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Coll. Antropol. **35** (2011) Suppl. 1: 239–247
Short communication

Cognitive Auditory Evoked Potentials in Children with Special Language Impairment

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A B S T R A C T

Perception and discrimination of auditory and speech stimuli in children aged 7–9 years with either receptive (n=6) or expressive (n=5) type of special language impairment and 7 healthy age-matched controls was investigated using evoked potential technique. The measurements were performed with a 32-channel Neuroscan electroencephalographic system. Two types of stimuli were applied, pure tones (1 kHz and 2 kHz) and double syllabi consisting of one consonant and one vocal characteristic of Croatian language. The stimuli were presented in an oddball paradigm, requiring a conscious reaction for the subjects. Latencies and amplitudes of P1, N1, P2, N2, P3, N4, and SW waves were analized, as well as the reaction time and number of responses. There were found no statistically significant difference between children with special language impairment and the control group in average response time and number of responses to tone burst or double syllable. Analysis of variance of all used variables showed a statistically significant difference in P3 and Sw wave latencies after double syllable stimulation, P3 and N4 waves latencies after target stimulation, P2 and Sw wave amplitude; and in N1 wave amplitude after pure tone stimulation. Our study showed that children with speech and language disorder take longer time to perceive and discriminate between either tonal or speech auditory stimuli than children with typical speech and language development.

Key words: *special language impairment, electroencephalography, event-related potentials, CAEP, pitch perception, speech perception, Croatia*

Introduction

Specific language impairments (SLI) is the term for heterogeneous group of language skill disorders whose cause is unknown. This disorder has been identified as recently as in the early part of 20th century, however, various research and clinical approaches resulted in frequent changes of its term. So even these days we do not have precisely determined terminology and classification for this type of language disorders. In literature we can find different terms such as: developmental aphasia, grammatical development disorder, structural disorder of language development, language impairments, developmental dysphasia, children with language and learning problems, postponed language etc[1].

Regarding the classification, SLI are the heterogeneous group of language disorders that has several subtypes; that is why is not easy to define their unique phenotype. Moreover, the entire language development of any single person is labeled by individual differences, and so the children with SLI, with no regard to which subtype belong, show individual differences. Also there is data lack of uniformity about the relation of language and non-language aspects of cognitive functioning in these children[2]. Besides language functioning, it is also damaged nonverbal cognition, motor skills, attention, visual and motor integration, symbolic game[3].

The World Health Organization's (WHO) International Classification of Diseases, Tenth Revision (ICD-10), discerns between two types – expressive and receptive. Expressive type of SLI (ICD F80.1) refers to a specific developmental disorder of speech and language where a

Received for publication October 16, 2009

child's ability of expression is significantly below age level, but speech comprehension is within normal limits. Articulation problems may or may not be present. Receptive type of SLI (ICD F80.2) refers to a specific developmental disorder where a child's language comprehension is significantly below age level. It is usually associated with impaired language expression and impaired articulation[4,5].

So far as the etiology of SLI is concerned, now we know for a fact that the cause is of neurological and not socio-cultural nature, as it was believed, with strong genetic basis[6].

It has made little progress in understanding the neurological basis of SLI. One of the reasons is the heterogeneity of the disorder but another is the small number of studies using direct measures of neurological structure or function. One line of evidence neurobiological abnormalities comes from electrophysiological studies of cognitive auditory evoked potentials (CAEP)[7]. With CAEPs we can obtain an indeks of the brain's responses to auditory stimuli in real time. Evoked potentials (EPs) in response to simple auditory, visual or somatosensory stimuli have long been used to evaluate sensory function in patients. It has long been held that while sensory EPs are reliable enough to be used in clinical contexts, cognitive auditory evoked potentials (CAEP) may be too variable to be clinically useful[8].

Research in perception of auditory stimuli in children with language and speech disorders began in the 1970's. Tallal et al.[9–11], who found that school-age children with language and/or learning disorders had more difficulty than typically developing age peers in the discrimination of non-speech tones and discrimination of both synthetic speech consonants embedded in consonant-vowel syllables and in brief synthetic vowels.

Event-related potentials (ERPs) are associated with cognitive processing of sensory information. They are used for non-invasive functional evaluation of cognitive cortical structures, i.e., processing and interpretation of sensory stimuli at higher cognitive levels, and processes of selective attention and perception.

