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Neuropsychological parameters as possible indicators of speech fluency disorder in children

Neuropsihološki pokazatelji kao mogući indikatori poremećaja fluentnosti govora kod dece

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Abstract

Background/Aim. Speech disfluency (stuttering) is a multifactor disorder and its aetiology is a big unknown for the experts from various fields. Hemisphere dominance as the highest level in the process of integration of cortical functions is of special significance for the entire development. Praxis and gnosis related cortical organizers are the first to form; they become differentiated and functionally full in early childhood while the process of condensing is completed somewhere around the age of 7. Cortical activity organizers are definitely set at that age and from then on act from one hemisphere which becomes dominant for that function. Laterality is determined by hemisphere dominance, but it occurs as a special phenomenon and it is of great significance for personality. The aim of this research was to examine the influence and the relationship between hemisphere asymmetry on the occurrence of speech disfluency in children. **Methods**. Sixty children aged 5 to 7 years participated in this research. Thirty children suffer from speech fluency disorder (person who stutters – PWS) and they belong to the experimental group while thirty children are fluent speakers (person who does not stutter – PWNS) and they were the control group. Individual testing was used as a test method. Laterality assessment test was used as an instrument which consists of 5 sub-tests as follows: the assessment of hand-use laterality, the assessment of gestural hand-use laterality, the assessment of foot laterality, the assessment of auditory laterality and the assessment of visual laterality. **Results**. Gestural hand-use laterality and auditory laterality in the PWS examinees were considerably worse in comparison to the PWNS examinees ($\chi^2 = 11.80$, $p = 0.002$, and $\chi^2 = 10.90$, $p = 0.003$, respectively). Male examinees had worse scores in comparison with female examinees. **Conclusion.** There are certain changes in establishing a dominant hemisphere and differentiation of laterality in children who stutter in comparison with the children who are fluent speakers, which has been shown by statistically significant difference in accomplishments at the test of gestural hand-use laterality and the test of auditory laterality.

Key words:
stuttering; functional laterality; child.

Apstrakt

Uvod/Cilj. Disfluentan govor (mucanje) je multifaktorijalni poremećaj, a njegova etiologija velika nepoznanica za stručnjake različitih oblasti. Dominacija hemisfera kao najviši domet u procesu integracije kortikalnih funkcija, od posebnog je značaja za celokupni razvoj. Prvo se formiraju praksički i gnostički kortikalni organizatori koji se diferenciraju i dostižu svoju funkcionalnu punoću u ranijem detinjstvu, da bi se proces sažimanja dovršio negde oko sedme godine života. Tada se definitivno postave kortikalni organizatori aktivnosti koji od tada deluju iz jedne hemisfere i ona postaje dominantna za tu funkciju. Lateralizovanost je određena dominacijom hemisfera, ali se javlja kao posebna pojava i od velikog je značaja za ličnost. Cilj ovog istraživanja bio je da se ispita uticaj i odnos hemisferne asimetrije na pojavu disfluentnog govora kod dece. **Metode.** U istraživanje je bilo uključeno 60-toro dece, uzrasta od 5 do 7 godina. Tridesetoro dece je imalo poremećaj fluentnosti govora, (*person who stutters* – PWS), i oni su činili eksperimentalnu grupu, a tridesetoro dece je bilo fluentno u govoru, (*person who does not stutter*– PWNS), i ona su činili kontrolnu grupu. Primenjen je metod testiranja tehnikom individualnog testiranja. Kao instrument korišćen je Test za procenu lateralizovanosti koji objedinjuje pet testova i to: procenu upotrebne lateralizovanosti-ruke, procenu gestualne lateralizovanosti-ruke, procenu lateralizovanosti noge, procenu auditivne lateralizovanosti i

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procenu vizuelne lateralizovanosti. **Rezultati.** Gestualna lateralizovanost ruke i auditivna lateralizativnost kod ispitanika PWS bile su značajno lošije u odnosu na PWNS, ispitanike (χ^2 = 11,80, p = 0,002, odnosno χ^2 = 10,90, p = 0,003). Ispitanici muškog pola su postigli lošije rezultate na testovima u odnosu na ispitanike ženskog pola. **Zaključak.** Postoje izvesne promene u uspostavljanju dominantne hemisfere i diferenciranju lateralizovanosti kod dece koja mucaju u odnosu na decu koja su fluentni govornici, što je pokazala statistički značajna razlika u postignićima na testu gestualne lateralizovanosti ruke i testu auditivne lateralizovanosti.

