which means that the problems did not result from inability to distinguish between these sounds. At later time studies that used verbal material met with critical opinions. They were accused of interpretational faults and Ress expressed that: "all positive results of those studies prove something we already know – that these children suffer from language impairment" [14]. Works by Tallal et al. contributed a great deal to studies on auditory processing in children with SLI. Studies were conducted on the basis of non-verbal stimuli. Two 75-ms-long stimuli consisting of sounds with frequencies contained in the frequency of human speech were used, although these sounds did not resemble any consonants of human language. Tallal and Percy observed that children with SLI require a significantly longer interval between the stimuli than the children in the control group [20]. They also noted that the duration of stimulus is important and prolongation of stimulus with the same intermission significantly improves results of children with SLI. Tallal [21] claimed that problems observed in children with SLI related to short intervals between stimuli were the evidence of something more than general immaturity of perception. In another study she demonstrated that with the longest interval between stimuli, children with SLI managed to complete test on a similar level as the oldest (in

this case 8.6 years on average) children from the control group, while with the shortest interval their results were lower than those of the youngest control group (mean age: 4.6 years). Therefore, it is important for studies on auditory perception to be conducted in specified, balanced age groups, since the auditory system is constantly maturing both in the healthy children as well as those with SLI. They used a dichotic hearing method. It involved observing an interval between two stimuli, such as a click administered to both ears. In the first attempt the stimulus was applied first to the right ear and the second stimulus was given to the left ear. In this study children with SLI required a longer interval between clicks in order to consider them two separate sounds compared to children from the control group. It may be therefore concluded that processing of rapidly appearing or short-lasting stimuli poses a problem for children with SLI. If problems with processing rapidly appearing stimuli interfere with perception of language or converge with problems with language acquisition, it is important to diagnose such difficulties at an early stage and implement therapy. Literature lacks reports focused on differentiation of sound stimuli with regard to frequency or duration, as in FPT and DPT tests. Obtained results corroborate the usefulness of psychoacoustic tests used in the diagnostics of central hearing disorders for assessment of auditory processing in children with language impairment. Lack of literature data regarding results of FPT, DPT, DDT, and CST in children with specific language impairment (SLI) prevents comparison of acquired results and makes them unique.

CONCLUSIONS

Analysis of results in light of the newest literature data allowed formulating the following conclusions that correspond to the goals of our work:

- Children with SLI present with abnormalities of some higher auditory functions, which substantiates the diagnosis of central hearing disorders according to the AHSA guidelines.
- In children with SLI, disorders of auditory perception involve differentiation between sounds with regard to its frequency and duration. These children suffer from impairment of temporal integration and, to lesser extent, ability to decode a distorted signal.
- Research indicates high clinical utility of FPT, DPT, CST and DDT tests in a group of children at an early school age (age range: 7-10 years).
- The GDT test is not recommended to use in this age group.

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