Functional Maturity of Brain Structures in Children Aged 7-8 with Differing Levels of Speech Development

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First graders (aged 7-8) in a public elementary school served as subjects for this study. The structural components of their speech were analyzed to determine speech maturity level; total EEG activity was analyzed to assess the functional maturity of brain structures. Results showed that children with levels of speech below the age norm exhibited abnormal EEG patterns suggesting immaturity of the cerebral cortex and fronto-thalamic regulatory system, as well as impairments in the functioning of the mesodiencephalic structures and nonspecific activation systems. Abnormalities in the functioning of brain regulatory systems and the presence of local abnormalities in EEG activity of deep origin are important factors in determining the severity of functional speech impairments.
Keywords: electroencephalogram (EEG), speech disorders, functional maturity of brain structures.

En el presente estudio participaron alumnos de primer grado de una escuela pública (7-8 años). Fueron analizados los componentes estructurales de su habla para determinar el nivel de madurez de la misma; se analizó la actividad total EEG para evaluar la madurez funcional de las estructuras cerebrales. Los resultados mostraron que niños con niveles de habla por debajo de la norma, presentaban patrones anómalos de EEG sugiriendo inmadurez en el cortex cerebral y en el sistema de reguladores frontotalámicos, así como mejora en el funcionamiento de las estructuras mesodiencefálicas y sistemas de activación no específicos. Las anomalías en el funcionamiento de los sistemas reguladores del cerebro y la presencia de anomalías locales en la actividad EEG de origen más profundo son factores importantes a la hora de determinar la severidad del deterioro en el habla.
Palabras clave: electroencefalograma (EEG), desórdenes del habla, madurez funcional de las estructuras cerebrales.

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Children's elementary school performance success is a function of a number of factors, among which speech development plays a particularly important role. According to numerous studies, every year there is an increase in the number of first graders with various impairments of speech development, such as phonetic speech defects, phonetic-phonemic immaturity, and general delay in speech development. The situation with respect to speech impairments is further complicated by the fact that less than adequate speech performance has a negative effect on sensory, intellectual and affective development, and on self-discipline (Bezrukikh & Loginova, 2002; Onda, 2003). This impedes development of adequate school performance. According to results obtained by the Scientific Research Institute for Developmental Physiology of the Russian Academy of Education, more than 60% of children identified as experiencing difficulties with schoolwork show impairment of speech development (Bezrukikh & Kreschenko, 2003; Dubrovinskaya, Farber, & Bezrukikh, 2000).

The developmental period occurring between ages 6 and 8 years is a critical one for the maturation of voluntary higher nervous functions (HNF). Improvement in cognitive functioning during this developmental phase depends, to a significant extent, on the functional maturity of the brain. Many researchers associate the delays in HNF development and learning difficulties experienced by children with abnormal speech development with inadequate functional maturity of the central nervous system (CNS) (Akhutina, 1998; Fotekova, 2003; Kiroy, 2002; Yastrebova, 2000). The maturation of rhythmogenic mechanisms of the cerebral cortex, as well as the development of regulatory processes controlled by subcortical structures, including those of the brain stem, play an important role in the progressive development of mental functions (Machinskaya, Lukashevich, & Fishman, 1997).

One objective and widely used approach to analysis of the functional maturity of the brain is the study of total electroencephalic activity (EEG). This method makes it possible to investigate the systems organization of the brain's integrative activity in various functional states and when there exist impairments of HNF (Farber, Beteleva, Dubrovinskaya, & Machinskaya, 1998; Livanov, 1972; Shepovalnikov & Ciceroshin, 2004).

The purpose of the present study was to identify the features of functional brain maturity in first graders with differing levels of speech development.

Method

Participants

A total of 65 boys and girls (mean age 7.33 ± 0.45 years) participated in this study. They were pupils in public elementary school No. 17 in Arkhangelsk, in an area where the families were well-to-do. Written consent to participation

was obtained from subjects' parents and teachers. The study was performed during the early part of the day (from 9:00 a.m. to 2:00 p.m.). Medical files showed all the children to be apparently healthy and without organic CNS damage or marked psychological or neurological abnormalities.

