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The influence of the dynamics and the level of maturity of cortical functions as prerequisites for the development of speech in children

Утицај динамике и нивоа зрелости кортикалних функција као предуслова за развој говора код деце

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SUMMARY

Introduction/Objective The development of speech is the result of the interaction of different systems of cortex, which gradually acquires the ability of phonological presentation and motor control, in the presence of a series of physical and physiological changes in the morphology of the articulation system. The objective of the study was to examine the impact of laterality and cortical responses on the development of speech in children.

Methods Research is a quasi-experimental design with two groups. Sample covered 60 children, from Belgrade, both sexes, ages 5.5 to 7 years, divided into two groups, experimental (30) and control (30). We used the following instruments: Test for assessing laterality and finding of Evoked Potentials.

Results On the subtest visual lateralization there is a statistically significant difference ($\chi^2 = 7.56$, $p < 0.05$) between the observed groups. The visual evoked potentials on all measured parameters gave a statistically significant difference between the groups (waveform cortical responses- left ($\chi^2 = 30.00$, df = 1, $p < 0.05$); cortical responses - right ($\chi^2 = 6.667$, df = 1, $p < 0.05$),waveform amplitude - left ($\chi^2 = 13.469$, df = 1, $p < 0.05$), amplitude - right ($\chi^2 = 40.00$, df = 1, $p < 0.05$), somatosensory potentials ($\chi^2 = 18.261$, df = 1, $p < 0.05$), waveform amplitude ($\chi^2 = 12.000$, df = 1, $p < 0.05$),waveform latency ($\chi^2 = 5.455$, df = 1, $p < 0.05$).

Conclusion Visual laterality, as well as visual and somatosensory cortical responses to stimuli is better in children without the present articulation disorder, which could be used for timely prevention planning.

Keywords: speech; laterality; children; articulation disorder; evoked potentials

САЖЕТАК

Увод/Циљ Развој говора од рођења до одраслог доба је резултат интеракције различитих система коре великог мозга, помоћу којих се постепено стичу способности фонолошке презентације и моторне контроле, уз присуство низа физичких и физиолошких промена у морфологији артикулационог система. Циљ истраживања је био испитати утицај латерализованости и кортикалних одговора, на развој говора код деце.

Методе Истраживање је квазиекспериментални дизајн са две групе. Узоком је обухваћено 60 деце (30 у експерименталној и 30 у контролној групи) из Београда, оба пола, узраста од 5,5 до седам година.Од инструмената смо користили тест за процену латерализованости и налаз евоцираних потенцијала.

Резултати На суптесту визуелна латерализованост постоји статистички значајна разлика ($\chi^2 = 7{,}56$, $p < 0{,}05$) између посматраних група. Визуелни евоцирани потенцијали на свим мереним параметрима су дали статистички значајну разлику између експерименталне и контролне групе кортикални одговори лево ($\chi^2 = 30{,}00$, df = 1, $p < 0{,}05$); кортикални одговори десно ($\chi^2 = 6{,}667$, df = 1, $p < 0{,}05$); амплитуда лево ($\chi^2 = 13{,}469$, df = 1, $p < 0{,}05$); амплитуда десно ($\chi^2 = 40{,}00$, df = 1, $p < 0{,}05$). Соматосензорни потенцијали су дали статистички значајну разлику, код кортикалних одговора лево ($\chi^2 = 18{,}261$, df = 1, $p < 0{,}05$); амплитуде ($\chi^2 = 12{,}000$, df = 1, $p < 0{,}05$); латенција ($\chi^2 = 5{,}455$, df = 1, $p < 0{,}05$).

Закључак Визуелна латерализованост, као и визуелни и соматосензорни кортикални одговори на стимулусе су бољи код деце без присутног поремећаја артикулације, што би се могло искористити за благовремено планирање превенције.