Cognitive auditory evoked potentials (CAEP) are useful in research of brain processes underlying auditory perception, such as loudness, pitch, and source of sound[12]. Exogenous components (P1, N1 and P2) provide information on the primary auditory cortex, whereas endogenous components N2 and P3 provide information on higher cognitive processes and may be useful for targeted treatment[13]. Some ERPs brainwave components may be considered brain correlates of language comprehension operations[14]. They provide a window on the earliest stages of processing in auditory cortex. P1 typically occurs 50 msec after the stimulus onset in adults with normal hearing. Neural generators of P1 include primary auditory cortex (Heschl's gyrus), hippocampus, planum temporale, and lateral temporal regions and possibly subcortical regions. N1 has multiple generators in the primary and secondary auditory cortex and at least three underlying components. The first component of N1 is a frontocentral negativity known as N1b, which is generated by bilateral vertically oriented dipoles located in/near auditory cortex in the superior temporal lobe. This response is therefore largest when measured by electrodes at/near the vertex electrode site (Cz). P2 seems to have multiple generators located in multiple auditory secondary cortex and the mesencephalitic reticular activating system areas[15,16]. These components precede more endogenous components such as N2, N4, and P3, which are associated with attention and cognition. Some authors showed that the N1 (adults) and P2 (children and adults) peaks were enhanced by the non-phonetic stimuli, the N2 and N4 peaks were enhanced by the syllables the N2/N4 peaks may reflect either a comprehensive, fine-grained acoustic analysis or a higher-order encoding of sound content features[17]. The P300 is cortical evoked potential that reflects cognitive processes involved in the discrimination of dissimilar sensory stimuli. It is an event-related potential that occurs approximately 300 ms following stimulus onset. The auditory-evoked P300 originates from multiple auditory and non-auditory centers, including the medial temporal lobe, the parietal lobe, the reticular thalamic nuclei, and the septohippocampal system[18,19]. Sw wave that appears around 500 ms after the stimulus was shown to represent inhibitory control during a task execution[20]. The discrimination between fine acoustic features in speech sounds is fundamental to speech perception. Clinical assessment of speech discrimination is legitimately concerned with the patient's ability to discriminate such acoustic differences[21].

Since 2007, in Croatia it is used evoked potentials technique for examining of language disorders. For now this is still a very rare method used. These researches are done in the Laboratory for psycholinguistic researches (POLIN)[1,22].

The auditory function at the level of representation of elemental speech sounds in order to determine the perception and discrimination of sound stimuli in children with SLI was investigated in comparison with typical language development. Speech-evoked auditory event-related potentials (ERPs) provide information about the biological processes underlying speech processing. It was the reason why speech stimulus (double syllable) was used in addition to tone burst stimulation.

Subjects and Methods

Subjects

The study was performed at the Suvag Polyclinic, Zagreb, Croatia in December 2008. The subjects were children aged 7–9 years with SLI. The study group consisted of children selected among the Suvag Polyclinic elementary school students. The inclusion criterion was the diagnosis of expressive or receptive type of SLI. In the SUVAG Polyclinic these children are diagnosed with ICD F80.1 or ICD F80.2. The age-matched controls were randomly selected children with typical speech and language development. Other possible neurological, psychological, audiological, and motor disorders were excluded.

The study was approved by the Polyclinics' Ethics Committee and parental consent was obtained for all children included in the study.The children were divided into three groups. The first group consisted of six children diagnosed with receptive type of SLI, the second group comprised of five children diagnosed with expressive type of SLI. The children from this group have been attending speech therapy in the SUVAG Polyclinic, Zagreb for 3 to 3.5 years. Case histories of all examinees were with no irregularities and neurological status was normal. Psychological WISC test (Wechler, 2003) of nonverbal intelligence was in normal range. Language and speech status was diagnosed by a speech pathologist-diagnostician in the SUVAG Polyclinic and children were classified according to diagnosis codes from WHO (ICD F80.1 and ICD F80.2). In children with SLI of expressive type (ICD F80.1 diagnose) memory difficulties and recollection of words, and difficulties in production of more complex syntactic structures were found. In children with SLI of receptive type (ICD F80.2 diagnose) difficulties of comprehension were present, too. The third group consisted of seven children with typical speech and language development served as control. There were 8 boys and 11 girls. A lower age limit of 7 years of age was set because of the nature of the testing, which requires the subject to be still and awake. Gender was not considered a relevant variable, as it does not influence the response to auditory stimulus. Examinees were interested in the research, in a good mood and willing to collaborate.

Method

The responses, latencies, and amplitudes of P1, N1, P2, N2, P3, N4 and Sw waves to two types of stimuli was measured, as well as the reaction time, which is an acceptable measure of cognitive processing after auditory target stimuli. The recording was performed on a 32-channel Neuroscan system (Compumedics Neuroscan, El Paso, TX, USA), using an electrode cap with a set of electrodes arranged according to the International 10–20 electrode positioning system. Reference electrodes were linked together and placed over the left and right mastoid processes. All electrode impedances were less then 5 kOhm. During the recording, a child with a head-set was lying comfortably on a bed, with eyes closed, in a dark and quiet room. ERP recording was done according to the auditory oddball paradigm consisting of two kinds of stimuli, target (rare) and non-target (frequent) stimuli. Subjects were instructed to ignore the non-target and to press the keyboard button with the index finger of their dominant hand as soon as the target stimuli is recognized. Recording was performed twice, for different type of stimuli, first for tone burst stimulation and second, for speech stimulation. Testing required 1 hour *per* examinee, with preparation and recording.