Materials

The short form diagnostic instrument described in Fotekova, 2000 was used to assess speech development. This instrument was designed to identify the developmental characteristics of speech development in young school-age children and provides both a qualitative and a quantitative analysis of the structural components of speech.

For the EEG studies we used a the Neuroscop-416 16-channel electroencephalograph with electrodes, manufactured by BIOLA Ltd, Moscow, a cap for affixing the electrodes, goggles to provide rhythmic photic stimulation and a computer (P4 processor with a 512 MB memory, and a 200 GB disk) loaded with the Neuroscop program for recording, storing and analyzing resulting data.

Procedure

During the first phase of the study we administered the Fotekova speech assessment instrument for young school children to the subjects. This instrument consists of a test with a standardized administration procedure and standardized scoring system. It is intended to identify the characteristics of speech development in children of young school age, including qualitative and quantitative assessment of abnormalities, and derivation and analysis of the overall structure of speech impairments. This makes it possible to obtain a graphic representation of speech impairments and to assess the severity of abnormalities in various aspects of speech. The children were tested individually and gave oral responses in four series of tests. The psychologist asked the child questions and recorded each answer on a form. There were no time limits imposed in the testing.

Test Series 1 consisted of exercises to determine the development of the sensorimotor aspect of speech, including phonemic perception, articulation, pronunciation of sounds and maturity of phonetic and syllabic word structure. To assess phonemic perception the child was asked to listen carefully and repeat syllables after the psychologist. Each pair of syllables was presented in both possible orders (pa-ba, ba-pa). To assess motor coordination in articulation, the child was told to watch the psychologist carefully and to reproduce her lip and tongue movements. Investigation of pronunciation of sounds and the phonetic and syllabic structure of words required the children to repeat words after the psychologist.

Test Series 2 contained exercises assessing development of oral grammar and included repeating sentences, correcting grammatically incorrect sentences, composing

sentences from a list of words presented in basic (undeclined, or unconjugated) form, filling in missing prepositions in sentences; and forming the nominative and genitive plurals of nouns. In the sentence repetition task the child was asked to listen carefully to the tester and then repeat a sentence as accurately as possible. In the task involving sentence correction, the psychologist read sentences containing errors to the child that he or she had to correct. In the sentence composition task, the child was given a list of words in their basic forms and had to make a well-formed sentence from them (including declension and conjugation). In the "fill in the preposition" task, the psychologist read the child a sentence in which a preposition was missing and asked him or her to provide the missing word. In the "formation of nominative and genitive plurals of nouns" task, the child was given the nominative or genitive singular of a noun and had to change it to the plural (in the same case).

Test Series 3 included exercises intended to assess the lexical level of the children's speech, such as vocabulary (providing the correct word for young animals) and word formation skills. In the former task, the psychologist named an animal and the child had to give the name used for its young. In the investigation of word formation skills, the child had to form adjectives from the nouns provided by the psychologist.

Test Series 4 consisted of exercises designed to assess the coherence of the child's speech and included the task of composing a story based on a series of thematically related pictures and the retelling of a text that had just been heard. In the "story composition" task, the psychologist asked the child to look carefully at a set of pictures, which had been laid out on the table, and to put them in order. After the child had correctly ordered the pictures (during this process the psychologist was permitted to provide assistance and hints) the child was told to make up a story based on the pictures. In the "retelling" task the psychologist asked the child to listen carefully to a short story the psychologist told and then to retell it. If the child had difficulty with the retelling, the psychologist asked leading questions and/or read the story aloud a second time.

Scores were computed on the basis of number of correct answers. These scores were used to compute correct performance percentages and a speech profile was created for each child. The highest score possible for the whole test series was 120. This number was set equal to 100%, and the percent correct performance was computed. For each child this number was associated with one of the four performance levels proposed by Fotekova (2000): 100-80% success = Level IV, which corresponds to the age norm; 79.9-65% = Level III, corresponding to a slight delay in speech development; 64.9%-45% = Level I, corresponding to a pronounced delay in speech development; and 44.9% and below = Level I, considered to indicate a severe delay in speech development. The lower boundary of the developmental norm for each test series was 80%.

