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The characteristics of language development and executive functioning in pre-schoolers (neuropsychological aspect)

Kseniya R. Grishchenko [1] **- Maria S. Kovyazina** [1,2] **- Nikita A. Khokhlov** [1,3]

[1] *Department of Psychology, Lomonosov Moscow State University, Moscow, Russia*

[2] *Department of Neurorehabilitation and Physiotherapy, Research Center of Neurology, Moscow, Russia*

[3] *Scientific and Methodical Department, Centre for Testing and Development "Gumanitarnye Tekhnologii" [Humanitarian Technologies], Moscow, Russia*

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ksegrishchenko@gmail.com

ABSTRACT

Significant differences in language and self-regulation skills exist among children when they enter school. Yet, the relationship between these functions is still not fully understood. This study explored bidirectional associations between language development and executive functions in preschool period. 124 children from 4,8 to 6,5 years old participated in the research. Seven neuropsychological tests were given to estimate the level of language development: The Picture Naming test, Naming of Actions, ULGC, Text Comprehension, USSW, Story Production and VFT. DCCS and SR were used to assess executive functions. An exploratory factor analysis was conducted to verify the hypothesis for a correlation between language development and executive functions. Unexpectedly, a zero correlation was found with cognitive flexibility. Verbal working memory was only associated with different parameters of story production task. Based on these results, it can be concluded that language and executive functions develop independently in preschool period.

Keywords: child neuropsychology; language development; preschool; executive functions

1. Introduction

Preschool period arouses a lot of interest. Most children make a significant progress in language development and executive functioning. This can be explained by the following. The neural organization of cortex actively changes. According to electrophysiological studies the functional interaction between frontal and parietal associative cortex as well as between hemispheres notably increases at the age of 4-8 years old (Semenova & Machinskaya, 2012). Neuropsychological assessment of 5-7-years-olds showed that most notable changes appear in self-regulation. Besides, executive functions, visual perception and language are closely related (Semenova & Machinskaya, 2012). Psycho-pedagogical research showed that during the preschool period the planning function of language and the ability to choose proper language means for a particular communicative situation significantly develop (Loginova, 2007).

At the same time, a research using fMRI showed that the number of connections in the left temporal gyrus increases between 5 and 6 years old. The greatest changes are observed in children with the highest progress in language development. In this period left frontotemporal pathways are actively formed, which correlate with the development of the receptive language (Xiao et al., 2016).

A number of researchers indicate the existence of a correlation between language and executive functions (EF) development in the preschool period (Blair, 2003; Carlson et al., 2004; Lang & Perner, 2002; Muller et al., 2005; Perner et al., 2002; Roebers & Schneider, 2005). However, language is mostly assessed using measures of verbal ability, particularly receptive vocabulary knowledge. At the same time, phonematic awareness, syntax, semantics are not considered. For this reason, other aspects of language differentially related to executive functions remain obscure.

According to the concept of Miyake, executive functions include working memory, cognitive flexibility and inhibition (Miyake et al., 2000; Lehto et al., 2003). The highest positive correlations are found between receptive vocabulary and the DCCS test (Hongwanishkul et al., 2005; Lang & Perner, 2002; Muller et al., 2005; Perner et al., 2002), as well as those between working memory and verbal ability (Davis & Pratt, 1995; Keenan, 1998). The findings regarding the relation between measures of inhibitory control and verbal ability are mixed (Carlson et al., 2004; Perner et al., 2002). Inhibitory control is not a unitary construct (Friedman & Miyake, 2004) and different aspects of it may be differentially related to verbal ability. In some research no correlation between inhibition and speech development was found (Akbar et al., 2013).

Different approaches were used to assess the relationship between

language and executive functions. For example, some researchers included speech directly in cognitive flexibility task performance (Muller et al., 2004, 2008; Jacques & Zelazo, 2001). Zelazo and colleagues (2003) showed that the majority of 4- and 5-year-olds perform correctly in the post-switch phase of DCCS. At that time speech becomes an instrument for self-regulation. A number of researchers explored the effect of labelling on the DCCS task performance. For example, Kirkham and colleagues reported that labelling significantly improved performance of the post-switch phase (Kirkham et al., 2003). In another experiment the Flexible Item Selection Task (FIST) was used to examine the influence of language on executive functions (Jacques & Zelazo, 2001). Results indicated that 4-year-olds performed better when labelling was introduced. At the same time performance of 3- and 5-years-olds was not affected. Another research showed that the number of correct decisions in DCCS test negatively correlated with the number of statements per minute. It means that EF performance in childhood is linked to the internalization of private speech (Alarcón-Rubio et al., 2014).

