

### Advanced Neuroimaging Techniques to Investigate the Impact of Bilingualism on Brain Structure

**Maftuna Qodirova Davronovna**

EFL teacher at UzSWLU, Tashkent, Uzbekistan

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#### ABSTRACT

*The article deals with the problem of the influence of bilingualism and multilingualism on the structure of the brain in the aspect of studying advanced methods of neuroimaging, which is especially important for children from international families. The paramount importance of the method of learning a second language and the age of learning languages is emphasized. The author gives an example and, based on the analysis, comes to the conclusion that for the formation of bilingualism, a clear separation of the language of communication at home and at school / kindergarten is necessary, when two full-fledged language environments that are vital for the child remain for a long time.*

If in a linguistically homogeneous (monolingualistic) society, the mother language is the only and natural means of social communication for the child, children of immigrants, children from international families, whose number in modern society is very large in all developed countries, constantly face the problem of choosing a language for the current situation of communication, as well as the need for imperative assimilation and improvement of a new language of communication. Mastering a second language involves the formation of a new functional speech system based on the already formed functional system of the first language, if two languages are acquired sequentially.

The underdevelopment of some functions in the native language is systematically reflected in the development of similar functions in the second language. It is also important that the time of assimilation of each of the languages corresponds to a different level of maturation of the brain and the formation of cognitive functions, which cannot but affect the brain organization of the functional system of each language. Of paramount importance is the way in which a second language is learned. "The method of learning (formal, organized assimilation) or mastering (more or less spontaneous way through communication) a new language becomes essential for neuropsychological analysis, since it determines what are the leading sensory channels for entering information and, accordingly, the brain areas involved in the implementation processes in a second language. Thus, the method of assimilation to a certain extent affects which components will be involved in the construction of a new functional system.

The method of language acquisition can also be reflected in varying degrees of formation of various speech functions: oral speech, writing, reading. So, with the direct method of involuntary comprehension of the language in a living language environment, speech understanding is ahead of the skills of expressive speech, with formal voluntary learning, as a rule, expressive speech is

better than understanding. The formal or direct method of learning a language affects the features of the semantic system of speech and the nature of speech generalizations: with the direct method, the word is initially mastered in only one meaning and understanding of a specific meaning goes from the general meaning of a text or phrase to a particular meaning. This creates certain difficulties for the formation of categorization processes. With the formal (logical) method, the word is immediately assimilated as polysemantic, and the formation of the phrase goes from the particular meaning of individual words to the general meaning of the phrase.

But the age of learning languages is also important. Parallel acquisition of languages in the first three years of life leads to an uneven development of each of the languages and a delay in the development of speech, at least in one of them. Knowledge of languages is extremely unstable, a few days without one of the languages are enough for the child to forget this language. S. Walter and R. Leue believe that up to three years of age children mix languages and only at the fourth year begin to differentiate them. It can be assumed that the brain of a child under three years of age is not ready for the development of bilingualism. Optimal for the formation of full-fledged bilingualism is the initial formation of one functional language system to the level of phrasal speech, followed by the parallel assimilation of both languages in two different communication environments: at home they speak only one language, and in the nursery and school - in another, or (in multinational families) with the father only in his native language, and with the mother in her native language. For the formation of bilingualism, a clear separation of the language of communication at home and at school / kindergarten is necessary, when for a long time two full-fledged language environments that are vital to the child are preserved, and in each of them they do not understand (or firmly do not want to understand) one language, i.e. e. You need a second language to communicate with them.

If preschoolers, when changing the language environment, one of the languages ceases to be necessary for communication, a small child forgets it and from bilingual becomes monolingual. The younger the child, the sooner he can forget his first language in a new language environment. First, reading and writing skills (if any) are lost, then speaking, the understanding of the language is the most durable. As you know, speech development is decisive for the formation of all other mental functions, therefore, language difficulties hinder the mental development of the child, the assimilation of knowledge and skills necessary for successful mental functioning and socialization in the children's team (kindergarten, school), and then, if these difficulties not overcome in society as a whole.

If earlier there was an idea that bilingualism negatively affects the development of a child, the origins of this idea are related to the fact that immigrant children were tested in a non-native language, now it has been proven that bilingualism contributes to the formation of more flexible thinking, the ability to approach the problem from different angles and from different perspectives, expands the possibilities of cognition. The positive influence of the assimilation of two language systems (the ability to read in two languages) on the formation of children's cognitive functions is shown. According to L. S. Vygotsky, bilingualism can be a favorable or inhibitory factor in the development of a child, depending on the specific conditions of life and the age of the child. So, for example, in the process of speech formation there are stages of both quantitative changes and qualitative leaps: the appearance of phrasal speech, mastery of writing and reading.

Simultaneous development of two languages is thus inhibited: a qualitative leap occurs first in one of the languages, that is, the simultaneous development of two languages is inhibited at the moment of transition to a higher functional level.

