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Influence of Neuropsychological Development of Children on Their Verbal Abilities

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Abstract

Learning disabilities in childhood are often caused by certain delays in language and higher mental functions development. So nowadays comprehensive research of child language development and its neuropsychological base is of great demand. The objective of the present study was to discover relationships between children's age, certain characteristics of speech production, neuropsychological and neurolinguistic development. 126 students (51 first-graders and 75 second-graders) were recruited. They underwent complete neuropsychological assessment along with the trial "Creating a Story based on the series of pictures". The results show that age is an important factor of neuropsychological development from the first to second grade. It concerns especially frontal lobe development. Neuropsychological development also correlates with neurolinguistical level: children who are better at programming and control, analytic and holistic strategies would be more successful in the trial "Creating a Story based on the series of pictures", their speech would be more correct lexically as well as grammatically and syntactically. We also show that speech particularities and their correlation with neuropsychological indexes would vary in first- and second grades.

Keywords: Lurian neuropsychology; child neuropsychology; neurolinguistics; neuropsychological development; Creating a Story based on the series of pictures; speech.

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1. Introduction

The correlation between cognition and language functions or more generally between language and consciousness, language and brain is one of the most relevant issues in science [4, 5]. This problem has always been quite multifaceted and thus considered in many different fields of knowledge: philosophy, linguistics, cognitive science, etc.

Nowadays the school neuropsychology which aims to solve the problem of learning difficulties becomes widely recognized [14]. T.V. Akhutina and N.M. Pylaeva [3] distinguish three main types of learning disabilities:

1. Difficulties in developing academic skills in children with predominant weakness *in programming and control of actions and serial organization* of movements.

2. Difficulties in developing academic skills in children with predominant weakness in the analytical (left-hemispheric) strategy of *processing auditory and kinesthetic information* (and in some cases also visual information).

3. Difficulties in developing academic skills in children with weakness in the *holistic (right-hemispheric) strategy of processing visual, visual-spatial, and auditory information*. [3]

Thus there are three main factors involved in the successful development of academic skills: development level of frontal lobes, right- and left-hemispheres.

Also it was shown that there is a strong correlation between child language development and learning disabilities [16] or, since speech is a higher mental function, between learning disabilities and development of higher mental functions [2, 13, 20].

Main stages of early language development in children up to 5 years old are well known [7, 10]. But the question of language development for schoolchildren, especially in Russia, is less elaborated. First of all language development concerns reading skills and vocabulary growth [19] or word acquisition [15]. But also it is grammar development. In linguistics grammar includes morphology and syntax. So grammar development supposes morphological and syntactic skills acquisition. As English is an analytical language, the syntax acquisition is a more important factor for good language skills. So most of the research papers starting with the famous "Aspects of a Theory of Syntax" and "Syntactic structures" by N. Chomsky [8, 9] concern syntactic development [18].

In Russia T.V. Akhutina showed that comprehension and production of various syntactic structures are good predictors of neurolinguistic development [3].

2. Methodology

Our main goal was to discover how certain characteristics of speech production (particularly syntactic complexity) and the level of children's neurolinguistic development correlate with their age.

Our principal tasks were:

- to reveal how neuropsychological and neurolinguistic indices vary according to child's age;

- to study how the neuropsychological functions development affects neurolinguistic and linguistic measurements obtained during the trial "Creating a Story based on the series of pictures" for the groups of first- and second-graders.

Our principle hypotheses:

1. Neuropsychological development would correlate with neurolinguistical level: a child would be more successful in the trial "Creating a Story based on the series of pictures".

2. Among neurolinguistic indices there would be three that a) intercorrelate; b) correlate with the production of complex and correct speech (assessed according to neuropsychological and neurolinguistical parameters). They are indices of a) programming and control of voluntary actions, b) development of left-hemisphere functions (analytic strategy) and c) development of right-hemisphere functions (holistic strategy). Children who are better at programming and control, analytic and holistic strategies would be more successful in the trial "Creating a Story based on the series of pictures", their speech would be correct lexically as well as grammatically and syntactically.

Participants

A total of 126 participants were recruited from 3 Moscow schools. All the children belonged to two groups: first and second-graders.

- The group of first-graders included 51 children, aged in average 7.5 years (standard deviation, SD, 0,41).

- The group of second-grades included 75 children, aged in average 8.8 years (standard deviation, SD, 0,29).

None of them had mental retardation, psychotic symptoms, brain lesions, auditory difficulties or comorbid dyslexia.

All the children went through complete neuropsychological assessment [3], in particular they composed a story based on the series of pictures "Garbage" by Bidstrup.

The trial was made orally and the story was recorded (by the voice recorder in iPhone 4s) and transcribed with indications of time, pauses etc.

Then the texts produced by children were assessed by a number of neurolinguistic and linguistic parameters.