Кључне речи: говор; латерализованост; деца; артикулациони поремећаји; евоцирани потенцијали

INTRODUCTION

What distinguishes people from animals is evolution of the brain. The brain is the manager of all physical and psychological activities. Due to the complex organization of the nervous system, a man can produce a large number of voices with the meaning and use hands to perform fine movements. Language is the one that allows man to control his behavior and behavior of others [1]. The brain is anatomically divided into two hemispheres that are approximately identical. Despite the relative similarity of brain hemispheres, they do not perform the same function. Due to the fact that the hemispheres have specialized, some skills became possible [2].The left hemisphere plays a role in the creation of a language, which is confirmed by a series of research. It is founded that in 95% of right-handed people speech is controlled by left hemisphere, and also in 70% of the left-handed, while in 15% of the others speech is controlled from both hemispheres [3]. The exact role of the right hemisphere is not known. It is considered to be responsible for performing visual-spatial tasks and to process information simultaneously and holistically. In addition, her role in controlling and processing musical abilities is indisputable [4, 5]. Neurons have to be stimulated in order to develop new synaptic connections. The development of new connections creates new opportunities for neural communication. Each new skill contributes to the new element of sensory perception and motor skills of the child. As a child has more neural connections - it is more capable for learning [6]. Functional brain differentiation indicates that different aspects of language and speech are located in different regions of the cortex [7, 8]. This point to the genetic basis of development, during which different aspects of language are distributed in different brain zones [9].

Laterality is determined simultaneously with the determination of the domination of the hemisphere. Through motor development, bilateral control is first established and then unilateral. Laterality is established between age 3 and 4. It is achieved gradually during maturation and the accumulation of experience acquired by observation, kinesthesia, manipulative activity, and finally the realization that this laterality has occurred [10]. In the next phase of maturation, the differentiation of laterality occurs when it becomes dominant for one side and subdominant to the other side of the body, it is recognized that one extremity or organ senses is leading and thus dominates the other [11]. Harmonic laterality implies identical dominant laterality level with arm, eye, ear and leg. The category of disharmonic lateralization consists of subjects with complete discrepancy between the dominance of the arm, the eye, the ear and the leg. The process of developing the ambivalence of the movement to selecting a leading right or left hand can be considered a process of maturation, because from laterality we are going to dominate the hemispheres and movements in the manipulative field, from the lower forms of organizing activities to more complex and more suitable levels, of the differentiated sensory needs and the enforcement of intelligence [12, 13]. Assessment of laterality and dominant laterality indicates the organization of the ability of senses and movements in the function of voluntary motor activity and the level of practicality of the cortex in relation to the development of the dominance of the hemisphere. [14].

The processes that precede the development of proper articulation are swallowing, sucking and chewing. Proper stimulation of these functions in the earliest age affects the good development of oral practice and, consequently, the smooth development of articulation [15, 16]. The child, by vocalization, elaborates the movements and coordination of peripheral speech organs. The speech production mechanism is undergoing significant changes during growth, and the progressive maturation of motor control capabilities is the basis of this process [17]. Motor control of the articulation mechanism, as in adults, reaches the middle of childhood. More complex motor patterns require a longer time for automation, and such are the patterns of articulation movements. The speed of automation is also affected by the plasticity of the nervous system. Automated articulation movements constitute the articulation base of native speakers of a language [18, 19].

The pathological articulation is a deviation in the pronunciation of the voices of the mother tongue, both on the visual, as well as on the acoustic and the kinesthetic level [20]. Poorly placed voice organs misjudge the air current, leading to articulation disorders. Parents and the environment often find that the child speaks well of a certain voice, not knowing that the visual presentation of this voice is not good and that for this reason the pronunciation of a certain voice is considered pathological [21, 22]. This is due to ignorance of motor patterns that are necessary for the proper pronunciation of the given voice [23].

The aim of the study was to examine the impact of laterality and cortical responses on the development of speech (articulation) in children.

METHODS

The basic method of organization of research is a quasi-experimental design with two groups. The sample included 60 children, both sexes, aged 5.5 to 7 years of age. The research was performed in the Children’s Outpatient Department at the Voždovac Community Health Center and University Children's Clinic in Belgrade, from 2015 to 2016. The research was carried out in accordance with the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects. The Ethical Committee approved the research, and taking into account that the re-search subjects were children, the informed consent was obtained from the parents/guardians. The experimental group (E) consisted of 30 children with diagnosed articulation disorders with Articulation Test, who were on continuous logopedic treatment, which lasted for an average of 6 months. The control group (C) of 30 children consisted of children from the general population who did not have any articulation disorders. We used the individual testing technique for both E and C group.

