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Assessment of cortical auditory evoked potentials in children with specific language impairment

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: The proper course of speech development heavily influences the cognitive and personal development of children. It is a condition for achieving preschool and school successes – it facilitates socializing and expressing feelings and needs. Impairment of language and its development in children represents a major diagnostic and therapeutic challenge for physicians and therapists. Early diagnosis of coexisting deficits and starting the therapy influence the therapeutic success. One of the basic diagnostic tests for children suffering from specific language impairment (SLI) is audiometry, thus far referred to as a hearing test. Auditory processing is just as important as a proper hearing threshold. Therefore, diagnosis of central auditory disorder may be a valuable supplementation of diagnosis of language impairment. Early diagnosis and implementation of appropriate treatment may contribute to an effective language therapy.

KEYWORDS: specific language impairment (SLI), auditory cortical potential, P300 potential

INTRODUCTION

About 7% to 15% of preschool and school children differs from their peers in terms of rate of language acquisition and language skills development according to numerous researches published globally [1, 2, 3]. This problem affects boys more often compared to girls, and frequently occurs in other family members, be it parents or siblings. Children suffering from specific language impairment do not learn how to speak in proper age and their language acquisition is particularly difficult. Due to these factors, such children are exposed to risk coming from language errors and deficits throughout the entire process of education [4]. The children in the study group can be diagnosed with specific language impairment (SLI).

SLI can be defined as:

- "incorrect acquisition of speech by children who had not been diagnosed with any defects of brain anatomy, hearing impairment, or significant learning impairment, and who had not been deprived of social contacts" [1],
- "definition of this impairment had been formulated based on the exclusion criteria; it means that the child has significant language problems which cannot be explained by hearing impairment, low intelligence, abnormal environment, or mental impairment" [1].

Stark and Tallal suggest SLI criteria which include at least moderate impairment of speech and understanding [8]. They also suggest inclusion and exclusion criteria to distinguish SLI from other speech disorders. Such criteria would primarily rely on intelligence quotient (verbal and nonverbal) and results of language skills tests, and differences between these factors [2]. An important criterion proposed by the authors is intelligence quotient of at least 85 in the nonverbal scale. Currently, many researchers abandon this method. Low intelligence quotient frequently appears to be a component of SLI and many children with language deficits do not meet the criteria proposed by Stark and Tallal.

Conti-Ramsden and Bolting [1] based their research on the following criteria of SLI diagnosis:

- nonverbal intelligence of the child is within normal limits,
- the main problem of the child is language deficit (determined on the basis of a difference between level of language and assessment of cognitive abilities),

the child has difficulties in coping with regular educational system.

Majority of authors state that proper hearing is an inclusion criterion, however it does not relate to auditory processing disorder. Włodarczyk states that statistically these children exhibit auditory processing disorder more often than their peers which can be observed in psychoacoustic tests [1]. Not all child patients can undergo psychoacoustic tests, the younger ones in particular. An alternative to such tests is recording the cortical auditory evoked potentials in case of this research. Higher auditory functions are assessed using endogenous stimuli, notably in the record of P300 wave. The wave occurs when a stimulus is not expected or carries new or important information. Despite the psychological role of P300 wave still being discussed, in accordance to common opinion its latency can be used to measure time required to process a stimulus (decoding, recognition, classification) while the amplitude shows the engagement rate of cognitive structures, peaking when the problem is solved. For this reason, the research on cortical auditory evoked potentials in children suffering from SLI proves to be important.

AIM

The aim of this research is to assess cortical auditory evoked potentials in children with SLI, caused by P300 wave latency in particular.

MATERIAL AND METHOD

The research was carried out on 200 children. The study group consisted of 100 children aged 7-10 (during diagnosis). On average, children in this group were 8.5 years old. The group consisted of 72 boys (72%) and 28 girls (28%). Table 1 shows the characteristics of children in each age group in relation to sex. A correlation discussed by the other authors is noticeable in every age group – the frequency of boys suffering from SLI is 2-3 times higher compared to girls [11, 12].

The control group consisted of 100 children aged 7-10. The children in this group did not suffer from SLI, did not have any problems at school, and exhibiting proper articulation, without auditory processing disorder. On average, children in this group were 8.6 years old. The group consisted of 59 girls (59%) and 41 boys (41%). Table 2 shows the characteristics of children in each age group in relation to sex.