Tone burst stimulation

Tone burst stimuli with frequency of 1000 Hz for frequent (non-target) and 2000 Hz for rare (target) stimuli were used. This choice is made because they are within the frequency range of speech. The two tone bursts were an octave apart, which ensured the auditory distinction between the sounds. Both stimuli were shaped with linear envelope with 10 ms rise time, 30 ms of constant amplitude and fall time of 10 ms.

Speech stimulation

For speech stimulation double syllable stimuli were used. For the first, frequent (non-target) stimulus, double syllable »ka-ka« was used (Figure 1) while, for the rare (target), double syllable »te-te« stimuli (Figure 2) was used. Both consisted of two consonants and two vowels typical of Croatian language. These syllables were chosen on the basis of optimal frequency range of their sounds (the range in which these sounds are easily recognized as belonging to Croatian language). The optimal frequency range for *k* and *a* sounds is 800–1600 Hz and 1600–3200 Hz for *t* and *e* sounds. The first octave (the frequency range for *k* and *a* sounds) contains the 1000-Hz frequency, while the other 1600–3200 Hz range contains the 2000-Hz frequency. Thus, both frequency ranges are comparable to tone burst frequencies. The duration of double syllable was 370 ms, and interval between two syllables was 30 ms.

For each ERP recording the intensity of every stimulus was equal and set to 70 dB nHL. The nontarget stimulus was frequently repeated, whereas target appeared rarely and randomly. The ratio of frequent to rare stimu-

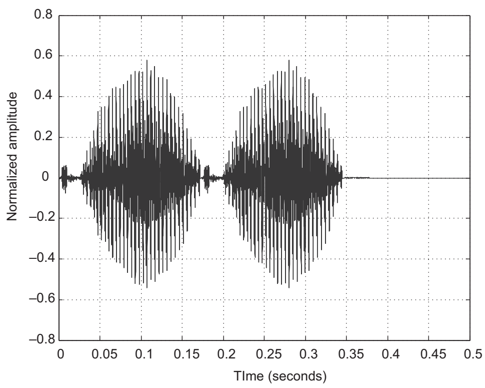

Fig. 1. Double syllable »ka-ka« stimulus.

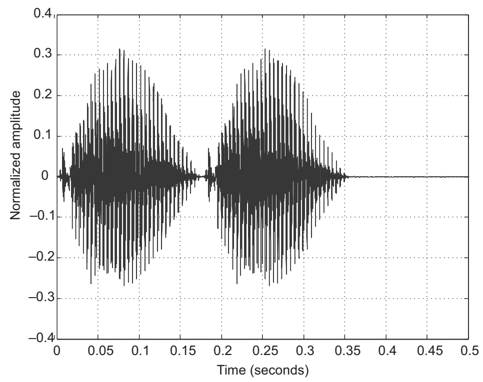

Fig. 2. Double syllable »te-te« stimulus.

lus was 4:1. During recording the interstimulus interval (ISI) was set to 2.5 s with the 10% of variability. The actual number of target stimuli presented was slightly above 50 because the averaging procedure stops after 50 artifacts free responses were collected. Therefore, non target stimuli were presented more then 200 times. Analyses time was set to 1100 ms including 100 ms of prestimulus interval for baseline correction. Amplifier gain was set to 40000, sampling rate to 1 kHz and EEG was processed with band pass filter of 0.1 to 30 Hz. The EEG sequences distorted by ocular movements and blinking were automatically rejected if their amplitudes override +/– 100 μV of artifact reject level. The averaging was performed on-line and off-line if to many ocular artifacts was detected. In such cases the Neuroscan ocular rejection artifact algorithm was applied. The responses to target and nontarget stimuli were averaged. Evoked potential latencies and amplitude were measured. Peak amplitudes at Cz electrode were measured relative to the prestimulus baseline.

Statistics

For the analysis of target stimuli reaction time, the number of non-responses was counted and, due to the non-normal distribution of the data, the three groups were compared with the Kruskal-Wallis test. The t-test for independent 2000-samples was used to evaluate possible differences between the children with speech and language disorder and their controls in average reaction time to tone burst and double syllable. Analysis of variance (ANOVA) was used to determine the differences among the three groups of children (expressive type of SLI, receptive type of SLI, and controls). All measured variables are presented as mean values with standard deviations (latencies and amplitudes obtained by averaging of individual responses) before ANOVA was applied, followed by Tukey post-hoc test for between-group comparison. Data were analyzed using Statistical Package for the Social Sciences, ver. 17.0 (SPSS Inc., Chicago, IL, USA). The statistical significance was set at $p<0.05$.