The instruments used in the research included: specialized test for lateralization assessment and evaluation of Evoked potential recordings. Lateralization test consists of questions and tasks classified according to the levels for the assessment of usage and gesture laterality of extremities, sight and hearing. The tested child was supposed to ask the questions by showing certain action or complete the specific task using the appropriate equipment offered.

Evoked Potentials (visual potentials - VEP and somatosensory - SSEP): The VEP challenge was performed by the rhythmic repetition of the light signal of certain intensity, duration, and defined distance of the light source from the subject. Light stimuli are structured or unstructured, and the test is performed by binocular, whole field of vision and half of the field of view. The series contains at least 128 stimuli that are analyzed and moderated by soft-technique, while responses contaminated by artifacts are rejected. Registration is done using surface electrodes at the head position determined by the 10-20 EEG system. Examined: Configuration of the induced response, waveform amplitude, P100 waveform latency and interocular latency P100 waveform.

SSEPs were tested by stimulation of both median nerves individually, averaging 512 stimulus of low intensity (5-15, mA), frequency of 3 stimuli per second, duration of 0.2 ms. Detection of the induced responses was performed above the Erb point (brachial plexus), the S7 and S2 spurgeon, as well as on the scalp above the contra lateral sensory cortical field. *Nervus medianus* is stimulated in the wrist of the arm, while the electrodes on the scalp are positioned according to the international 10-20 system. The following parameters were analyzed: absolute primary cortical response waveform latency (N20), configuration and waveform amplitude of the primary complex (N20-P25).

Statistical processing and analysis was done in the computer program SPSS ver. 20 (Statistical Package for the Social Sciences). The measure of descriptive statistics used the arithmetic mean with the corresponding standard deviation, as well as the minimum and the maximum. Frequency and percentage were used. Chi-squared test was used to examine the relationship of two categorical variables, as well as to determine the cross-ratio of the results of the applied instruments.

RESULTS

Table 1 shows that the age of the subjects ranged from 5.5 to 7 years. After the categorization of these variables into three categories: 5.5-6 years, 6.1-6.5 years and 6.6-7 years, we have the following percentile representation of respondents by category: 60% of the experimental group is 5.5-6 years, 13.3% belong to the group from 6.1 to 6.5 years and 26.7% belong to the group 6.6-7 years. Within the control group, 23.3% of the respondents belong to the group 5.5-6 years, 46.7% belong to the group 6.1-6.5 years and 30.0% belongs to the group 6.6-7 years.

Table 2 shows that the average age of the E group was M=6.07±0.5 years of age, while average age of the C group was M=6.34±0.46 years of age.

Figure 1 shows that the control group comprised more respondents of male gender (76.7%), while the control group comprised more female gender respondents (56.7%).

Figure 2 shows that statistically significant difference exists only on visual laterality ($\chi^2 = 7.56$, $p < 0.05$). The statistical significance is below the limit of 0.05. A statistically significant difference between the experimental and control group does not exist on other laterality tests.

Table 3 shows that when we categorize the results obtained on VEP, we obtain statistically significant differences on all measured parameters, between the experimental and control group of the respondents.

Table 4 shows that when categorizing the results of the E and C group measured on SSEP, statistically significant differences are obtained on all measured parameters, except on the waveform cortical response - right.

Figure 3 shows that respondents with lower waveform amplitude on the left eye dominantly use the right eye (68.4%). Those who use this waveform amplitude have a regular dominant use of the left eye (54.5%). The finding of VEP (amplitude to the left) is statistically significant in relation to visual laterality ($\chi^2 = 7.56$, df = 2, $p = 0.023$).