During the second phase of the experiment electroencephalography was performed on the first graders. The procedure was performed with the child seated in a chair adjustable for height. Leads and electrodes were positioned in accordance with the international "10-20" system. EEG recordings were made while the subjects were in a state of alert rest with eyes closed (2 minutes) and open (1 minute). In the rhythmic photic stimulation (RPS) condition, goggles with photodiodes creating flashes of light were placed on children who had been told to close their eyes. The frequency of the light flashes during the RPS condition changed automatically between 4 and 12 Hz at 1 Hz intervals. Each stimulation series lasted 7 seconds, with a 10 second interval between series. This was followed by a provocative test involving hyperventilation (1.5-2.5 minutes). Results obtained underwent structural analysis of total EEG (Lukashevich, Machinskaya, & Fishman, 1994). The analysis consisted of several modules. In the first module, "cortical functioning," performed assessments on the basis of alpha-wave characteristics, including, nature of alpha rhythm, alpha-rhythm frequency, amplitude, topography, amplitude asymmetry, and changes in alpha waves in response to the provocative tests (see Table 1).

In the second module, "overall brainwave changes," the parameters analyzed were: diffuse deviant EEG abnormalities in the form of prevalence of polymorphic slow or polymorphic rapid fluctuations as well as peaks or isolated sharp waves in various frequency bands without clear localization. Analysis of these variables by this module provides information about the severity of brainwide abnormalities. Results suggestive of moderate brainwide abnormalities include isolated sharp fluctuation in alpha- and theta-waves, mono- and bi-phase peaks, or combinations of these. Severe brainwide abnormalities are suggested by prevalence of polymorphic diffuse delta- and theta-waves or diffuse beta activity, as well as occurrence of more than one of these phenomena.

The "local deviations" module describes local abnormalities in the electrical activity of the major regions of the right and left cerebral cortex: the frontal, central, temporal (anterior and posterior), parietal and occipital regions. This analysis describes deviations in electrical activity in one or several adjacent areas. These abnormalities are best identified with bipolar leads with large (for local electroencephalic abnormalities of deep origin) and small (for local electroencephalic abnormalities of cortical origin) distances between electrodes using the "reverse phase" method. The following parameters of local electroencephalic abnormalities are described: the type of local deviations in electrical activity, topography, abnormal response to provocative tests; conclusions that may be drawn from analysis of local abnormalities in electrical activity, the nature and severity of local EEG abnormalities. Isolated peaks, individual monophase and bi- or tri- phase sharp waves, isolated delta waves, and

Table 1

EEG features used to determine cortical development of children aged 7-8 with respect to the developmental norm)

EEG Feature	Developmental level
Nature of alpha-rhythm	
Polyrhythmic	D
Diminished frequency (6-7 Hz)	D
Disorganized and/or sharpened	+
Regular modulated 8-9 Hz	+
Regular modulated 10-11 Hz	-
Reaction of basic rhythm to rhythmic photic stimulation	
No tracking	D
Rhythm driving at 4-6 Hz but not between 7-12 Hz	D
Rhythm driving at 7 Hz isolated and/or in addition to 4-6 Hz.	D
Rhythm driving in the 8-9 Hz alpha-frequency band isolated and/or in addition to other frequencies	+
Rhythm driving in the 10-12 Hz alpha-frequency band isolated and/or in addition to other frequencies	+

Key: + - feature indicates age appropriate development; D-feature indicates deviation from age appropriate development in electric activity of the cortex; - - Feature not manifest at this age.

Table 2

EEG features used to determine functioning of deep regulatory structures in children aged 7-8 with respect to the developmental norm

Bilateral-synchronic abnormalities in electrical activity	Developmental Level
Generalized fluctuations or groups of fluctuations at 4-6 Hz	+
Generalized alpha- and/or beta-fluctuations of diencephalic origin	-
Groups of fluctuations at 4-6 Hz in the frontocentral areas of upper brainstem origin	D
Hypersynchronic alpha-rhythms and/or groups of fluctuations at 4-6 Hz in the occipitoparietal regions of lower brain stem origin	D