Results

The number of non-responses was expressed as percentage. Thus, the control group had 98.3% and 98.8% response rate to tone burst and double syllable, respectively. The children with receptive type of SLI had 94.5% and 99% response rate to tone burst and double syllable. The children with expressive type of SLI had 98.5% response rate to tone burst, and 98.0% response rate to double syllable. No statistically significant difference was found among the three study groups in the number of missed responses to tone bursts (Kruskal-Wallis test, $p=0.779$) or double syllable (Kruskal-Wallis test, $p=0.582$). Analysis of variance did not reveal any difference between the three groups in reaction time to tone burst

TABLE 1
MEAN CAEP WAVE LATENCIES IN (ms)

Latency	Control subjects (X±SD)	Expressive SLI subjects (X±SD)	Receptive SLI subjects (X±SD)
P1 wave of tone burst 1000 Hz	68.14±9.04	64.67±6.41	76.40±22.90
N1 wave of tone burst 1000 Hz	105.29±18.17	133.33±61.60	117.40±25.02
P2 wave of tone burst 1000 Hz	171.57±14.75	21733±61.09	182.60±60.29
P1 wave of tone burst 2000 Hz	68.14±8.25	65.83±5.38	73.60±25.20
N1 wave of tone burst 2000 Hz	105.00±17.89	140.33±63.71	121.60±39.99
P2 wave of tone burst 2000 Hz	174.00±23.49	217.50±64.99	192.40±59.84
N2 wave of tone burst 2000 Hz	250.29±38.99	288.67±78,16	300.40±118.91
P3 wave of tone burst 2000 Hz	356.00±57.65	401.50±72,53	386.80±113.56
P1 wave of double syllable »ka-ka«	71.71±15.93	73.67±6.83	86.80±19.21
N1 wave of double syllable »ka-ka«	132.00±30.81	166.17±26.44	156.80±48.37
P2 wave of double syllable »ka-ka«	206.29±26.34	193.17±94.74	212.60±52.23
N2 wave of double syllable »ka-ka«	292.14±35.47	295.17±147.91	295.40±65.11
P3 wave of double syllable »ka-ka«	373.29±36.09	507.00±55.61	464.50±84.32
N4 wave of double syllable »ka-ka«	473.43±49.37	574.40±70.33	525.33±79.71
SW wave of double syllable »ka-ka«	555.00±59.33	687.40±71.24	649.67±45.22
P1 wave of double syllable »te-te«	74.14±12.89	82.83±14.15	74.20±16.51
N1 wave of double syllable »te-te«	128.57±27.89	153.33±27.8	152.40±50.06
P2 wave of double syllable »te-te«	193.57±51.01	171.50±89.50	204.60±67.17
N2 wave of double syllable »te-te«	276.43±69.51	247.00±122.80	289.40±57.78
P3 wave of double syllable »te-te«	360.14±29.36	450.60±62.34	449.17±64.32
N4 wave of double syllable »te-te«	405.29±29.28	506.20±89.58	492.67±62.95
SW wave of double syllable »te-te«	506.57±43.92	576.80±85.96	582.00±58.52

(ANOVA, $F_{2,17}$=0.05, p=0.955) or double syllable (ANOVA, $F_{2,17}$=0.52, p=0.604). Table 1 shows mean values with standard deviations for all wave latencies, whereas Table 2 shows amplitudes of all investigated waves.

Analysis of variance of all studied variables showed a significant difference in P3 latencies after non-target double syllable stimuli between the control group and both groups of children with SLI (p=0.042 for receptive type of SLI and p=0.005 for expressive type of SLI); in Sw latencies for non-target double syllable stimuli between the control group and both groups of children with SLI (p=0.028 for receptive type of SLI and p=0.004 for expressive type of SLI); than in P3 latencies for target double syllable stimuli (p=0.021 for receptive type of SLI and p=0.026 for expressive type of SLI); in N4 latencies for target double syllable stimuli, but only for children with expressive type of SLI (p=0.034); and than in P2 amplitude for target stimulus between the control group and group of children with receptive type of SLI (p=0.045) and in Sw amplitude also for target stimulus between the control group and group of children with expressive type of SLI (p=0.050). Tukey post-hoc test showed that these differences existed between the control group and two groups of children with SLI (Table 3). The control group had a significantly shorter latency time for P3 wave after non-target double syllable stimulus (F2.15 =7.696, p=0.005); for Sw wave after non-target double syllable stimulus (F2.15=8.331, p=0.004); for P3 wave after target double syllable stimulus (F2.15=6.233, p=0.011); for N4 wave after target double syllable stimulus (F2.15=4.985; p=0.022); and for Sw amplitude after target double syllable stimulus (F2.15=1.184, p=0.030). No difference was found between the two groups of children with SLI.