Figure 4 shows that respondents with lower amlouras are predominantly left-handed (50%), while subjects with regular waveform amplitude are predominantly right-handed (70%), indicating that the finding on the SSEP (amplitude) in a statistically significant relationship with gestural laterality ($\chi^2 = 6$, 72, df = 2, $p = 0.035$).

DISCUSSION

The study included children from 5.5 to 7 years of age. This age was observed because it is consider that the development of articulation should be finished at 5.5 years of age. The sample is divided into three subgroups, at the age of half the age of children (Table 1). The average age of the E group was M = 6.07 ± 0.5 years, while the average age of the group C was M = 6.34 ± 0.46 years (Table 2.). All the achievements of the examinees were analyzed collectively for both subgroups and individually for each subgroup. We started from the fact that speech (articulation) and laterality, as cortical functions of the developmental category adopted by learning and intensively developing during the pre-school period.

The analysis of results in relation to gender (Figure 1) showed that, in the E group, were more boys (76.7%) than girls (23.30%), while in C group was the larger number of girls (56.7%) compared to boys (43.30%). As a prospective section study, the sample structure by sex reflects the numerical representation of groups in the population. The results of the laterality test show that a statistically significant difference exists on the subtest visual laterality ($\chi^2 = 7.56$, $p < 0.05$). By analyzing the percentage representation of certain categories, we can see that both groups are predominantly right lateralized. The analysis shows that in the E group there are more left-handed (36.7%) than the C group (13.3%). The number of ambidextrous is higher in the E group (13.3%) compared to the C group (3.3%), which shows the existence of a larger number of respondents with undifferentiated lateralization within E group (Figure 2).This indicates the existence of disharmonic laterality and slow maturation of certain functions in these subjects. The category of disharmonic laterality consists of subjects with complete discrepancy between the dominance of the arm, the eye, the ear and the leg. In addition, we registered the presence of undifferentiated lateralization, i.e., the presence of an ambient, within the group. [24–27]. The results of Evoked Potentials show that both the E and C group of subjects are at the physiological age limits, but that certain differences within these values exist. The results of VEP show that in the E group, waveform cortical responses to the left in 66.7% of the subjects were less formed, and 33.3% were well formed, in the C group, 100% of the respondents were well formed, which gave statistically significant difference ($\chi^2 = 30.00$ df = 1, $p < 0.05$). A better waveform cortical response to the left is present in the subjects in control group. Waveform cortical responses to the right in 20% of the examinees of the E group were less formed, and in 80% of the respondents were well formed, within the C group cortical responses were 100% well-formed, and there was a statistically significant difference ($\chi^2 = 6.667$, df = 1, $p < 0.05$). The waveform amplitude is right at 20% of the E group of examinees, lower, while in 80% of the subjects is regular. In 100% of the group C, waveform amplitude the right is regular ($\chi^2 = 40.000$, df = 1, $p < 0.05$). Waveform amplitude on left 63.3% of the examinees in E group is lower, and in 36.7% of the examinees it is regular, while in 100% of the C patients it is regular ($\chi^2 = 13.469$, df = 1, $p < 0.05$) (Figure 3). Waveform latency is in the physiological limits of the examinees and E and C groups.In the assessment of the waveform cortical response of the left eye, the results showed that in the E group of patients the cortical response was worse in 43.3% of the subjects, and that in 56.7% of the subjects without clear lateralization (equal to the left and right eye), there is a statistical a significant difference between the E and C groups ($\chi^2 = 16.596$ df = 1, $p < 0.05$), as in 100% of the group C patients, the response is without a clear laterality - equable. When we observe the interocular difference (IOR), it is in 80% of the E group of patients, at the damage of the left eye, and in 20% of the examinees at the damage of the right eye. In the C group, the interocular difference is 13.3% of the respondents is equal - there is no difference, in 56.7% of the respondents at the damage of the left eye, and in 30% of the respondents at the damage of the right eye. In the final analysis of the results, the difference would be reflected in the larger number of subjects with a balanced interocular difference of 13.3%, within the

C group, which is a better result. This result can be observed through the functional localization of parts of the body in the cerebral cortex (eye, mouth-tongue, arm, leg)[28].