In another approach the bidirectional relation between expressive vocabulary and self-regulation was explored (Bohlmann et al., 2015; Skibbea et al., 2019). A longitudinal 2-years study of 250 children established that language and executive functions develop simultaneously within the preschool period. Between the age of 3- and 6-years children show increased ability to attend to activities and to inhibit inappropriate behaviour. Study findings provided initial evidence for a bidirectional relation between self-regulation and English expressive vocabulary. Children who had a good self-regulation ability tended to make larger gains in expressive vocabulary (Bohlmann et al., 2015).

A more detailed research showed the way that early, intermediate and late development of self-regulation predicts the development of such aspects of language as phonemic awareness, reading comprehension, decoding and expressive vocabulary. 350 children were assessed two times a year during four years from preschool to second grade. An earlier development of self-regulation leaded to higher indicators for decoding and reading comprehension but not to faster development. Furthermore, children with early development of executive functions had higher characteristics of expressive vocabulary, than children with intermediate or late development of EF (Skibbea et al., 2019).

Interesting findings were obtained when studying the influence of vocabulary and mathematical language on executive functions development (Schmitt et al., 2019). Mathematical language includes complicated forms of language and abstract terms (more, less, as many, etc.). It has two specific aspects: quantitative and spatial. The first includes such terms as “more”, “less”, “many” and the second - “behind”, “before”, “near” and allows to describe spatial relations between objects. A study of 558 children showed that

vocabulary was a significant predictor of EF at the end of preschool (Schmitt et al., 2019). When mathematical language was added into the models, it became a more significant factor. Therefore, mathematical language skills are associated with gaining higher levels of EF during the preschool period. Children who had high language development in the first testing obtained better results in executive functioning six month later.

Finally, Akbar and colleagues (2013) examined language skills and executive functions in 62 children with autism. They assessed four specific domains of EF: Working Memory, Organization, Shifting and Inhibition. The analysis showed that language skills bring about 62% of working memory development. Structural and pragmatic language ability were associated with working memory, nonverbal cognition with Organization and autistic symptom severity with Shifting (Akbar et al., 2013).

Summing up, numerous researches report a specific connection between language and executive functions development. However, results are contradictory. Some authors analyze only expressive vocabulary (Bohlmann et al., 2015) or only the receptive characteristics of language in disregard of the expressive language (Schmitt et al., 2019). The current study aim was to explore the relation between cognitive flexibility and verbal working memory with different aspects of language (phonemic awareness, understanding of logical grammatical structures, reading comprehension, verbal fluency and story production) in the preschool period.

2. Methods

2.1 Sample

The study included 124 children from 58 to 76 months old (M = 68; σ = 3,6). All of them studied in the last year of preschool in Moscow. The sample was comprised of 72 males and 53 females. The parents of preschool children gave their written informed consent for their children's participation in the study. Only children without psychological disorders were included. It was controlled by the preschool psychologist.

2.2 Procedure

Participants were administered a neuropsychological assessment, matched to developmental level, levels of language and executive functions. The assessment was conducted individually in the second half of the schoolyear, in a quiet

room. The parents gave their written consents for their children's participation in the study. The procedure was approved by the Board of Ethics, Faculty of Psychology, Lomonosov Moscow State University.

2.3 Language measures

Six different measures were used to assess language development. All of them were developed in the Laboratory of Neuropsychology in Lomonosov Moscow State University. Different aspects of language can be assessed using these tests.