In non-target stimulation with the double syllable ka-ka (Figure 3), a difference was found in wave morphology between children with expressive and receptive language disorders. The P1 amplitude was significantly higher in children with receptive type of SLI than in those with expressive type of SLI, while latencies were prolonged in children with receptive type of SLI. The morphology of N2 was changed in children with expressive type of SLI, with a possibility of N2b wave occurrence (one after 220 ms, and the other after 320 ms). The latencies of P3, N4, and Sw waves were prolonged in both groups of children with SLI in comparison with healthy controls. In the children with receptive type of SLI, the amplitude of N4 was markedly small. In the group of children with expresive type of SLI, the amplitude was larger than in the receptive group, although, the amplitudes of N4 were smaller in these two groups in comparison with the control group. The greatest difference between the children with expressive type of SLI and control group was found in the morphology of P2 and N2

TABLE 2
MEAN CAEP WAVE AMPLITUDES (μV) WAVES

Amplitude	Control subjects (X±SD)	Expressive SLI subjects (X±SD)	Receptive SLI subjects (X±SD)
P1 wave of tone burst 1000 Hz	1.28±3.10	3.67±4.00	.22±4.79
N1 wave of tone burst 1000 Hz	–9.46±4.64	–16.51±4.71	–9.72±3.97
P2 wave of tone burst 1000 Hz	5.44±8.05	9.62±6.21	10.35±8.88
P1 wave of tone burst 2000 Hz	1.77±6.92	2.23±2.89	5.30±5.78
N1 wave of tone burst 2000 Hz	–9.43±9.52	–18.17±6.27	–10.80±5.76
P2 wave of tone burst 2000 Hz	8.52±10.25	9.36±11.12	11.03±8.77
N2 wave of tone burst 2000 Hz	–7.42±6.87	–11.71±9.54	–2.23±13.17
P3 wave of tone burst 2000 Hz	14.04±11.24	12.21±8.35	13.10±6.41
P1 wave of double syllable »ka-ka«	1.44±2.23	2.86±1.89	.67±2.59
N1 wave of double syllable »ka-ka«	–5.88±3.88	–8.09±4.43	–6.60±4.58
P2 wave of double syllable »ka-ka«	1.84±4.31	–1.03±3.87	–1.65±1.98
N2 wave of double syllable »ka-ka«	–7.36±6.14	–8.49±7.09	–10.07±1.49
P3 wave of double syllable »ka-ka«	.96±3.14	–2.57±3.46	–1.36±5.54
N4 wave of double syllable »ka-ka«	–5.85±3.17	–5.58±3.38	–3.87±4.39
SW wave of double syllable »ka-ka«	1.85±1.79	1.12±3.76	2.22±2.98
P1 wave of double syllable »te-te«	2.73±2.55	1.36±2.92	1.06±4.16
N1 wave of double syllable »te-te«	–7.58±6.70	–11.48±6.03	–12.86±6.38
P2 wave of double syllable »te-te«	2.64±3.95	–2.71±4.40	–4.82±6.22
N2 wave of double syllable »te-te«	–11.75±7.25	–12.11±11.22	–13.11±5.19
P3 wave of double syllable »te-te«	4.07±8.06	.47±3.96	2.89±9.18
N4 wave of double syllable »te-te«	–3.16±9.11	–5.42±4.84	–1.16±7.37
SW wave of double syllable »te-te«	16.23±4.72	6.05±5.08	7.11±9.31