Ključne reči:
mucanje; lateralnost; deca.

Introduction

The development of speech is usually monitored through the development of expressive and impressive speech. Impressive speech is decoding of perceptive speech which implies clear understanding of what has been said and expressive speech is language production. Speech and language functions are predominantly localized in the left hemisphere, while the right hemisphere is dominant for understanding of colour and tonality of verbal expressions, rough discrimination of the meaning of frequent words, and it also has a considerable role in learning of a new language, in other words, an irreplaceable role in the development of speech in childhood. The results of empirical and experimental studies on both healthy and sick people suggest that the left hemisphere in people is dominant for speech in 90% of cases and that the entire cortex participates in realization of language activities [1, 2]. The term fluency means the ability to generate new forms of speech in a given unit of time. Fluent speech implies easy, fluent and natural speech flow which unwinds without strain, interruption, hesitation, stopping and prolongation [3]. Speech disfluency (stuttering) means irregular pronunciation where speech tempo is noticeably disrupted as one of the basic suprasegmental speech structures. About 55 million people around the world stutter nowadays. The disorder occurs at all ages, but most frequently in children [4]. This communication disorder changes the speech accuracy, its rhythm, intensity, frequency, emotional colour and therefore the speech as whole [5–7]. Stuttering has negative influence on the general adaptation in society and nature, and this is why it should be considered and treated as a multidimensional problem [8]. There is evident difference in functional organization of the brain in persons who are disfluent speakers and those who are not. This organization includes a series of both cognitive and emotional processes [9, 10]. Some scientists claim that there are certain deviations in functioning of both cortical and subcortical parts of the brain in disfluent speakers in comparison with fluent speakers as well as considerable influence of hemisphere dominance on the appearance of stuttering [11].

Laterality is realized gradually in the course of central nervous system (CNS) maturation and gathering experiences acquired by perception, kinaesthesia, manipulative activities and finally cognition that this laterality occurred. In the following step of maturation, there is differentiation of laterality when laterality becomes dominant for one side and subdominant for the other side of the body (cognition that one extremity or sight organ are leading and thus is dominant over the other one). The assessment of laterality and dominant laterality points at the organization of ability of senses and movements in the function of voluntary motor activities and to the level of practognostic cortical organization in comparison to the development of hemisphere dominance [12]. Laterality is determined simultaneously with dominance determination. It is first estimated if the dominant side is always the same and stabilized in comparison with the subordinate one. After that conclusion, it is determined which side is stabilized as dominant one, and which always appears as subordinate.

Some researches have shown that there is a link between the occurrence of stuttering, hemisphere dominance and differentiation of laterality. Undifferentiated laterality was noticed in persons who stutter, although this claim was not supported nor proved by application of contemporary neuroimaging techniques by measuring metabolic activities at cell level [13]. Undifferentiated laterality was noticed at the level of upper limb, which was brought into connection with stuttering [14, 15]. Verbal organization and laterality of expressive speech centre in disfluent speakers also show certain differences in comparison with fluent speakers [16, 17]. The studies of auditory laterality in the examinees with disfluent speech showed results which confirmed aberrations from the results of fluent speakers and support undifferentiated auditory laterality of this population [18, 19].

Findings from modern neurodiagnostic techniques have implicated cortical and subcortical structures with PWS. Electroencephalographic measurements demonstrated greater activity in the nondominant right hemisphere in subjects with PWS during the speaking condition [20]. No such brain activity was reported in individuals without stuttering. Upon fluency improvement with treatment, this focused physiologic activity shifted to the left hemisphere [21–23].

The aim of this research was to examine the influence and the relationship of hemisphere asymmetry on the appearance of disfluent speech in children.

Methods

For the purpose of this research the sample of 60 children, aged 5 to 7 years, was formed. The research was carried out at the Institute for Psychophysiological Disorders and Speech Pathology "Dr Cvetko Brajović" and the Clinic of Neurology and Psychiatry for Children and Youth in Belgrade. 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 research subjects were children, the informed consent was obtained from the parents/guardians.