Results in SSEP show that in group E, waveform cortical responses to the left in 46.7% of the respondents were less formed, and 53.3% were well formed, in the C group 100% of the respondents had well-formed waveform cortical responses on left side ($\chi^2 = 18.261$ df = 1, $p < 0.05$) (Figure 4). A better waveform cortical response to the left is present in the subjects in control group. Waveform cortical responses to the right in 3.3% of respondents, E groups were less formed, and 96.7% of respondents were well formed, within the C group, waveform cortical responses were 100% well-formed on the right ($\chi^2 = 1.017$, df = 1, $p> 0.05$). Sophisticated and coordinated movements of the hands affect on the sensomotor development of the central nervous system, and on the development of speech over it, which requires a higher level of sensomotor coordination[26].

The waveform amplitude is in 33.3% of the E group of examinees, lower, while 66.7% of the subjects are neat. In 100% of the group C amplitude groups is regular, which gives a statistically significant difference ($\chi^2 = 12.000$ df = 1, $p < 0.05$). Waveform latency is in 83.3% of the experimental group in the physiological limits, while in 16.7% of the subjects latency is the limit value (which implies latency at the physiological limit for the age), in 100% of the examinees of the control group latency is at physiological limits ($\chi^2 = 5.455$ df = 1, $p < 0.05$). At evaluation of the waveform cortical response, the left n. Medianus results showed that 46.7% of subjects in the E group were worse, and in 53.3% of the subjects without clear laterality (equal), in the control group, the waveform cortical response was equal ($\chi^2 = 18.261$ df = 1, $p < 0.05$). This result suggests that in some patients of E group on the left hand is mild dysfunction of central afferents, within the physiological limits. We tested with Chi-squared test whether the results of the applied tests were statistically significant. Connection testing was done in E group. The reason for this is that the C group generally has unified results and there is no point in doing comparison (numbers are constants). VEP (amplitude of waves of the left eye) is statistically significant with visual laterality ($\chi^2 = 7.56$, df = 2, p = 0.023) (Chart 3).Respondents with lower waveform amplitude on the left side dominantly use the right eye (68.4%). Those with this amplitude have a regular dominant use of the left eye (54.5%). SSEP (median nerves, cortical wave amplitude) is in a statistically significant connection with gestual laterality ($\chi^2 = 6.72$, df = 2, p = 0.035). Respondents with lower amplitude were predominantly left-handed (50%), while subjects with regular amplitude were predominantly right-handed (70%) (Figure 4). Considering that the gestural lateralization of the hand is seen here, we can conclude that laterality did not succumb to sociocultural pressure [29] and reflects spontaneous, individual maturation and that is precisely the reason for this result.

CONCLUSION

Articulation disorders are more manifested in boys than in girls. The diffusion of visual lateralization children with articulation disorders is worse than children with neatly developed speech. Results of visual and somatosensory waveform cortical responses, which are finding within the physiological values for age, represent better results children with well-developed articulation than children with articulation impairment in mutual comparison. Accordingly, neuropsychological and neurophysiological indicators give us the possibility of detecting the risk of speech development in pre-school children. This result suggests that further monitoring of findings could provide data that could be used to timely prevention planning.

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Table 1. Structure of the sample according to the age categories of the respondents

Parameter			**Age of respondents (years)**			**Total**
			5.5–6	**6.1–6.5**	**6.6–7**	
Group	Experimental	Total (n)	18	4	8	30
		%	60	13.3%	26.7%	100
	Control	Total (n)	7	14	9	30
		%	23.3	46.7%	30.0%	100
Total		Total (n)	25	18	17	60
		%	41.7	30.0%	28.3%	100

Table 2. Sample structure according to average age of the respondents

Group	n	Min.	Max.	M	SD
Experimental	30	5.50	7	6.0700	0.50729
Control	30	5.50	7	6.3433	0.46065
	60	5.50	7	6.2067	0.49979

Min. – sample minimum variable value; Max. – sample maximum variable value; M – sample arithmetic mean (sample average variable value); SD – standard deviation (average deviation of individual sample variable values)