TABLE 3
MULTIPLE COMPARISONS – TUKEY POST HOC TEST

Dependent variable	Group I.	Group II.	Sig.
N1amplitude for frequent tone burst stimulus	Control subjects	Expressive disorder	.033
		Receptive disorder	.995
	Expressive disorder	Control subjects	.033
		Receptive disorder	.061
	Receptive disorder	Control subjects	.995
		Expressive disorder	.061
P2 amplitude for double syllable »te-te«	Control subjects	Expressive disorder	.145
		Receptive disorder	.045
	Expressive disorder	Control subjects	.145
		Receptive disorder	.753
	Receptive disorder	Control subjects	.045
		Expressive disorder	.753
Sw amplitude for double syllable »te-te«	Control subjects	Expressive disorder	.065
		Receptive disorder	.050
	Expressive disorder	Control subjects	.065
		Receptive disorder	.964
	Receptive disorder	Control subjects	.050
		Expressive disorder	.964
P3 latency for double syllable »ka-ka«	Control subjects	Expressive disorder	.042
		Receptive disorder	.005
	Expressive disorder	Control subjects	.042
		Receptive disorder	.499
	Receptive disorder	Control subjects	.005
		Expressive disorder	.499
Sw latency for double syllable »ka-ka«	Control subjects	Expressive disorder	.028
		Receptive disorder	.004
	Expressive disorder	Control subjects	.028
		Receptive disorder	.551
	Receptive disorder	Control subjects	.004
		Expressive disorder	.551
P3 latency for double syllable »te-te«	Control subjects	Expressive disorder	.021
		Receptive disorder	.026
	Expressive disorder	Control subjects	.021
		Receptive disorder	.999
	Receptive disorder	Control subjects	.026
		Expressive disorder	.999
N4 latency for double syllable »te-te«	Control subjects	Expressive disorder	.055
		Receptive disorder	.034
	Expressive disorder	Control subjects	.055
		Receptive disorder	.931
	Receptive disorder	Control subjects	.034
		Expressive disorder	.931

waves. Target stimulus (te-te double syllable) (Figure 4) elicited a waveform of different morphology in this group. P3 wave appeared earlier in comparison with non-targeted stimulus (for all groups), having a very small amplitude in children with receptive type of SLI. N4 was absent in children with receptive type of SLI, but present in children with expressive type of SLI and having a very small amplitude. Sw was invariably present in both groups, but appeared earlier than when non-target stimulus was applied and showed pronouncedly larger amplitudes in the control group than other two groups.

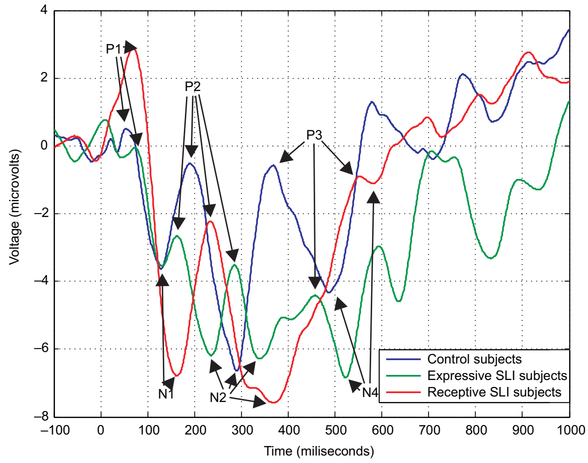

Fig. 3. EP recorded on CZ electrode for double syllable »ka-ka«.

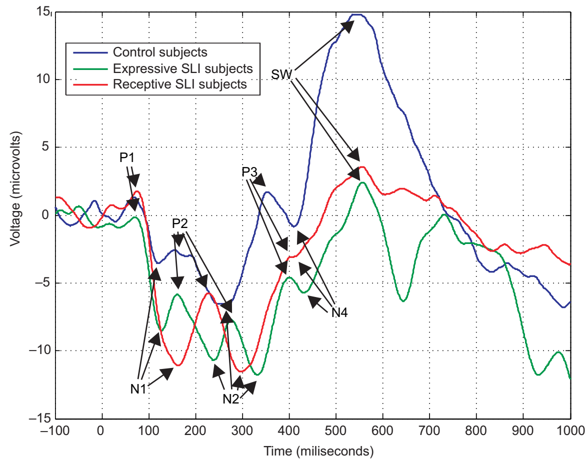

Fig. 4. EP recorded on CZ electrode for double syllable »te-te«.

For non-targeted stimulus (tone burst of 1000 Hz; Figure 5), the amplitudes were larger in children with receptive type of SLI than in those with expressive type of SLI or controls. P2 latency was somewhat prolonged in children with receptive type of SLI in comparison with other two groups. There were no differences in amplitudes and latencies between children with expressive type of SLI and children in control group. For target stimulus (tone burst of 2000 Hz; Figure 6), the amplitudes of N1 and P2 waves were larger and latencies were prolonged in the group of children with receptive type of SLI in comparison with the other two groups. There was no significant difference in latencies between children with expressive type of SLI and children in control group. Also, N4 and Sw waves were present in both groups of

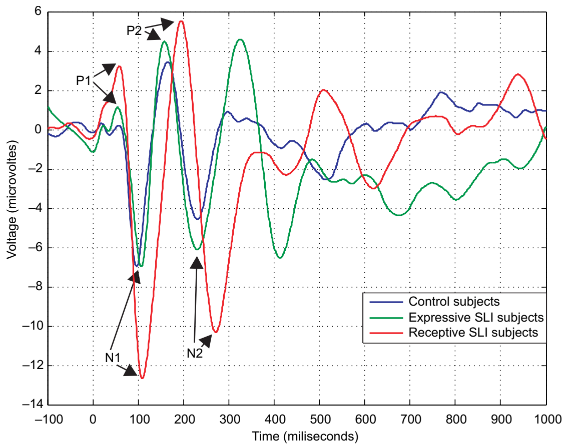

Fig. 5. EP recorded on CZ electrode for TB 1 kHz stimulation.