Thirty children were selected according to the criteria of the presence of stuttering and they were monitored as an experimental group (E); the other thirty children were fluent speakers and this group was monitored as a control group (C). For both the experimental and control groups the additional criterion was defined – the absence of other impediments and disorders in intelligence, motor ability or sensory perception. The research was carried out from November 2014 until May 2015. In line with the set goal, we used the research method which included the method of documentation analysis and testing. Testing included the techniques of individual testing for the groups E and C. The instruments used in the research included specialized test for lateralization assessment (Bojanin, 1975). The lateralization test consisted of questions and tasks classified according to the assessment levels of and gesture laterality of extremities, sight and hearing. In order to assess the dominant hand-use laterality, a test consisting of 12 tasks was used and to assess the gesture laterality, a test consisting of 6 tasks was set by the trained measurer. The tested child was supposed to answer the questions by showing certain action or complete the specific task using the appropriate equipment offered. In the course of testing the dominant hand-use laterality of upper extremities, the measurers asked the following questions: "Show me how you comb your hair?" or "Show me how you hold the spoon?", and so on. It was recorded which hand the child used to show the action and based on the collected answers, it was assessed if the left or right hand was dominant, or if the child is ambidextrous. It was similar with the assessment of dominant gesture laterality of upper extremities. The tested child was asked "How would you put your fists together, one above the other?" and the child showed that spontaneously. Depending on which hand was above (in this case which fist was put as the upper fist), we recorded that this hand was gesture-dominant. By calculating the collected data we made the assessment regarding the dominant gesture lateraly.

The dominant laterality of lower extremities was assessed by movements made on an everyday basis in the social environment. There were 4 tasks. The tested child was supposed to perform the action according to the request "Show me how you kick the ball?" or "Show me how you stand on one foot". It was recorded which leg the child used to complete the task. By calculating the collected data, the dominant laterality of lower extremities was assessed.

The evaluation of dominant auditory laterality was made by searching for or by approaching the sound source. There were 4 tasks. The tested child was supposed to complete the task when asked to "Listen to this clock to hear if it is ticking" (we give a wrist watch to a child), and so on. It was recorded which ear the tested child used to complete the set task. By calculating all the data, the dominant ear was determined. The evaluation of dominant sight laterality was assessed by means of a cardboard with one hole, two distant holes and the telescope. There were 4 tasks. The tested child was supposed to complete the task upon the request "Look at me through this hole" (when the tester was holding the cardboard), or, "Take a cardboard and look at me through the hole". It was recorded which eye the tested child used to complete the task and by calculating the results, it was determined which eye was dominant during the task completion. The tests were performed so that the set tasks could be verbally repeated but not shown.

The collected data were processed using statistical analysis by means of parameter algorithms in Statistical Package for Social Sciences for Windows (SPSS) version 17. Out of the descriptive statistics measures, frequency and percentage were used as well as arithmetic mean with standard deviation. The differences between groups were determined by χ^2 test. Statistical significance was defined at the level of probability of null hypothesis $p \leq 0.05$ to $p < 0.01$.

Results

Sixty examinees, all aged 5 - 7 years, participated in the research. Within the experimental group there were 60% of male examinees, 40% of female examinees, while within the control group there were 56.7% of male examinees and 43.3% of female examinees. The groups were adjusted per sex ($p = 0.793$) (Table 1). The groups were also adjusted according to the average age ($p = 0.276$); the average age of the experimental group was 6.1 years, while the average age of the control group was 6.25 (Table 2).

Table 1

Structure of examinees with respect to the sex and age in children with speech fluency disorder (the Experimantal group – E) and those with fluent speech (the Control group – C)

Groups of exameenes	Gender, n (%)		Age (year)	Total
	males	females	r ± SD (min-max)	n (%)
Group E	18 (60)	12 (40)	6.10 ± 0.51 (5–7)	30 (100)
Group C	17 (56.7)	13 (43.3)	6.25 ± 0.46 (5–7)	30 (100)
Total	35 (58.3)	25 (41.7)	6.20 ± 0.50 (5–7)	60 (100)

n – number of respondents; min – minimum value of the variable in the sample; max – the maximum value of the variable in the sample; r – arithmetic mean (average value of the variable in the sample); SD – standard deviation (average deviation of the individual values of the variables in the sample).