- The *Picture Naming* subtest of the WPSI (2006) (Rzhanova et al., 2018) and the *Naming of Actions* (Akhutina, 2016) were used as an index of nominative function and expressive vocabulary development. Children were asked to name 18 pictures of objects and 15 pictures of actions. Each correct answer scored one point. These tasks included such parameters as number of right answers, verbal perceptual replacements, refuses, distortions and word combinations.
- *Understanding of Logical Grammatical Constructions* (ULGC) (Akhutina, 2016) includes two different tasks. The first allows to examine the children's understanding of active and passive constructions. A child is shown a pair of pictures, one of which matches the instruction. For example, one picture contains a newspaper covered by a book and the other – a book covered by a newspaper. The instruction is "Show me where a newspaper is covered by a book." In the second task a child is given six pictures at the same time with different positions of barrels and boxes. The instruction can be, for example, to show where the barrel is behind the box or where the box is on the barrel. The number of correct answers was counted in each of two measures.
- *Text comprehension (TC)* (Akhutina, 2016) and its retelling allows to assess coherent speech, the capacity to understand and to memorize voice information (auditory information processing), to listen attentively and to distinguish the main idea (programming and control), to draw up the retelling plan (serial organization of speech). This task required participants to listen to the fable of L.N. Tolstoy "The jackdaw and the pigeons" and to retell it. If a child could not do it, the text was read again (no more than three times). Time of the retelling and the number of words was recorded. The analysis of Text comprehension included proximity to the original text and idea understanding.
- *Understanding of Similar Sounding Words* (USSW) (Akhutina, 2016) was referred to phonemic awareness and auditory verbal memory

assessment. Ten pictures of objects, which names sound similar, were used. At first, children were asked to name all of them to be confident that they know these words and pronounce them correctly. Then series of words were pronounced clearly without pauses. Children were required to show them silently in the same order. The number of items increased gradually from two to six. The task ended when mistakes were made in three series in a row. It included such parameters as the number of correct answers, replacements by similar-sounding words, replacements by dissimilar-sounding words, omissions, extra words, duplication and word disorder.

- *Story Production (SP)* (Akhutina, 2016) based on story pictures is another measure of coherent speech. It allows to assess the capability to construct phrases and logical grammatical comprehension. A child was shown two series of story pictures, called "The Tower" and "The cat and the dog". Additionally, a story picture called "The cup" was given. The child was asked to make a story based on the picture. Time of speaking and number of words were recorded. Proximity to the original text and idea understanding were assessed as well.
- *The Verbal Fluency Test* (VFT) (Akhutina, 2016) was used to assess word actualization process and verbal fluency. In total there were three types of tasks: free associations and two series of directed associations. In the first one a child is asked to give as many words as possible within a minute. In the second task he or she is required to name actions in a minute, in the third – to name animals. This task was given at the end because word actualization excessively tires 5- and 6-year-olds. To assess The Verbal Fluency Test five parameters were introduced: productive associations (corresponding to the instruction), repetitions, inadequate and generalized associations, word combinations.

2.4 Executive functioning measures

Numerous researches report a connection between working memory, cognitive flexibility and language. Therefore, two measures were used to assess executive functions:

- *The Dimensional Change Card Sort (DCCS)* requires to sort a series of bivalent test cards, first according to one dimension (e.g. color), and then according to the other (e.g. shape). DCCS included three parameters: result before switching, after the first switching and after the second switching.
- *A subtest of the NEPSY-II Sentence Repetition (SR*) allows to assess

verbal working memory. A series of sentences was read to a child, who was asked to repeat it immediately. Gradually the task gets more complicated. Each correct repetition scores two points, with one or two mistakes – one point, more than two – zero points. The main index for working verbal memory was the total score.

Overall, 55 parameters were obtained and included into factor analysis.

2.5 Data analytic methods

Statistical programs JASP 0.8.5.1, SPSS 23.0.0.0, R Studio 1.1.463, Microsoft Excel 16.16.15 were used for data analysis. The sample was divided in two equal groups. The first group included children from 58 to 68 months, the second – from 68 to 78. Percentile standardization was used for each group. Accordingly, data was transferred from the ordinal scale to the interval scale.

Exploratory factor analysis using the minimal residual method, parallel analysis and orthogonal rotation (varimax) indicated that 20 factors are needed to explain 76% of variation (RMSEA < 0,1). To reduce dimension the Kaiser criterion was used. As a result, 8 factors explaining 47% of variation were distinguished. Additionally, the results were verified with the Holm's method for multiple comparisons.

3. Results

Variables of the cognitive flexibility (*DCCS*) did not correlate with anything, as well as logical grammatical constructions, word distortions in *The Picture Naming* and the *Naming of Actions*, different mistakes in the phonemic awareness task. The verbal working memory was included only in one factor.