Key: + - feature indicates age appropriate development; D-feature indicates deviation from age appropriate development of electric activity of the cortex; - - feature not manifest at this age

isolated delta fluctuations attest to the residual nature of local EEG abnormalities. Local EEG abnormalities of paroxysmal nature are diagnosed when there are complexes composed of a combination of peaks and sharp waves with slow components or multiple peaks. Groups of high-amplitude delta waves or polymorphic slow fluctuations indicate pathological abnormalities in electrical activity. In some case we observed a combination of pathological and paroxysmal activity-that is paroxysms in the context of a general picture of pathological local abnormalities. Analysis of changes in local deviant activity in response to provocative tests suggested conclusions about the severity of abnormalities. Minor local abnormalities were exhibited in response to provocative stimulation, but the stimulation failed to lead to generalization of effects and/or their increase to the point of discharge of sharp waves or paroxysmal discharges. Moderate abnormalities occurred in the baseline condition but did not generalize in response to provocative stimuli or increase to the point of discharge of steep waves or paroxysmal discharges. Severe abnormalities were defined as those that were present at baseline and in response to provocation generalized or increased to the point of generation of sharp waves or paroxysmal discharges.

The fourth module is "functioning of deep regulatory structures" (see Table 2). According to the terminology used in anatomy and physiology, the brain stem includes the metencephalon (the lower stem areas), the mesencephalon and the diencephalon (upper brain stem area). This module describes and analyzes the bilateral-synchronic deviations in electrical activity, their localization and reactions to provocative tests.

Table 3

Components of speech development in groups of children differing with regard to level of speech maturity

Parameters	Mean group values (%)			Statistical significance of group differences (p)		
	Group 1	Group 2	Group 3			
	$n = 11$	$n = 38$	$n = 16$	$p_{1,2}$	$p_{1,3}$	$p_{2,3}$
Phonemic perception	57	73	88	$< .01$	$< .001$	$< .01$
Articulation	70	77	82	n.s.	$<. 05$	n.s.
Sound pronunciation	84	88	93	n.s.	$<.05$	n.s.
Phonetic and syllabic structure of words	74	87	88	$< .01$	$< .001$	n.s.
Grammatical structure of speech	67	76	90	$< .001$	$< .001$	$< .001$
Lexical structure of speech	53	70	85	$< .001$	$< .001$	$< .001$
Coherence of speech	52	61	81	$< .05$	$< .001$	$< .001$

n.s. = not significant

The type of bilateral deviant activity and its topography provide a basis for assessing the functional status of various areas of the brain stem and of certain subcortical foci. This module provides a description of EEG abnormalities associated with impaired functioning of deep structures at various levels. Analysis covers the following EEG abnormalities, reflecting the status of deep structures at various levels: generalized bilateral synchronic abnormalities of diencephalic, mesencephalic, metencephalic, frontobasal and limbic origin. The aspects of bilateral synchronic EEG deviations considered include: their type, the nature of bilateral-synchronic deviations on the electroencephalogram, their response to provocative tests, and their severity.

Statistical analysis

The statistical analyses included analysis of the distribution of values of parameters and their numerical characteristics (means, standard errors of the mean, standard deviations). An analysis of variance was performed using a procedure that compares mean values of samples and computes the overall significance level of differences (ρ-value of the F statistic). In all cases statistical analysis of differences, applied a test of equivalence of variance (Levene's test). To identify pairs of samples differing from each other we used Fisher's Least Significant Difference procedure for paired *post hoc* comparisons. Statistical analysis of the EEG parameters used the chi-square non-parametric test. Differences were considered to be statistically significant if the probability of erroneous rejection of the null-hypothesis concerning equality of overall means was less than .05.

Results

Results of the investigation of speech maturity in children aged 7-8

The children were divided into three groups on the basis of the overall evaluation of their speech maturity. The first group contained 11 first-graders with level II speech maturity (corresponding to an assessment of pronounced overall immaturity of overall). The second group consisted of 38 children whose speech maturity had been assessed as level III (slight overall immaturity of speech). The third group consisted of 16 children whose overall speech was assessed as level IV (corresponding to the developmental norm).