Neurolinguistical parameters were taken from "Methods of neuropsychological assessment" [1]. They included: semantic completeness, semantic adequacy/inadequacy, serial organisation, grammar correctness, length of a story, an average length of a phrase, lexical correctness, number of grammar mistakes (paragrammatisms), number of sentences and phrases, time of speech production and speech tempo etc.

Linguistical parameters were indices of syntactic complexity taken from [6, 10-12, 17]. They included: frequency of phrases with inversion of subject and inversion of adjectives and objects, quantity of compound verbal predicates, frequency of passive voice phrases (among them reflexive verbs) and some indexes.

The obtained results were proceeded by tools, developed in the laboratory of the neuropsychology of psychology department (MSU) and described in "Methods of neuropsychological assessment" [1]. The score depends on the number of mistakes made (the more mistakes are made, the higher is the score). So the higher index matches the lower level of function development. The value below zero corresponds to the well-developed function.

3. Results

3.1. Influence of age on the success in execution of speech subtest

The analysis showed that second-graders were more successful than first-graders. Second-grade students showed a tendency to compile more detailed stories (length of stories told by the first-graders - 21.9 ± 8.9 words, by the second-graders - 23.2 ± 6.5 words). Significant differences were obtained on measure the "semantic completeness" (the mention of the key elements of the story in the storyline): the average for first-grade students is 14.1 points, for second-graders is 17.5 ($z= -3.476$, $p <0.005$, U–test).

To the further assessment how the age and the stage of education affect the neuropsychological parameters of the trial "Creating a Story based on the series of pictures", we divided the children into groups ("high", "medium", "low") by the index of the formation of executive function.

Evaluation of the differences between the first and second grades in three subgroups revealed that children from the high subgroup showed significant differences only in the measuring data of the semantic completeness ($z= -2.485$, $p=0.013$, U–test). The greatest differences were observed in groups of children with a low level of

development of executive function (lengths of sentences (z= -2.796, p =0.005, U–test), quantity of complex sentences (z= -3,068, p=0,002, U–test), semantic completeness (z= -2.988, p=0.003, U–test), semantic adequacy in the left hemisphere type (z= -3.425, p=0.001, U–test), programming of stories (z= -3.273, p=0.001, U–test)).

3.2. Effect of the level of formation of neuropsychological mechanisms on the success in execution of speech subtest

3.2.1. The index of programming and control (executive function)

We identified three groups depending on the level of this index: "high", "medium" and "low". The "high" and "low" subgroups of first-graders and second-graders are compared further. A similar procedure was performed to differentiate subgroups by the indices of left-hemispheric and right-hemispheric functions.

Children from the "high" subgroup create more complete in content stories (z= -2.017, p=0.044, U–test), they had fewer errors in the type of inadequacy due to the weakness of the left hemisphere (z= -3.298, p=0.001, U–test), the stories were better programmed (z= -4.670, p<0.001, U–test) and grammatically arranged (z= -3.362, p=0.001, U–test), contained fewer paragrammatisms (z= -2.219, p=0.027, U–test). They more often used complex sentences (z= -3.219, p=0.001, U–test), and built more detailed sentences (length of sentences by the number of words (z= -3.379, p=0.001, U–test)). Significant differences were obtained only with respect to the parameter "the quantity of predicate inversions" (z= -2.131, p=0.033, U–test) and "the frequency of predicate inversions" (z= -2.072, p=0.038, U–test) among the neurolinguistic parameters of the task.

There was a different upshot in the second grade: children with a high index of programming and control functions create better programmed (z= -2.333, p=0.020, U–test), better grammatically (z= -2.705, p=0.007, U–test) and lexically arranged (z= -1.973, p=0.048, U–test) stories and at the same time used more compound verbal predicates (z= -3.469, p=0.001, U–test) and reflexive verbs (z= -2.537, p=0.011, U–test) (their frequency also differed significantly z= -3.100, p=0.002 and z= -2.537, p=0.011, U–test).

3.2.2. The left hemispheric strategy index

In analysis the productivity of creating story trial of subgroups of children that differ in the left hemispheric strategy index we observe similar flexibility and dynamism of links with the above described. There also considered the "high" and "low" subgroups of children in terms of the quantitative measure of the strategy index.

The group of first-graders with a high index of the left hemisphere strategy significantly differed from the children who demonstrated a low index by the semantic completeness (z= -2.518, p=0.012, U–test), semantic adequacy in the left hemisphere (z= -2.366, p=0.018, U–test) and right hemisphere types (z= -2.634, p=0.008, U–test), programming (z= -2.983, p=0.003, U–test) and grammatical arrangement of the story (z= -1.995, p=0.046, U–test), the number of complex sentences (z= -2.713, p=0.007, U–test) and the number of words in the sentence (z= -3.254, p=0.001, U–test), by the number of predicate inversions (z= -2.575, p=0.010, U–test) and the frequency of the predicate inversions (z= -2.719, p=0.007, U–test).