The first factor included such variables as phonemic awareness productivity and four parameters of *Text retelling*: idea understanding, proximity to the original text, time and number of words. All of the parameters of the text "The cup" formed the second factor and parameters of the text "The tower" – the third factor. The fourth factor included word combinations, replacements and incorrect answers in the *Naming of actions*.

The next factor was composed by the number of correct answers in The *Picture Naming* task, the productivity of free associations and repetitions, as well as the productivity of directed associations. The sixth factor included the verbal working memory total score and the proximity to the text and idea understanding in the story "The cat and the dog". Three variables of directed associations: productivity, repetition and word combinations composed the

seventh factor. Finally, the last factor comprised the incorrect answers, refusals and word combinations in the *Picture Naming* task.

4. Discussion

Unlike similar research (Veraksa et al., 2018) our results showed that executive functions are not connected with language development or have a weak correlation with it in the preschool period. Furthermore, not all the constituent elements of the language function are related between themselves, that proves its complicated organization.

The strongest correlation is revealed between phonemic awareness and different variables of the Text comprehension task. This factor was called "The receptive language". Apparently, the ability to understand a text and to make complete coherent statements depends on the exactness of speech comprehension and auditory verbal memory development. These results match the theory of Lapshina about the stages of the formation of receptive language (Lapshina, 2010).

The second factor unites variables of one task – Story production based on the picture "The cup". When assessing text comprehension, one of the most important characteristics is the understanding of the whole situation. Therefore, we can speak about the factor of simultaneous perception. At the same time, the next factor includes variables of another text – "The tower". In this case, children have to initially determine the order of the events. Consequently, this factor is related to the successive perception. It demonstrates that story production depends on the appropriate way of visual perception.

The fourth factor is related to difficulties in the Naming of Actions. If this task is difficult for a child, then word combinations, incorrect answers and verbal perceptive replacements start to dominate. Probably, this factor is related to the premotor cortex according to the theory of systemic dynamic localization of higher mental functions of Luria (Luria, 2003).

Free and directed associations formed the fifth factor. On the one hand, it represents the expressive vocabulary of the child. On the other hand, it demonstrates the ability to actively extract words and to distinctly choose words referring to one lexical semantic group in the case of the second and the third task. Some authors suppose that this method already contains the assessment of executive functions, particularly, the first two tasks (Fotekova, 2008).

The sixth factor reveals the relations between language development and executive functions to the greatest extent. It demonstrates correlation among different variables of story production based on picture "The cat and the dog" and

the verbal working memory. We can suggest that working memory inclusion as an executive function parameter in this case is related to the necessity of simultaneous perception of the whole situation and the sequence of pictures.

The next factor represents the ability of verb nomination. It contains three variables of the second series of directed associations. It should be noted that this task is the most difficult for children. In the first series children name 16,7 words on the average, in the third – 11,9, while in the second only 7,7. In addition, productivity of the second series is closely related to word repetitions and combinations. It is possible that verb actualization request more self-regulation and efforts in preschool years.

The last factor shows nominative function deficit: incorrect answers in noun nomination, refuses, word combinations. Such difficulties can be connected with expressive vocabulary deficit. Furthermore, in this task children are requested to choose one appropriate word from a complex of connections.

Summing up, we obtained eight factors describing the structure of the language function in the preschool period. The major components are general language comprehension, simultaneous and successive perception of language, expressive vocabulary, noun and verb nomination. We suppose that in primary school this structure can change and become wider.

There was no correlation revealed between DCCS results with language development which contradicts with findings of Muller (2004), Kirkham (2003) and Zelazo and colleagues (2003). This discrepancy can be explained. In the foregoing research labeling was directly included in DCCS performance. It regulated the child activity and consequently improved task performance. In the recent study language and executive functions were assessed separately. Accordingly, results turned out to be different. Contrariwise, it is possible that there is no correlation between these functions only in preschool period. They can become more integrated due to growing up and cognitive development.

5. Conclusions

The recent study showed that language development is not related to executive functions in preschool period. A significant correlation was revealed only with verbal working memory. Eight different factors describing the structure of language in preschool period were reported.

This study is the first part of a 3-year longitudinal study. It is planned to reassess children in primary school to see how the structure of language and its connection with executive functions are changing.

5.1 Limitations

The children's executive functions were not fully analysed in our study. For example, we did not assess inhibition. Furthermore, our sample included 124 children whereas it should be minimum 250 for a factor analysis.

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