The scores on the phonemic perception task for children in the first and second group were 57% and 73% correct task performance respectively (see Table 3). In this measure they differed significantly from children testing overall as normal ($p < .001$, $p < 01$, respectively), whose mean group score on this parameter was 88%, corresponding to the norm for this age. The phonemic perception deficit for the first and second groups was attributable to errors in repeating two pairs of syllables similar in sound (for example, ba-pa, pa-ba) and two sets of three syllables (for example, tsa-sa-tsa, sa-tsa-sa).

Mean scores on the articulation tasks for the first and second groups were below the norm, at 70% and 77% respectively. In the normal group, this parameter corresponded to the lower boundary of the norm at 82%. A comparison of group means for pairs of groups (Post Hoc Tests, LSD method) established that articulation was significantly poorer in children of group I than in the normal group ($p < 05$). The most common impairments

were slow and labored performance of the movements, too long a time to achieve the initial position, presence of concomitant involuntary movements, and failure to perform the movement.

Mean scores on the sound pronunciation tasks corresponded to the norm in all three groups of children. The mean scores were 84%, 88% and 93% in groups the first, second and third (normal) groups, respectively. Errors made included distortions of individual sounds and combinations of sounds. The significance of differences between the first and third groups in sound pronunciation was ($p < .05$).

Mean scores on tasks relating to the phonetic and syllabic structure of words (74%) were below the developmental norm in the first group of children. Mean score on this task series were 87% and 88% for the second and third group respectively; both these groups differed significantly from the first ($p < .01$).

The first groups also scored lowest on tasks pertaining to the grammatical structure of speech at a mean of 67%. The second group scored significantly higher ($p < .001$) than the first at 76%. The children in these groups had most difficulty with the task requiring forming sentences out of words given in their basic forms (for example, Peter, ball, to buy, red, and mama) [Translator's note: the form of most of these words has to be changed to make a well-formed Russian sentence.] This task requires not only usage of correct grammatical structure, but also construction of an appropriate semantic program. Errors on this task included omissions and substitutions of the words given, semantic and grammatical errors, and distorted word order. The second most common source of errors was the task requiring formation of the plural of nouns in the nominative and genitive cases. The mean score on grammatical tasks for the children in the third, normal, group was 90% (within the normal developmental range). This score differed significantly ($p < .001$) from that of the other two groups.

The children in the first two groups exhibited lexical immaturity in their speech. The mean score on this dimension was 53% for the first group. The second group averaged 70%, which was significantly higher than the first ($p < .001$). The inadequate word formation skills shown by these two groups of first graders suggest poor vocabulary and world knowledge. The mean lexical score of the normal group corresponded to the developmental norm at 85%, which was significantly higher than the scores of the other two groups ($p < .001$).

The mean scores on speech coherence tasks failed to reach the lower boundary of the norm for the first and second group. The mean score here was 52% for the first group and 61% for the second; the difference between the two groups was significant ($p < .05$). The stories these children told about the picture series were marked by the loss of semantically significant links, incorrect reproduction of cause and effect relationships and incompleteness, which significantly distorted meaning. The difficulties they

experienced understanding a story was evident even when they were required to put the pictures in proper order. When asked to retell an orally presented story, these children experienced the following problems: the need to hear the story a second time and/or for prompting with a series of leading questions before they were able to retell it. The lexical and grammatical structure of the stories they told or retold exhibited agrammatism, inappropriate use of lexical elements, stereotyped sentence structure, and inexact use of words. Scores on speech coherence were significantly higher in the normal group than in either of the others ($\rho < .001$) and, at 81 %, corresponded to the age norm.

Results of investigation of functional brain maturity in children aged 7-8

Immaturity in functioning of the cerebral cortex was found in 27% of the first graders in the first group and 3% of those in the second group (see Figure 1).

Indicators of cerebral cortex immaturity included polyrhythmic and decreased frequency (6-7 Hz), of alpha waves, and rhythm driving only in the low frequency range (4-7 Hz). The EEG records of all children in the third, normal, group demonstrated the functional maturity of the cerebral cortex and this result differed significantly from that for the first group ($\chi^2 = 4.91$, $p < .05$).