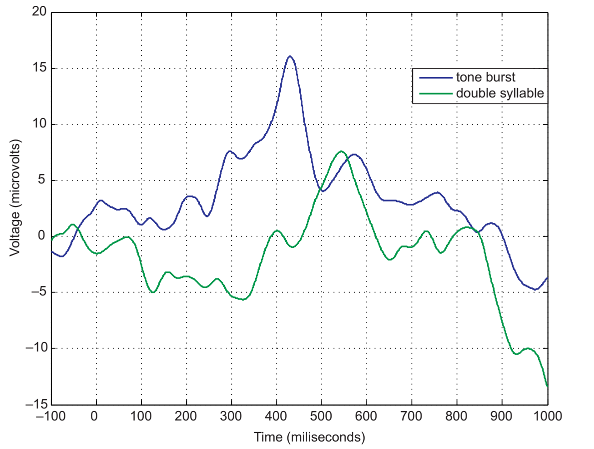

Fig. 7. Difference between rare and frequent stimuli responses for expressive SLI subjects.

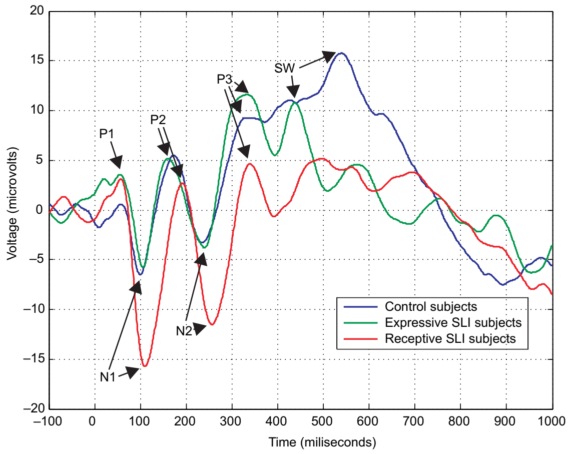

Fig. 6. EP recorded on CZ electrode for TB 2 kHz stimulation.

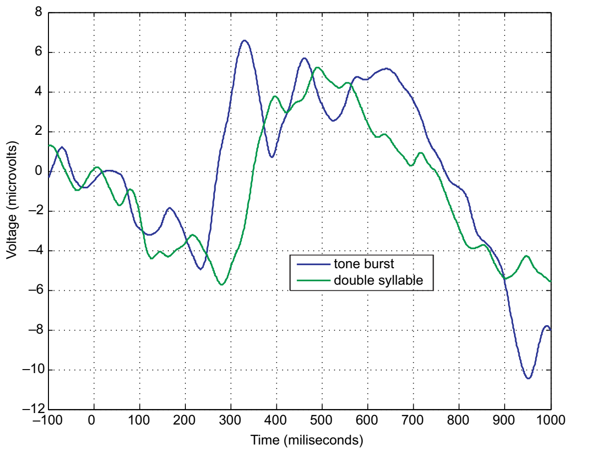

Fig. 8. Difference between rare and frequent stimuli responses for receptive SLI subjects.

children with SLI, but absent in control group. Figures 7 and Figure 8 show the differences that appear when non-target response is subtracted from the target averaged response.

Discussion

Target stimuli response rate and statistical analysis of reaction time did not show any significant differences between the control group and groups of children with SLI. Children with receptive type of SLI had the lowest tone burst response rate, which may indicate the uncertainty in recognizing a stimulus of such short duration[23]. On the other hand, they had the highest response rate to double syllable, which is a finding that excludes the possibility of impaired attention[24]. Uncertain auditory perception may reflect on faulty speech production (dyslalia) because it is likely a matter of rapidity of auditory signal processing which is in these children slow and that because without precision[25]. Imprecise auditory perception gives rise to creation of wrong phonemic representations that then result in wrong production[26]. Although this group of children belongs to receptive type of SLI, it is known that they also have impairments of expressive type – in the word and syntagm structuring as well as in the production of speech sounds[2].

In responding to double syllable (speech stimulus), the children with expressive type of SLI had the lowest result, indicating problems in wrong imprecise speech perception. Results of responses to short TB indicate that the problem is not in the primary cortex but in high, cognitive structures responsible for the processing of speech sounds[27]. This finding should be verified on a larger study sample.