The following criteria had to be met in order to include a child to the control group:

Tab. I. Age and sex distribution in children with specific language impairment

AGE	GIRLS		BOYS		TOTAL
	Number	Percent	Number	Percent	
7	16	64,0%	9	36,0%	25
8	17	68,0%	8	32,0%	25
9	20	80,0%	5	20,4%	25
10	19	76,0%	6	24,0%	25
Total	72	72,0%	28	28,0%	100

Tab. II. Age and sex distribution in controls

AGE	GIRLS		BOYS		TOTAL
	Number	Percent	Number	Percent	
7	17	85,0%	3	15,0%	20
8	21	75,0%	7	25,0%	28
9	10	47,6%	11	52,4%	21
10	11	35,5%	20	64,5%	31
Total	59	59,0%	41	41,0%	100

- correct result in audiometry (pure tone audiometry conducted at frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz)
- lack of central auditory disorder risk factors – only negative replies to questionnaire (regarding problems related to articulation, school, delayed speech and psychomotor development).

Children suffering from SLI were chosen amongst the ones submitted to the Audiology and Phoniatrics Clinic of the Institute of Physiology and Pathology of Hearing (Klinika Audiologii i Foniatrii Instytutu Fizjologii i Patologii Słuchu). All children included in the research underwent tests in accordance to predetermined protocol consisting of the following points:

1. phoniatric examination and evaluation of peripheral organs of speech,
2. audiological examination, including pure tone audiometry and impedance audiometry, in order to exclude hearing loss,
3. psychological examination in which intelligence quotient of a child was determined (results of children were all within the norm limit for their proper age),
4. speech and language evaluation for purposes of speech and language impairment assessment; the evaluation was conducted in accordance to Demmel speech assessment, tests assessing language skills of children and/or speech and language test for language skills evaluation,
5. record of cortical auditory evoked potentials.

Tab. III. Mean P1, N1, and P2 latencies in different age groups in children with specific language impairment

AGE (YEARS)	P1 LATENCY [MS]		N1 LATENCY [MS]		P2 LATENCY [MS]	
	Mean	SD	Mean	SD	Mean	SD
7	78,9	9,1	106,1	13,0	159,4	21,2
8	76,3	7,2	102,2	12,1	158,7	20,6
9	76,2	12,2	100,0	9,1	160,8	22,7
10	73,6	10,1	100,1	10,3	160,4	21,3

Tab. IV. Mean P1, N1, and P2 latencies in children with specific language impairment (SLI) and controls

GROUP	P1 LATENCY [MS]		N1 LATENCY [MS]		P2 LATENCY[MS]	
	Mean	SD	Mean	SD	Mean	SD
children with SLI	61,2	9,9	101,0	11,1	159,8	21,2
controls	63,1	10,9	97,8	9,2	154,4	22,9

The record of cerebral cortex potentials and cognitive potentials (N1, P1, N2, P2, P300 waves) was conducted using *the oddball procedure* with standard stimuli of 500 Hz, and oddball stimuli of 2k Hz in bilateral CHART stimulation. The probability of stimuli occurrence was 80% for the standard stimuli, and 20% for the oddball stimuli.

RESULTS

P1, N1, and P2 potentials

In the assessment of time parameters of electrophysiological responses relating to latency of initial P1, N1, and P2 potentials, no statistically significant differences were observed between particular age groups in the study group. The values are presented in Table 3. This allowed for assessment of relation between occurrence of pathology (speech and language impairment) and latency values while comparing the study group with the control group. This correlation was determined by calculating average latency for the entire study group and the entire control group.

Table 4 presents average values and deviations of P1, N1, and P2 latency in the control group and the study group. No statistically significant differences in P1, N1, and P2 latency were observed between both groups. The analyzed material consisted of 100 tests in the control group and 99 tests in the study group (electrophysiological response could not be recorded in one child).

N2 potential

The statistical analysis proves that N2 wave latency decreases with the age of a child (F = 3.07, p = 0.0336). A statistically

Tab. V. N2 latencies in children with specific language impairment

AGE (YEARS)	NUMBER OF TESTS	MEAN	SD
7	25	220,7	36,6
8	24	209,9	24,9
9	25	204,5	17,3
10	25	196,1	15,3
Total	99	208,8	27,3

Tab. VI. Mean N2 latencies with standard deviations (SD) and p values for comparisons between children with specific language impairment (SLI) and controls

AGE (YEARS)	CONTROLS		CHILDREN WITH SLI		P VALUE
	Mean	SD	Mean	SD	
7	220,7	36,6	238,9	30,0	0,0676
8	209,9	24,9	230,9	27,9	0,0128
9	204,5	17,3	228,3	26,4	0,0058
10	196,1	15,3	221,7	27,4	0,0009
Total	208,8	27,3	230,0	28,2	0,0000

Tab. VII. P300 latencies in children with specific language impairment

AGE (YEARS)	NUMBER OF TESTS	MEAN	SD
7	25	337,3	24,9
8	24	322,6	26,7
9	25	307,7	23,6
10	25	298,6	20,9
Total	99	318,5	28,2

significant difference in N2 latency was observed during the research in children aged 7 and 10. No statistically significant differences were observed for other values.