The EEG records of children in the first and second groups exhibited residual signs of local abnormalities of cortical and deep origin in the form of isolated sharpened waves in the alpha and theta bands. These were noted in 82% of children in the first group and 21% in the second (see Figure 1). Statistical analysis showed that the differences between first and second groups in the rate of occurrence of local EEG abnormalities of deep (and cortical origin were significant ($\chi^2 = 15.868$, $p < .001$ and $\chi^2 = 34.887$, $p < .001$, respectively.) . Local abnormalities of deep origin occurred in 67% of the children in the first group and 13% of those in the second, while local abnormalities of cortical original were found in 15% of those in the first group and 8% of those in the second. In addition, children in the first group were more likely (in 67% of the cases) to exhibit abnormalities in the right hemisphere, and children in the second group were more prone to such abnormalities in the left hemisphere (62% of the cases) (see Figure 2).

Bilateral-synchronous groups of waves in the theta band in the frontal and central regions, which attest to dysfunction of regulatory structures in the upper brain stem, were detected in 64% of the first graders in the first group and 32% of those in the second group (see Figure 1). Children in the third group failed to exhibit such EEG abnormalities. The differences between group three and each of the other two groups with regard to this parameter were statistically significant ($\chi^2_{1,3} = 13.75$, $p_{1,3} < .001$; $\chi^2_{2,3} = 6.50$, $p_{2,3} < .05$).

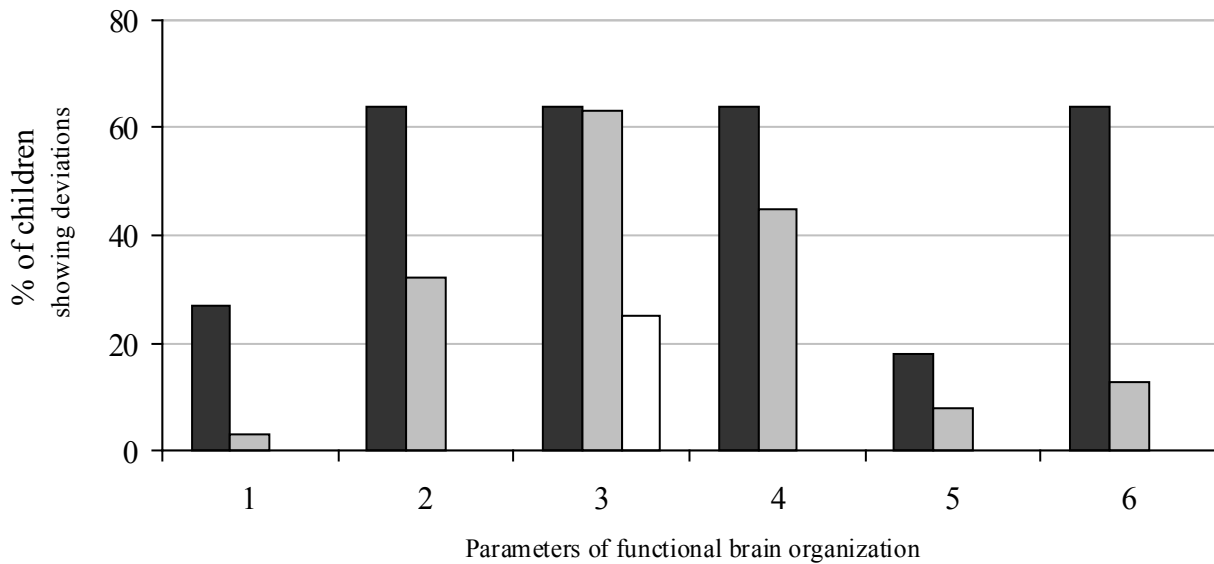Children in all three groups displayed bilateral synchronous abnormalities in electroencephalographic

