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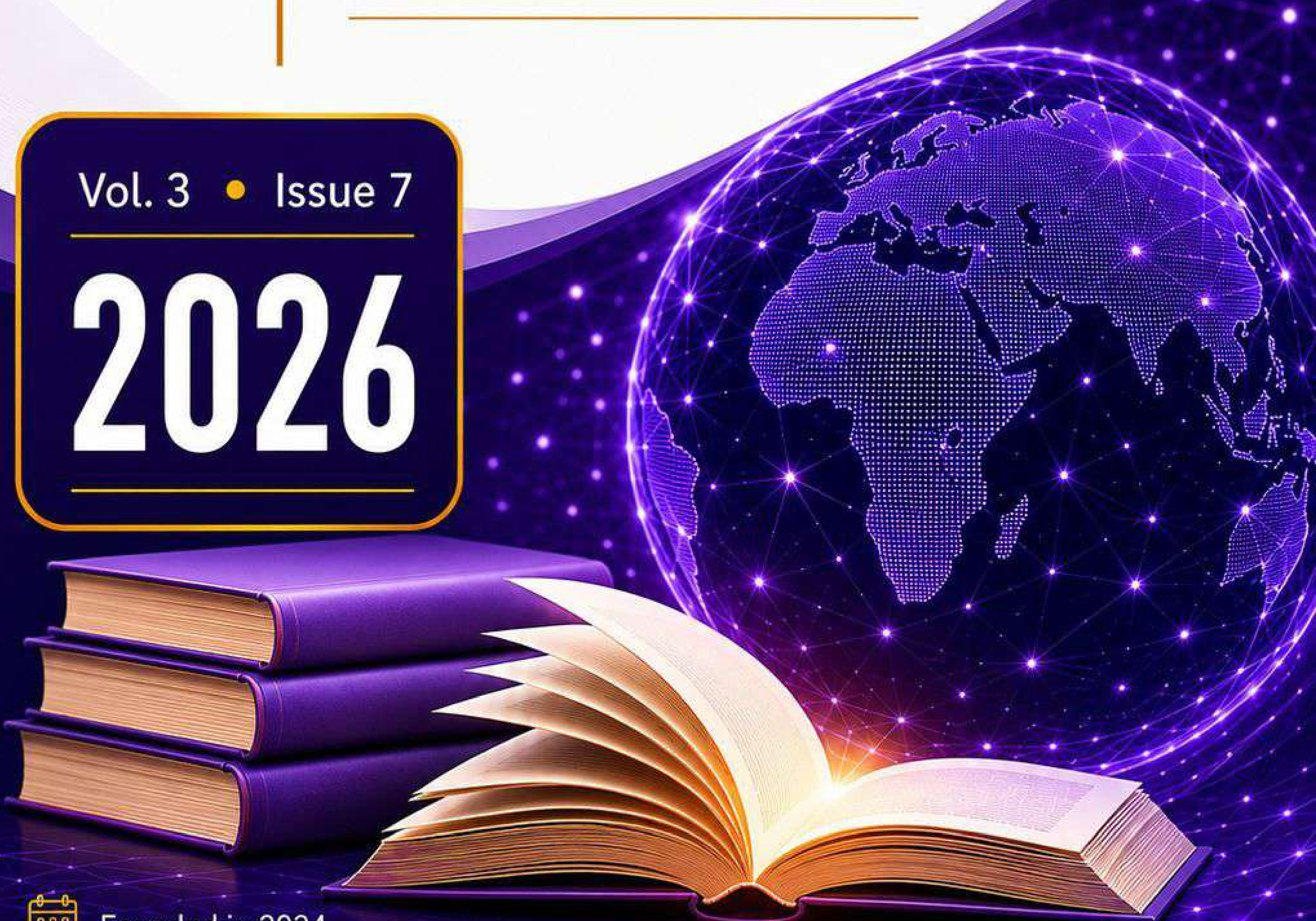

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YANGI TILNI O'RGANISHNING ILMIY ASOSLARI: TIL O'RGANISHNING MIYA FAOLIYATIGA TA'SIRI

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Annotatsiya.

Yangi tillarni o'rganish uzoq vaqtdan beri muhim kommunikativ va madaniy ko'nikma sifatida qadrlanib kelinadi. Biroq, kognitiv neyrofan sohasidagi tobora ortib borayotgan ilmiy dalillar ikkinchi tilni o'zlashtirish jarayoni miya va uning funksiyalariga keng ko'lamli ta'sir ko'rsatishini tasdiqlamoqda. Ushbu maqolada inson rivojlanishi davomida ko'p tillilikning neyron va kognitiv ta'sirlarini aniqlagan so'nggi tadqiqotlar ko'rib chiqiladi. Neyroimaging, uzun muddatli (longitudinal) tadqiqotlar va meta-tahlillar natijalarini birlashtirgan holda, ushbu sharh quyidagi uchta yo'nalishga alohida e'tibor qaratadi: (a) ikkinchi tilni o'rganishning miya tuzilishi va funksiyasiga ta'siri; (b) ko'p tillilikning diqqatni almashtirish, tormozlovchi nazorat va ishchi xotira kabi ijro etuvchi funksiyalarni rivojlantirishdagi roli; hamda (c) bilingval tajribaning kognitiv zaxira va kech boshlanuvchi demensiyaga ta'siri.