Table 2

Differentiation of laterality in children with speech fluency disorder (the Experimantal group – E) and those with fluent speech (the Control group – C)

Parameters	Groups of exameenes, n (%)						*p*
	group E			group C			
	males 18 (60)	females 12 (40)	total 30 (100)	males 17 (56.7)	females 13 (43.3)	total 30 (100)	
Hand-use laterality							
left	5 (16.66)	7 (23.33)	12 (40)	4 (13.33)	8 (26.67)	12 (40)	
right	7 (23.33)	3 (10)	10 (33.33)	7 (23.33)	4 (13.33)	11 (36.67)	0.133
undiff.	6 (20)	2 (6.67)	8 (26.67)	6 (20)	1 (3.33)	7 (23.33)	
Hand- gestural laterality							
left	8 (26.67)	6 (20)	14 (46.67)	5 (16.67)	4 (13.33)	9 (30)	
right	7 (23.33)	4 (13.33)	11 (36.67)	12 (40)	9 (30)	21 (70)	0.002*
undiff	3 (10)	2 (6.67)	5 (16.67)	0 (0)	0 (0)	0 (0)	
Lower limb laterality							
left	7 (23.33)	5 (16.67)	12 (40)	9 (30)	7 (23.33)	16 (53.33)	
right	8 (26.67)	4 (13.33)	12 (40)	5 (16.67)	3 (10)	8 (26.67)	0.066
undiff	3 (10)	3 (10)	6 (20)	3 (10)	3 (10)	6 (20)	
Auditory laterality							
left	2 (6.66)	2 (6.66)	4 (13.33)	5 (16.67)	3 (10)	8 (26.67)	
right	8 (26.67)	6 (20)	14 (46.67)	12 (40)	10 (33.33)	22 (73.33)	0.003*
undiff	8 (26.67)	4 (13.33)	12 (40)	0 (0)	0 (0)	0 (0)	
Visual laterality							
left	4 (13.33)	5 (16.67)	9 (30)	8 (26.67)	6 (20)	14 (46.67)	
right	8 (26.67)	4 (13.33)	12 (40)	4 (13.33)	4 (13.33)	8 (26.67)	0.166
undiff	6 (20)	3 (10)	9 (30)	5 (16.67)	3 (10)	8 (26.67)	

undiff. – undifferetiated laterality; *values that show significant difference.

As for the test score of estimated upper limb laterality, in the test of hand-use laterality out of 12 trials only 2 resulted in statistically significant difference in the groups E and C, which in final consideration of the results did not produced statistically significant difference between them (χ^2 = 4.37, p = 0.133). In the examinees from the group E, gestural hand-use laterality ranges from undifferentiated laterality (ambidexterity), which was present in 5 examinees, left-hand gestural laterality was observed in 14 examinees and 11 examinees had right-hand gestural laterality. In the group C, none of the examinees had undifferentiated laterality, 9 examinees had left-hand gestural laterality while 21 examinees had right-hand gestural laterality. The data processing resulted in a statistically significant difference (χ^2 = 11.80, p = 0.002) between the groups E and C. As for the distribution according to sex, there were 8 male examinees in the group E with the left gestural hand-use laterality, 7 with the right, while 3 examinees did not have laterality differentiation. In the female examines 6 of them had left gestural hand-use laterality, 4 of them had the right, and 2 did not have laterality differentiation. According to the sex of examinees the distribution in the group C was as follows: 5 male examinees had left-hand gestural laterality, 12 of them the right, while undifferentiated laterality was not present in any of the examinees in this group. In the female examinees, 4 of them had left gestural hand-use laterality, ?9 of them had right while undifferentiated laterality was not present in any of the examinees in this group.

As for the laterality of the lower limb – foot, a statistically significant difference between the groups E and C (χ^2 = 0.80, p = 0.666) was not determined.

The distribution of the results for auditory laterality showed that 4 examinees in the group E had left auditory laterality, 14 had right and 12 had undifferentiated (ambidextrous) auditory laterality. In the group C, 22 examinees had right auditory laterality and 8 of them had left. Statistical processing showed a statistically significant difference between the groups E and C (χ^2 = 10.90, p = 0.003). With respect to the sex, there were 2 male examinees in the group E with left auditory laterality, 8 with the right, while 8 examinees did not have auditory laterality differentiated. As to the female examinees, 4 of them had left auditory laterality, 14 had the right, and 12 examinees did not have laterality differentiated. In the group C, the distribution according to the sex was as follows: 5 male examinees had left auditory laterality, 12 had the right while undifferentiated auditory laterality was not present in any of the examinees in this group. As to the female examinees, 3 of them had left auditory laterality, 10 of them had the right, while undifferentiated laterality was not present in any of the examinees in this group. The data processing regarding the estimation of visual laterality did not provide statistically significant difference between the groups E and C (χ^2 = 1.70, p = 0.166).