Figure 1.
Percentage of children with deviations in functional brain organization in groups differing with regard to level of speech maturity.
Key:
1-cortical immaturity; 2 – abnormalities originating in upper brain stem; 3 – abnormalities originating in the lower brain stem; 4 – abnormalities of mesodiencephalic origin; 5 – local cortical abnormalities; 6 – local deep abnormalities.
The data depicted reflect statistically significant between-group differences ($\chi 2$, p <0.05-0.001).
Abscissa label: Parameters of functional brain organization.
Ordinate label: Percentage of children (showing deviations).
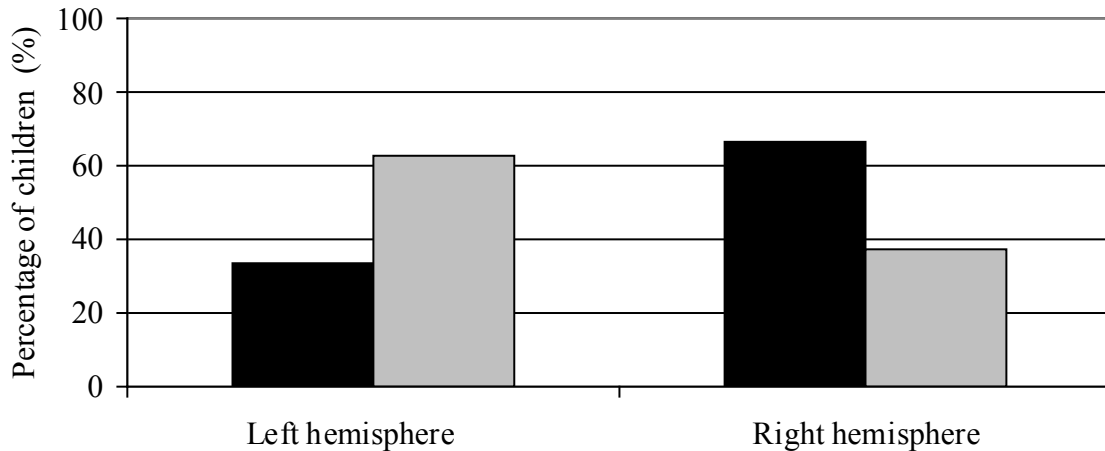

Figure 2.
Percentage of children in each group with local electroencephalic abnormalities in the right and left hemispheres.

activity of mesodiencephalic origin in the form of monophase and biphase sharp waves in the alpha band and isolated sharp waves in the theta band in the parietocentral leads. Such abnormal EEG patterns were seen in 64% of the children in the first group and 45% of those in the second (see Figure 1). The incidence of such mesodiencephalic abnormalities was lower in the third group, occurring in 13% of the cases. The third group differed significantly from both of the other two in this respect ($\chi^2_{1,3}$ = 7.67, $p_{1,3}$ < .01; $\chi^2_{2,3}$ = 5.13, $p_{2,3}$ < .05.)
Indications that the functioning of lower brain stem areas failed to accord with the developmental norm occurred

significantly more frequently in the first and second groups than in the third ($\chi^2_{1,3}$ = 4.03, $p_{1,3}$ < .05; $\chi^2_{2,3}$ = 5.68, $p_{2,3}$ < .05). In the first group 64% of the children exhibited a hypersynchronic alpha rhythm recorded in the occipital and parietal areas, as did 63% of those in the second group and 25% of those in the third.

Discussion

The results of our study have demonstrated that the speech development of children at a particular stage of ontogeny (7-8 years) is not uniform. We identified three groups of children among the first graders of a public elementary school that differed significantly with regard to the maturity of their speech. Analysis of the development of the verbal function showed a significantly higher maturity of speech components in the children of our normal third group (those with a normal level of speech development). The children in the first and second groups (identified as having slight and marked immaturity of speech, respectively) displayed significantly lower maturity levels in the sensorimotor component of speech, deficiency in grammatical aspects of speech and in vocabulary, poor knowledge of the world around them, and inadequate skill in constructing coherent utterances.

Not infrequently children with insufficiently mature speech fail to succeed in school. Speech impairments in school children may lead to failure to understand the utterances, assignments and instructions of the teacher, leading to difficulties learning, which, in the absence of timely remediation, can have a cumulative effect. Developmental delay in speech in children is frequently not the only problem and may well be accompanied by delay in the development of nonverbal functions. However, the integration (mainstreaming) of such children in normal school environments is possible given the opportunity for remediation of abnormalities in higher psychological functions through developmental (adaptive) classes within the school. (Akhutina, 1998; Yastrebova, 2000).