Analysis of wave morphology shows that waves elicited by target and non-target stimuli by double syllable show more variability than those elicited by tone burst. The amplitudes for non-target stimulus were larger than those for the target stimulus. There were differences between all three groups in the number of waves and their shape for both target and non-target stimulus. In children with expressive type of SLI there is no pronounced amplitude of P3 to either target or non-target stimulus, which may indicate a problem in cognitive processing. Also, N4 has a small amplitude, which could imply lower ability to process a speech signal as information[28]. In the group of children with receptive language disorder, N2 wave appeared as a double wave after both target and non-target stimulus, thus showing the greatest difference in comparison with N2 in controls. In the control group of children, Sw showed pronouncedly large amplitude, which could indicate a strong focus on reaction (pressing of the button). In both group of children with SLI the amplitude of Sw wave was not so pronounced which could indicate a stronger focus on stimuli than on reaction.

The morphology of P1, N1 and P2 waves elicited by tone burst does not vary across the three groups. Larger amplitudes of all these are characteristic for children with expressive type of SLI. For N1, there is also a statistically significant difference in the size of the amplitude. Target stimulus elicited N4 and Sw in both groups of children with SLI. Especially large was N4 amplitude in children with receptive type of SLI; it is possible that these children, due to poorer perception (as implied by the number of non-responses to stimuli), tried to find information in the stimulus to discriminate it more easily. In the control group, large Sw amplitude was elicited only by target stimulus, N4 amplitude was barely visible. Statistical analysis showed that the significant differences refer to double syllable stimuli, i.e., speech stimulation.

Conclusion

The study showed that it takes more time for children with either expressive or receptive type of SLI to perceive and discriminate tonal and speech auditory stimuli. However, the results were obtained from a small sample size, which is a limitation that does not allow any firm conclusion. We found that children with SLI take longer time to perceive and discriminate between either tonal or speech auditory stimuli than children with typical speech and language development. From the morphology of the waves, it may be concluded that the differences in amplitude, latency, and waveform for N2, P3, N4, and Sw – the waves that provide information on congitive processes[29] – are larger. (Cognitive processes here mean – attention, perception, signal processing). The comparison between target and non-target stimulus showed that processing of a speech stimulus took longer than processing of a tonal stimulus (pure tone) for both groups of children with SLI.

Results of this research will be useful in speech and language therapy as well as in diagnostics of these difficulties because they give us more objective pattern and directions for more effective therapy.

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KOGNITIVNI SLUŠNI EVOCIRANI POTENCIJALI U DJECE S JEZIČNO-GOVORNIM TEŠKOĆAMA

S A Ž E T A K

U ovom istraživanju ispitivana je sposobnost zamjećivanja i razlikovanja zvučnog i govornog podražaja u djece s jezično-govornim teškoćama u dobi od 7 do 9 godina. Ispitanici su bili djeca s posebnim jezičnim teškoćama (PJT) podijeljena u dvije skupine. Jedna skupina su bila djeca s ekspresivnim tipom PJT (šifra dijagnoze F80.1), njih 5; te, druga skupina s receptivnim tipom (šifra dijagnoze F80.2), njih 6, te, kontrolna skupina, njih 7, djeca urednog govorno-jezičnog razvoja. Korištena je tehnika evociranih potencijala. Mjerenje je izvršeno na 32-kanalnom aparatu za moždanu kartografiju tipa Neuroscan. Upotrijebljena je kapa s kanalima prema 10–20 internacionalnom sustavu. Provedena su dva eksperimenta. U prvom su kao podražaj korištena dva čista tona (1kHz i 2kHz), a u drugom dva dvostruka sloga, sastavljena od jednog suglasnika i jednog samoglasnika hrvatskog jezika, odabranog prema karakteristikama tzv. optimalnog filtra (frekvencijskog područja u kojem se određeni glas najbolje percipira kao glas hrvatskog jezika). Podražaji su bili prezentirani u odd ball paradigmi, te se od ispitanika tražila svjesna reakcija. Mjerene su latencije i amplitude analiziranih (P1, N1, P2, N2, P3, N4 i Sw) valova, te vrijeme reakcije i broj točnih odgovora. Ispitivanje je pokazalo da, u djece s PJT u odnosu na djecu urednog govorno-jezičnog razvoja, nema statistički značajne razlike u vremenu reakcije na ciljni podražaj, niti u broju propuštenih reakcija. Analizom varijance (ANOVA) svih ispitivanih varijabli, statistički značajna razlika pokazala se za podražaj duplim slogom i to, za neciljni podražaj, u latencijama valova P3 i Sw; te za ciljni podražaj, u latencijama valova P3 i N4 i u amplitudi vala Sw. Ovo ispitivanje je pokazalo da djeca sa PJT sporije zamjećuju i razlikuju slušni podražaj, osobito onaj govorni, u odnosu na djecu urednog govorno-jezičnog razvoja.