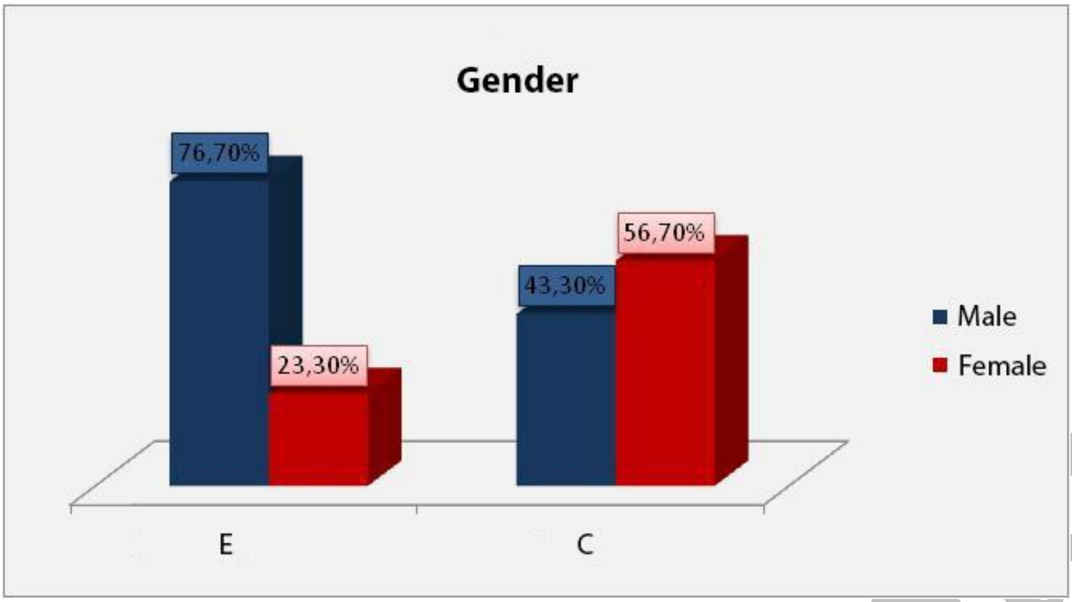

Figure 1. Sample structure according to gender of the respondents

Figure 2. Test of assessment of laterality – the difference between the experimental and the control group

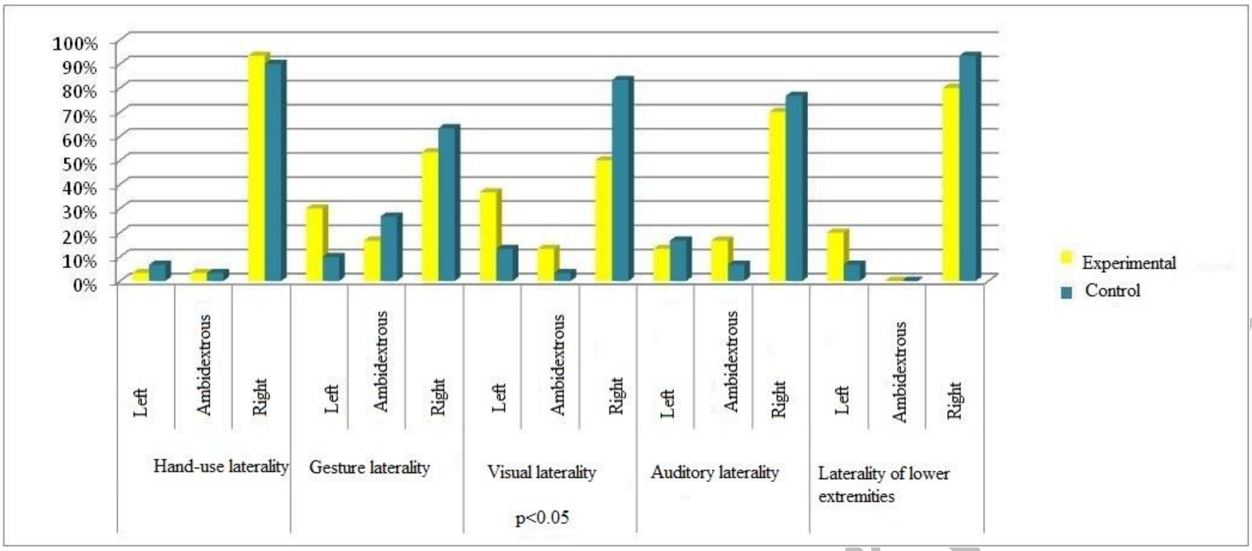

Table 3. Visually evoked potential – the difference between the experimental and the control group on the measured parameters