We will illustrate these theoretical points by the example of a description of the case of early multilingualism in a preschool child: *Description of the case. Safiya, 9 years old, lives with her mother, father, brother and nanny. Mom and nanny are Uzbeks, dad is Turkish. Due to the*

nature of his professional activity, he often changes his country of residence. From birth, the girl was in a situation of Uzbek-Turkish bilingualism, the coexistence of two language systems, with the help of which the same objects and phenomena were coded. The mother spoke to the child in Uzbek, the father in Turkish, but the dominant language of communication has always been Uzbek. When the girl was 2 years old, the family moved to Germany for a year, where the girl had a German governess who taught her German, and in the yard, playing with children, Safiya began to speak and understand German. Returning to Tashkent at the age of 3, the girl quickly forgot both Turkish and German. At the age of three, the girl went to a French school/kindergarten in Uzbekistan, which she continues to attend at the present time. Children from families of different nationalities study at the school, but Safiya mostly communicates with Uzbek-speaking children. In a few months, Safiya will have to move to Turkey. Basic information from the girl's early development questionnaire: Born from the first pregnancy, at the time of birth, the mother was 31, the father was 39 years old. The pregnancy proceeded without significant features, delivery at term, planned caesarean section, at birth, 9 points were scored on the Apgar scale. Development during the first two years: motor development in time, as well as speech development (babbling from three months, words from twelve months, phrases from one year to ten months), however, both words and phrases first appeared in Uzbek, then in Turkish. In March 2014, the girl's parents applied to the Research Center for Child Neuropsychology with complaints about difficulties in emotional regulation (emotional lability, whims, manifestations of aggression), hyperactivity, and fatigue. During a neuropsychological examination (carried out in Turkish), Safiya showed some disinhibition, restlessness, and general arousal. A score on the Conner's scale completed by the mother - indicates a pronounced ADHD (Attention Deficit Hyperactivity Disorder) syndrome. The girl came into contact with the psychologist quite easily, the emotional background was even and positive. During the entire examination, Sonya demonstrated criticality to her own mistakes and the specialist's comments, a high interest in success and a painful reaction to failure. In the study of neurodynamic parameters, a tendency to exhaustion was revealed at a high level of brain activity, as well as non-rough fluctuations in mental performance. The lateralization of functions is formed according to the left hemispheric type (i.e., the child is right-handed).



**Fig. 1. Graphic test for dynamic praxis before correction**

In the study of the motor sphere, stereotypy, inertia during the transition from one program to another when performing tests for dynamic praxis, multiple perseverations and spatial errors in the graphic test for dynamic praxis (Fig. 1), alternate performance with failures in tests for reciprocal hand coordination were observed. Tests for praxis of the posture of the fingers were performed with errors of the type of secularity, as well as with kinesthetic search. In the choice reaction, multiple echopraxias were observed, which were corrected after indicating the error. The girl coped successfully with copying drawings that corresponded to age standards.

The study of the gnostic functions of Sophia revealed the insufficient formation of visual-spatial gnosis. Sonya found it difficult to perform a variant of Benton's test for 5 years. Visual, acoustic, tactile and color types of gnosis are well formed. During the study of letter gnosis, the girl found a good knowledge of Uzbek letters, but the girl performs a similar test with Latin letters with

errors: she perceives Latin letters as French or Turkish. That is, the literal gnosis is formed in only one language. In the speech sphere, the girl also showed differences in the 3 languages she now uses (Table 1).

**Table 1. Speech functions in various languages Characteristics of the dictionary.**

<i>Number of free associations in 1 minute</i>			<i>% of named pictures</i>			<i>The number of semantic associations in associations</i>		
Uzbek	French	Turkish	Uzbek	French	Turkish	Uzbek	Turkish	French
15 (of which 5 verbs and 1 adjective)	6 (all nouns)	12 (all nouns)	95	50	70	3	0	5

**Reading characteristic**

<i>Uzbek</i>	<i>French</i>	<i>Turkish</i>
<i>Holistic reading with full reading comprehension</i>	<i>Reading by syllables with difficulty understanding, alienation of the meaning of the words read</i>	<i>Reading by syllables with elements of guessing and substitutions for more frequent words</i>

The expressive speech of the girl in Uzbek (the language of preferred communication) is characterized by smoothness and development, the use of different grammatical categories. In French, expressive speech with hesitation, search for words, verbal paraphasias. The search for nominations was observed in Uzbek only for individual low-frequency words and intensified when Sophia was worried. In the other two languages, there were distinct difficulties in the nominative function of speech. Phonemic hearing and understanding of logical and grammatical constructions are formed, ordinary speech is formed in direct and reverse order in Uzbek and Turkish, and only in direct order in French. It is also important to note that Sophia's holistic reading is only in the Uzbek language. But the associative process is characterized by a low ability to categorize: words are rarely combined into semantic categories and more often on a situational rather than categorical basis, for example, an umbrella is rain, a house is a dishwasher. Such difficulties in categorization may be explained by the insufficient formation of brain mechanisms of inter hemispheric differentiation of functions in conditions of multilingualism. This correlates with some modern psychophysiological data. When performing this test in French, there were no semantic associations at all, and in the associative test in Turkish, on the contrary, there were many categorical associations: apple - pear, grandfather - mother - father, month - star, but grammatical categories were limited to nouns. Thus, French turned out to be the least developed language, despite attending a French kindergarten / school for 3.5 years. This is because the girl was allowed to communicate there in Uzbek with Uzbek-speaking children, while there were two separate communication environments for Uzbek and Turkish.