Among the second graders analogical subgroups demonstrated significant differences in performing other parameters. It was the quantity of inversions of the predicate (z= -2.643, p=0.008, U–test) and the quantity of other members of a sentence inversions z= -2.519, p=0.012, U–test, as well as their frequency (z= -2.800, p=0.005; z= -2.391, p=0.017, U–test).

3.2.3. The right hemispheric strategy index

Subgroups of first-graders with different level of formation of the right hemisphere strategy distinguish significantly only in neuropsychological parameters: the programming of the story (z= -2.375, p=0.028, U–test), the grammatical arrangement (z= -2.181, p=0.029, U–test) and the number of words in the story (z= -2.055, p=0.040, U–test). Second-graders also showed differences in the number of words in the story (z= -2.117, p=0.034, U–test), as well as in the number of compound verbal predicates (z= -2.049, p=0.041, U–test) and in the parameter situationality of the utterance (z= -1.965, p=0.049, U–test).

4. Discussion

4.1.

The analysis showed that the factor of school-grade turns to be significant: it clearly shows notable improvement in subtest performing primarily for children from the low executive function subgroup. This can be regarded as a result both of the functional maturation of the cerebral cortex and of schooling.

4.2.

Analysing the index of programming and control (executive function) we identified three groups depending on the level of this index: "high", "medium" and "low". The links between the formation of programming and control functions and various components of expressive speech were not strictly determined. The instability of relations can be caused by the complexity of the speech system: the various aspects of speech will develop primarily at various stages of the ontogeny of a child. And if in the first form the relative lack of coordination of the executive function predominantly affects the development of the semantic aspect of narrative (parameters "semantic completeness" and "semantic adequacy"), then in the second form it affects directly on the development of syntax and vocabulary (lexical arrangement parameter, quantity and frequency of composite verbal predicates and quantity and frequency of reflexive verbs). At the same time, several parameters (programming and grammatical correctness) are sensitive to the weakness of the programming and control functions both in the younger and in the older age groups. Presumably, these indicators reflect the late developing components of the speech statement, so children from the low subgroup continue to lag the high group of their peers.

4.3.

In analysis the productivity of creating story trial of subgroups of children that differ in the left hemispheric strategy index we observe similar flexibility and dynamism of links with the above described. There also considered the "high" and "low" subgroups of children in terms of the quantitative measure of the strategy index.

4.4.

First-grade students with a high level of the holistic (right hemispheric) strategy created more well-programmed and more grammar correct stories (lower score is more successful performance, it shows smaller penalty points); second-grade students had the same tendency, but there were no statistically significant differences. This may be due to the high level of correlation between the index of the right hemisphere strategy with the index of programming and control in a sample of first-graders.

There were obtained similar results for the number of words in a story in the first and second grade: children with a well-formed right hemisphere strategy made longer stories.

Thus, the analysis of influence of the level of formation of neuropsychological mechanisms on the success of the creating story trial showed the dynamism in the development of the links between the formation of the programming and control functions, the analytic and holistic strategy, and various indices of the monologic speech utterance in children. The students of the first grade have more diffusive connections, in second grade we see a great differentiation. In this group the level of the formation of the programming and control functions had a greater influence on the neuropsychological parameters of the trial assessment, as well as on the quantity and frequency of use of compound verbal predicates and reflexive verbs; the level of formation of analytical strategy affect the quantity and frequency of predicate inversions and inversions of other members of the sentence; the level of formation of the holistic strategy affect the unfolding of the story (the number of words) and the situationality of utterance.

5. Conclusions

Age is an important factor of neuropsychological development for primary school students. The programming and control functions develop at the higher rate, the other functions also show significant dynamics. For the first-graders complex cortex functional immaturity is characteristic, for the second-graders partial deviations in the development of neuropsychological functions are characteristic.

Neuropsychological development affects the neurolinguistical level: first-graders made more mistakes when creating a story on a series of pictures, especially children with a low level of formation of the executive function.

Children who are better at programming and control, analytic and holistic strategies are more successful in the trial "Creating a Story based on the series of pictures". But for

first- and second grades there are different links between neuropsychological indices and speech particularities. To sum up, we found out the following patterns.

Development of *right-hemisphere functions* (holistic strategy) influences the number of words in the story for all children, and for second-graders influences the situationality index of the utterance.

Development of *left-hemisphere functions* (analytic strategy) influences the number and the frequency of predicate inversions in both grades. In the second grade it also influences the number and the frequency of adjective and object inversions.

Functions of programming and control of voluntary actions influence the greatest amount of speech particularities. They are: programming and grammatical arrangement of the text for all children; compound verbal predicates and frequency of compound predicates, reflexive verbs, and frequency of reflexive verbs for secondgraders. For the first graders there are some parameters that depend both on executive function and left-hemisphere function: semantic completeness, semantic adequacy in the left-hemisphere type, length of sentences, complex sentences, predicate inversions and frequency of predicate inversions. We think that it is in accordance with the data about complex cortex functional immaturity and maturity recieved for the first-graders.

The task of future research is to check the obtained regularities in a longitudinal study.

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