Table 5 presents average N2 wave latency values in particular age groups in the study group.

Due to N2 wave latency differences in particular age groups, observed both in the study group and in the control group, the statistical analysis was conducted separately for each group. The results of the study group are presented in Table 6 and Figure 1.

The children aged 8 to 10 of the study group indicated statistically longer N2 latency when compared with the control group. The children aged 7 indicated the same correlation, however it was not statistically significant.

P300 potential

The statistical analysis indicates a significant correlation between the age of a child and decrease of P300 latency ($F = 9.51$; $p = 0.0000$). Statistically significant differences of P300 latency were observed between results of children aged 7, and children aged 9 and 10. Moreover, the results of 8-year-olds were statistically significantly different from the results of 10-year-olds. Comparison of other groups did not indicate any statistically significant differences. Table 7 presents average P300 latency values in particular age groups.

Table 8 and Figure 2 present average P300 latency values in particular age groups in the control group.

P300 latency was statistically significantly longer in children with SLI In all analyzed age groups when compared with the control group.

Statistical analysis of latency values of particular electrophysiological parameters enabled assessment of threshold parameters which in turn allowed for classification of control group's results as correct or incorrect. P1, N1, and P2 wave analysis, in relation to both the age of children and distribution characteristics, enabled the authors to determine the threshold parameter for all age groups. For the components of the potentials, observed as N2 and P300 waves, a different threshold parameter for each age group was implemented due to ambiguity of correlation between particular age groups. Table 9 presents average values, standard deviations, and thresholds of P1, N1, and P2 latencies, and Table 10 presents the aforementioned parameters for N2, and P300 latencies in relation to age of children. The latency threshold for each diagnosed wave was calculated, including two standard deviations from the average value.

Tab. VIII. Mean P300 latencies with standard deviations (SD) and p values for comparisons between children with specific language impairment (SLI) and controls, accounted for age group.

AGE (YEARS)	CONTROLS		CHILDREN WITH SLI		P VALUE
	Mean	SD	Mean	SD	
7	337,3	24,9	366,2	49,0	0,0163
8	322,6	26,7	354,8	39,3	0,0033
9	307,7	23,6	333,5	33,5	0,0184
10	298,6	20,9	316,6	33,0	0,0498
Total	318,5	28,2	342,9	43,2	0,0000

Tab. IX. Mean P1, N1, and P2 latencies with standard deviations (SD) and reference values in controls

LATENCY	MEAN	SD	REFERENCE VALUE
P1	63,1	10,9	84,9
N1	97,8	9,2	116,2
P2	154,4	22,9	200,2

DISCUSSION

The processing time of acoustic stimulus in auditory system is indicated by recording the auditory evoked potentials, called cortical potentials, notably in P300. For this reason, the research conducted by the authors includes analysis of electrophysiological tests for the purpose of determining whether this method can be implemented in early diagnosis of auditory perception deficit which can be diagnosed in children with SLI.

P300 potential occurs whenever the perceived stimulus is unexpected or carries new or important information. It peaks at around 300 ms after the occurrence of stimulus, and requires attention and auditory memory [13]. The psychological significance of P300 wave remains a subject of further discussion. It is believed that its latency is a measure of time required to process the stimulus (decoding, recognition, classification), and its amplitude provides information on the engagement rate of cognitive structures and peaking when a problem is solved.