The study of the mnestic functions of the girl showed a good formation of auditory-speech, visual and motor types of memory. Tasks aimed at studying the intellectual sphere of the girl revealed the formation of generalization operations, however, finding a generalizing concept caused difficulties for the child. Understanding the meaning of the plot picture and a series of plot pictures did not cause any difficulties for Sofia.

Thus, against the background of fluctuations in the level of mental performance and exhaustion, Sofia had an insufficient formation of motor (kinetic, kinesthetic, regulatory and spatial) and

some speech functions. At the same time, a good level of formation of gnostic, parochial, intellectual and most verbal functions in the Uzbek language can serve as a support in the correctional process. In this case, the good development of intellectual functions is combined with the weakness of the neurodynamic and emotional-affective aspects of mental activity. The girl is very demanding of herself and painfully experiences failure in any task.

The main strategy of neuropsychological correction was to implement an integrated approach to the correctional process, combining psychological, speech therapy, neuropsychological (cognitive and motor) and general health-improving types of assistance to the child, both within each lesson and with the involvement of different specialists. The data of neuropsychological diagnostics allowed us to outline the tasks of the first stage of correction. The main targets of correctional and developmental classes were: increase in brain activity (neuro-dynamics of mental activity); development of motor functions; formation of self-regulation and control; formation of spatial representations; formation of nominative processes; formation of the categorization process; harmonization of the emotional-affective state of the girl.

To activate the child's energy potential, much attention was paid to breathing exercises - the development of proper diaphragmatic breathing, which improves blood circulation, massage of the abdominal organs, calming down, concentration of attention, general improvement in well-being and, of course, the formation of arbitrary self-regulation of breathing. First, the specialist taught the girl how to breathe correctly in a playful way, which improved efficiency and emotionally involved the child. For example, a toy that had to be "rolled" was placed on the stomach of Sophia, who was in a horizontal position, and how mobile such an "elevator" turned out to be was an indicator of the correct inhalation and exhalation. Then various breathing games were connected: "Feather", "Dutiball", etc., the essence of which is to direct the air flow to the desired object, keeping it in the air or directing it to a given target.

Later, when breathing skills were already automated, we began to include breathing exercises in some exercises of the motor correction stage. To relieve emotional stress (excitation), relaxation exercises were carried out at each lesson, using elements of body-oriented therapy. This is also given a lot of attention, because bodily "clips", deviations from the normal tone, can be both a cause and a consequence of the child's emotional difficulties that have arisen and adversely affect its development. An important role in relaxation is played by music, lighting, smells, memories of events and sensations. In addition, during relaxation, certain zones were massaged (for example, the feet, because representations of all brain zones are concentrated in this part of the body, and its stimulation also increases brain activity in general). After relaxing in the classroom, Sophia became calmer, more attentive, as a result of which she could perceive more information. The girl really likes such exercises.

This case very well demonstrates the features of the formation of speech and other mental functions on the structure of the brain in conditions of bilingualism and multilingualism based on neuroimaging methods:

- non-simultaneous and uneven development of different languages and, above all, non-simultaneous appearance of qualitative leaps in the development of speech functions in different languages;
- non-compliance with the necessary conditions for the formation of bilingualism (a clear separation of the language of communication at home and at school / kindergarten) led to the emergence of a situation of unformed bilingualism, which even a very capable child had a negative impact on the development of some cognitive (primarily categorical), motor and emotional functions;
- A child in a situation of bilingualism and multilingualism needs psychological, including neuropsychological, support.

Overall, research consistently shows that bilingualism has numerous benefits for the brain. It can improve cognition, delay cognitive decline, and positively affect brain structure. These results highlight the importance of encouraging bilingualism and understanding the impact of language on brain development and function.

Thus, the brain processes native and foreign languages differently, with certain areas of the brain dedicated to language processing. Studies have shown that the left hemisphere of the brain plays a critical role in speech processing, especially Broca's and Wernicke's areas. Research on the location of mother tongue in the brain shows that language acquisition is closely related to brain development, and brain plasticity plays an important role in language acquisition.

On the other hand, studies have also shown that there are differences in brain processing between native and foreign languages, with the latter requiring more effort and cognitive resources. Age differences in foreign language acquisition and brain processing have also been observed, suggesting that early exposure to foreign languages may lead to better language acquisition.

Bilingualism has been shown to have several benefits for cognitive function, including improved executive function and greater resistance to cognitive decline. It has also been found that the brain structure of bilinguals differs from that of monolinguals, which may have implications for cognitive processing.

The study of language processing in the brain has important implications for language education and learning, emphasizing the importance of early language exposure and providing information on the best language teaching practices. Future research may further explore the complex relationship between language and the brain, with potential implications for broader fields such as cognitive neuroscience and education in terms of advanced neuroimaging techniques to investigate the impact of bilingualism on brain structure.

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