Parameter		**Experimental**		**Control**		χ^2	**Df**	**p**
		Total (n)	**%**	**Total (n)**	**%**			
Cortical response – left	Well formed	10	33.3%	30	100%	30.000	1	0.000
	Less formed	20	66.7%	0	0%			
	No response	0	0%	0	0%			
Cortical response – right	Well formed	24	80%	30	100%	6.667	1	0.010
	Less formed	6	20%	0	0%			
	No response	0	0%	0	0%			
Amplitude – right	Lower	6	20%	30	100%	40.000	1	0.000
	Good	24	80%	0	0%			
Amplitude – left	Lower	19	63.3%	30	100%	13.469	1	0.000
	Good	11	36.7%	0	0%			
Latency	Within physiological limits	30	100%	30	100%	/	/	/
IOR	Equal	0	0%	4	13.3%	5.795	2	0.050
	Prolonged at the cost of the left side	24	80%	17	56.7%			
	Prolonged at the cost of the left side	6	20%	9	30%			

Df – degrees of freedom

Table 4. Somatosensory evoked potential – the difference between the experimental and the control group on the measured parameters

Parameter		**Experimental**		**Control**		**χ²**	**Df**	**p**
		Total (n)	**%**	**Total (n)**	**%**			
Cortical response – left	Well formed	16	53.3%	30	100%	18.261	1	0.000
	Less formed	14	46.7%	0	0%			
	No response	0	0%	0	0%			
Cortical response – right	Well formed	29	96.7%	30	100%	1.017	1	0.313
	Less formed	1	3.3%	0	0%			
	No response	0	0%	0	0%			
Amplitude	Lower	10	33.3%	0	0%	12.000	1	0.001
	Good	20	66.7%	30	100%			
Latency	Within psysiological limits	25	83.3%	30	100%	5.455	1	0.020
	Prolonged latency	0	0%	0	0%			