Morphology, amplitude, and latency of P300 are analyzed reasonably well in the literature [14]. Recording potentials is possible mainly in children aged above 5. Latency in children with age ranging 5-12 fluctuates between 241-396 ms. A clear trend of the average N2 and P300 latency time to decrease exists in researched age groups. Similar decrease of average latency value was observed in researched study group of children suffering from SLI, however the average values are higher when compared with the control group. Jirsa and Clontz [15] present similar results. They indicate that P300 latency in children suf-

Tab. X. Mean N2 and P300 latencies with standard deviations (SD) and reference values for different age groups in controls

AGE (YEARS)	N2 LATENCY			P300 LATENCY		
	Mean	SD	Border value	Mean	SD	Border value
7	220,7	36,6	293,9	337,3	24,9	387,1
8	209,9	24,9	259,7	322,6	26,7	376,0
9	204,5	17,3	239,1	307,7	23,6	354,9
10	196,1	15,3	226,7	298,6	20,9	340,4

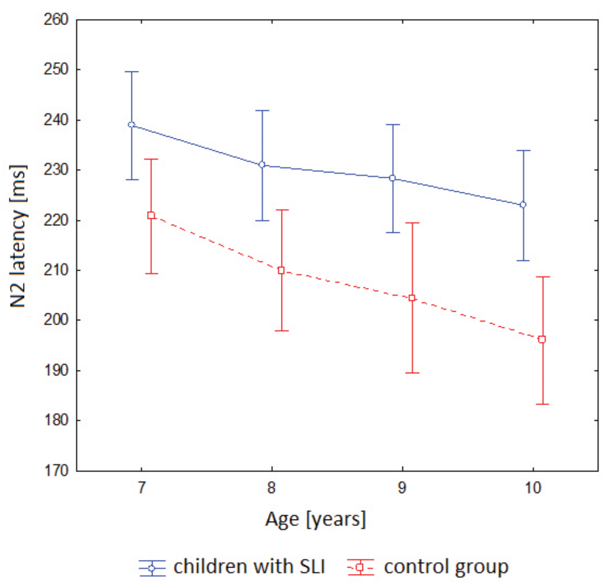

Fig. 1. Average values and 95% confidence interval of N2 latency in the control group and the study group in relation to age groups.

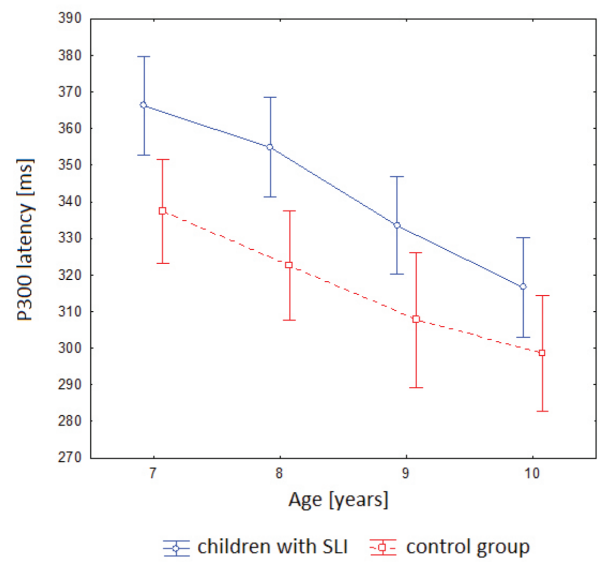

Fig. 2. Average values and 95% confidence interval of P300 latency in the control group and the study group in relation to age groups.

fering from central auditory processing disorders (CAPD) was significantly longer when compared with the control group, the wave amplitude was significantly decreased, with a considerably higher intrersubject variability. Shaheen observes P300 in children with SLI aged 4-6 and compares them with the control group of 20 children in the age groups [16]. Average latency values in the study group were longer when compared with the control group.

P300 wave record is connected to record of P1, N1, P2, and N2 potentials which occur earlier. The researchers are not unanimous when referring to the aforementioned latency of potentials in children with SLI. Some researchers indicate that differences in P1, N1, P2, and N2 latency values between children with SLI and the control group are statistically insignificant [17, 18]. Similar results were achieved in this research. The average P1, N1, and P2 latency values do not indicate statistically significant differences between the study group and the control group. On the other hand, the results of research conducted by Korpilathi and Langa, and Tonnquist-Uhlen are disparate [19, 20]. This disparity may result from either insufficient size of groups included in the research in relation to both the study group and the control group, or a different recording procedure of cortical auditory evoked potentials. The N2 and P300 latency results are consistent in the majority of researches, as the latency of these waves is longer in the study group than in the control group. Consistency of the results achieved in this research with the reports of other researchers points to the conclusion that recording the P300 latency can be effectively used as a tool for early diagnosis of auditory processing dysfunction in children suffering from SLI.

CONCLUSIONS

The record of cortical auditory evoked potentials and the assessment of N2 and P300 latencies can be a valuable supplementation of diagnostic procedure in children suffering from specific language impairment. Early diagnosis of central auditory disorder in the youngest children enables implementation of a proper listening training during the process of rehabilitation.

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