Discussion

The scores obtained at the test of laterality were analysed collectively for both groups (30 PWS children and 30 PWNS children). Observation of dominant laterality of motor ability and senses suggests the dominance of the CNS functions. The problem appears when the result is ambiva-

lent (ambidexterity), and this is not a physiological ambivalence characteristic for children of 3 to 4 years of age. Harmonious laterality means identical dominant laterality at the level of a hand, eye, ear and foot. The category of inharmonious laterality consists of the examinees with complete disharmony in dominance of a hand, eye, ear and foot. In addition to this, the presence of undifferentiated laterality, i.e. the presence of ambidextrous children within the group is also disputable. It can be seen from the above-mentioned that at the test of gestural laterality of the upper limb – hand, the PWS examinees were statistically considerably worse. Unsuccessfulness of the PWS examinees reflected in overall larger number of examinees present in ambidexterity and the left-handedness. The results suggest that at the laterality test, the test of gestural hand-use laterality, in the PWS examinees, there were more examinees with undifferentiated laterality and the examinees with dominant left hand-use than in the PWNS examinees. According to our results, the children who stutter had mostly undifferentiated gestural hand-use laterality or left-hand gestural laterality. The distribution of the results in relation to the sex in the PWS in comparison with the PWNS examinees showed that undifferentiated gestural hand-use laterality appeared mostly in the male examinees. Unsuccessfulness of the male examinees in this task, reflected in totally larger number of the examinees in the ambidexterity group. Some findings reflected the imprecise functional connectivity within the right frontal cortex and incomplete segregation between the adjacent hand and mouth motor representations in stutterers during speech production. During speech production, the right motor-premotor cortex generated consistent evoked activation in fluent speakers but it was silent in stutterers [24]. There is increasing body of evidence supporting the various manners of linguistic information processing, both for perception and production, in those who stutter and in their peers who do not stutter. At cortical level there is increased activation of the right hemisphere present in the language centres and sound-processing centres. Therefore, it is necessary to stimulate the development of sensory and work capacities in the organization of therapy. In this way, there is influence on the development of perceptual attention and perception in general, the function of the hand being dominant in its significance, since it is by the hand exactly that concentration of all personal capacities is achieved, from perceptual attention, which cannot be separated from pure motor ability, to the higher cognitive functions, which speech actually is. Considering in detail the obtained research results, we can conclude that in children with fluent speech disorder hand-use and gestural hand-use laterality are not in agreement. This may mean that the environment enforced the hand-use laterality by daily manipulative activities and led to forced change of the dominant hand which might have created a “confusion” in the brain.

The results of the test of auditory laterality in the PWS examinees in comparison with the PWNS ones mean that the PWS examinees obtained worse scores. On the test of auditory laterality in comparison with the PWNS examinees. This can be seen in the overall number of examinees with undifferentiated auditory laterality. The distribution of the scores on this test related to the sex, showed that undifferentiated auditory laterality is more frequent in the PWS male examinees than in the PWNS examinees. In fluent speakers, the left auditory cortex is more sensitive to the side of stimulation (right versus left ear), whereas the right auditory cortex is more sensitive in the stutterers. The stutterers were also reported to have difficulties in sound localization [25].

In literature, the research which deals with the cause of stuttering shows that there is hypoactivity of the left hemisphere which is caused by reactive amygdala response. Considering that speech centres are localized in the left hemisphere, we can assume that its hypoactivity causes dysfunction of neuromotor processes and discoordination of speech motor ability based on motor programming which can represent a causal factor for occurrence of stuttering [26]. Some research where bioelectric activities of both hemispheres electroencephalography (EEG) were monitored find the cause of stuttering in suppressing the activity of alpha waves over the right temporal part which causes increased activity of the right hemisphere in this part [27, 28]. Accordingly, stuttering can also occur when both the input data from both hemispheres are processed and motor programming of the separate linguistic units are in the right hemisphere. These differences in processing can refer to the to process separate language aspects under certain circumstances. This shows the significance of linguistic division since it refers to motor programming in some PWS people [21, 29].

Conclusion

Our results suggest that 5 (16.67%) children who stuttered had mainly undifferentiated gestural hand-use laterality, while all children with fluent speech had gestural laterality differentiated. According to the results, auditory laterality was not differentiated in children with speech fluency disorder in 12 (40%) examinees, while in all children with fluent speech the auditory laterality was differentiated, which also showed that differentiation of auditory laterality was considerably better in children who were fluent speakers. The results suggest that it was the accomplishment of these two sub-tests (gestural hand-use laterality and auditory laterality) that showed significant difference between the children with fluent speech and the children with speech fluency disorder, which might perhaps be used to predict possible speech fluency dysfunction.

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