Df – degrees of freedom

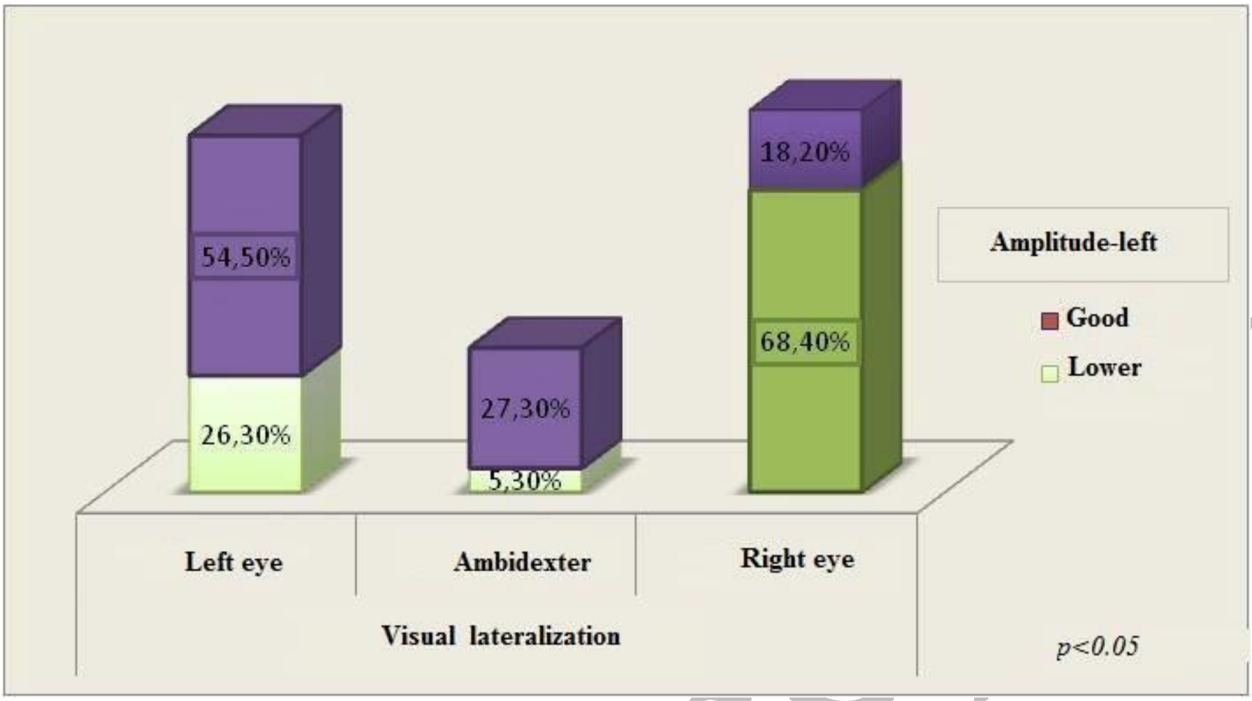

Figure 3. Cross-ratio of visually evoked potential findings (amplitude on the left) and visual laterality

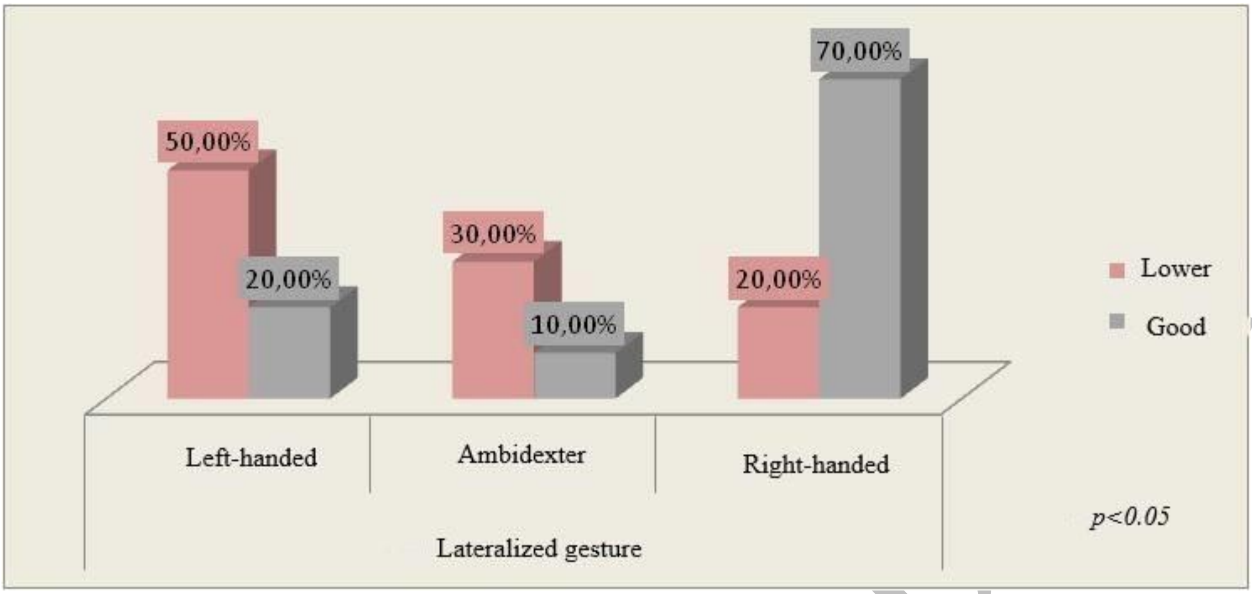

Figure 4. Cross-sectional relationship between somatosensory evoked potential (amplitude) and gestual laterality