Developmental delays in individual higher psychological functions and sets of functions may be caused by dysfunction of individual neuronal structures, disrupting the productive functioning of the entire CNS (Mikadze & Chursina, 2002). Through visual structural analysis of EEG records, we identified reliable differences in parameters of maturity in brain functioning among the groups of children in our study. Functional immaturity of the cortex detected in children of the first and second groups may additionally diminish

vocabulary, information and understanding of the world. The EEG records of children in the first two groups showed signs of minor local electroencephalographic abnormalities of cortical and deep origin in the form of individual sharp waves in the alpha and theta bands. In the first group the predominant local changes occurred in the right hemisphere and in the second group in the left one. The initial stages of speech development are known to proceed under enhanced control and with the direct participation of the right hemisphere (Rivina & Levontina, 2001; Fishman, 2001). In all likelihood, the prevalence of local changes in the right hemisphere in children of the first group is the reason for the greater abnormality they show in the development of the structural components of speech. The left hemisphere contributes the analytic, logical, verbal processing of verbal information, enabling mastery of the complex semantic and grammatical forms of language (Luria, 1968; Rivina & Levontina, 2001; Fishman, 2001). The prevalence of local electroencephalic abnormalities in the left hemisphere in children in the second group, in all likelihood, is associated with difficulties in the analysis of complex grammatical constructions and semantic processing of verbal input. This is corroborated by the results of analysis of the maturity of various speech components.

Indications of immaturity of the fronto-thalamic system, mesodiencephalic structures and systems of nonspecific activation were observed significantly more frequently in the first and second groups. According to modern concepts in neurophysiology, dysfunctions in the fronto-thalamic system cause lack of maturity in voluntary regulation and performance of actions, including speech acts (Fishman, 2001; Semenova, Machinskaya, Akhutina, & Krupskaya, 2003). This may lead to inadequate voluntary regulation and organization of speech performance and perception, distorting the (required) focus of attention on the perceived word and determination of its semantic meaning.

EEG indicators of functional immaturity of mesodiencephalic origin are associated with enhanced activity of synchronizing structures and of the midbrain. As the literature notes, mesodiencephalic structures are closely linked with support of memory processes (Grigorjeva, 2002; Luria, 1973). According to neuropsychological models, analysis of the acoustic and (concomitant) articulatory features of speech sounds, as well as of the visual and spatial-visual parameters of letters occurs at the gnostic-praxic[1] level of the speech system. This is associated with memory for words at as acoustic-articulatory and visual

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[1] Translator's note: "gnostic-praxic" is A.R.Luria's term for the presemantic apperception of linguistic stimuli involving recognition and internal representation of the physical components /including proprioceptive representation of associated articulatory movements/ of the speech or written signal. The term "gnostic-praxic" has been widely used in English also in the book of Tatyana B. Glezerman, Victoria I. Balkoski (1999): Language, thought and the brain. New York: Kluwer Academic.

graphic complexes, i.e., the gnostic-praxic level may support mechanical (without understanding) repetition of speech and copying of text (Glezerman & Dmitrova, 1989). The gnostic-praxic level of speech, along with memory processes, plays a decisive role during the early stages of speech development. Thus, dysfunction of the mesodiencephalic structures, affecting memory processes and the gnostic-praxic level of speech may be responsible for the lower developmental level of the speech functions in children of the first and second group.

Electrical abnormalities originating in the lower brain stem attest to a decrease in activating influences from regulatory formations of the *medulla elongata* and *pons,* resulting in increases in synchronizing influences coming from rhythmogenic structures of the thalamus. Dysfunction of the structures in the lower brain stem may weaken overall activation and diminish level of nonspecific attention with a negative effect on the development of the speech function.

Thus, the abnormalities found in the functioning of the neuronal ensembles of the cortex, regulatory brain systems at various levels and the presence of local abnormalities in EEG patterns are important factors determining the severity and specific features of impairments of the speech function. Considering the level of severity of speech impairments and the possibility of remediating them, it should be noted that the children of the first and second group require more comprehensive study of psychophysiological status, the results of which should define the basis for individual remedial educational programs.

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