Kalit so'zlar: bilingvalizm, til o'rganish, kognitiv zaxira, ijro etuvchi funksiyalar, neyroplastiklik, demensiyaning oldini olish.

НАУЧНЫЕ ОСНОВЫ ИЗУЧЕНИЯ ИНОСТРАННОГО ЯЗЫКА: ВЛИЯНИЕ ОБУЧЕНИЯ НА МОЗГ

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Аннотация.

Владение несколькими языками издавна считается ценным коммуникативным и культурным навыком, однако растущее количество данных в области когнитивной нейронауки свидетельствует о том, что процесс изучения второго языка оказывает широкомасштабное влияние на мозг и его функции. В данной статье рассматриваются современные исследования, посвящённые нейронным и когнитивным эффектам многоязычия у человека на протяжении его развития. Объединяя данные нейровизуализации, лонгитюдных исследований и метаанализов, данный обзор уделяет особое внимание трём направлениям: а) структурным и функциональным изменениям, связанным с изучением второго языка; б) роли многоязычия в развитии исполнительных функций, таких как переключение внимания, тормозной контроль и рабочая память; в) влиянию двуязычного опыта на когнитивный резерв и развитие деменции в пожилом возрасте.

Ключевые слова: билингвизм, изучение языков, когнитивный резерв, исполнительные функции, нейропластичность, профилактика деменции.

THE SCIENCE BEHIND LEARNING A NEW LANGUAGE: THE EFFECTS OF LEARNING ON THE BRAIN

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Abstract.

The addition of new languages has long been held as an esteemed communicative and cultural ability, but a growing body of evidence from cognitive neuroscience suggests that the process of acquiring a second language has wide-reaching effects on the brain and its functions. The present paper reviews recent research that has established the neural and cognitive effects of multilingualism in humans over the course of development. Combining the evidence of neuroimaging, longitudinal studies and meta-analyses, this review looks at three areas in particular: (a) the structural and functional effects of learning a second language; (b) the role of multilingualism in enhancing executive function such as attention switching, inhibitory control and working memory; and (c) the effect of a bilingual background on cognitive reserve and late-onset dementia.

Keywords: bilingualism, language learning, cognitive reserve, executive functions, neuroplasticity, dementia prevention

Introduction

The ability to communicate in more than one language has traditionally been regarded as an important social, educational, and cultural competence. In an increasingly interconnected world, knowledge of a second or additional language facilitates intercultural communication, academic mobility, professional development, and participation in global information exchange. However, recent advances in cognitive neuroscience have significantly broadened the understanding of multilingualism. Second language acquisition is now considered not only a linguistic process but also a complex form of cognitive training capable of inducing lasting changes in brain structure, neural functioning, and cognitive performance. Learning and regularly using more than one language places continuous demands on the human cognitive system. Multilingual speakers must select the appropriate language, suppress interference from competing linguistic systems, switch between languages when necessary, and monitor contextual cues during communication. These processes engage a broad network of cortical and subcortical regions associated with language processing, attention, executive control, memory, and decision-making. Consequently, multilingual experience may contribute to experience-dependent neuroplasticity, whereby the brain adapts structurally and functionally in response to repeated cognitive demands. Neuroimaging studies have provided increasing evidence that second language learning is associated with measurable changes in the brain. Research employing magnetic resonance imaging, functional magnetic resonance imaging, diffusion tensor imaging, and electroencephalography has identified alterations in gray matter volume, cortical thickness, white matter integrity, and functional connectivity among bilingual and multilingual individuals. These changes have frequently been observed in regions involved in language control and executive processing, including the inferior frontal gyrus, anterior cingulate cortex, prefrontal cortex, hippocampus, basal ganglia, and inferior parietal areas. Such findings suggest that language learning may reshape neural systems beyond those directly responsible for linguistic comprehension and production.

A central area of debate concerns the relationship between multilingualism and executive function. Executive functions are higher-order cognitive processes that enable individuals to regulate attention, inhibit irrelevant information, update working memory, resolve conflict, and flexibly adapt to changing tasks. Because multilingual speakers continuously manage competing linguistic representations, it has been proposed that this experience strengthens domain-general control mechanisms. A number of studies have reported advantages among bilingual individuals in tasks measuring inhibitory control, attentional switching, cognitive flexibility, and working memory. Nevertheless, findings remain inconsistent, with some investigations failing to identify a reliable bilingual advantage. These discrepancies may be related to differences in language proficiency, age of acquisition, frequency of language use, sociolinguistic environment, educational background, socioeconomic status, and methodological design. The cognitive consequences of multilingualism may also extend across the lifespan. In children and young adults, managing multiple languages may support the development of metalinguistic awareness, attentional regulation, and flexible thinking. In adulthood, sustained multilingual language use may contribute to the maintenance of efficient cognitive control networks. In older age, bilingualism has increasingly been investigated as a potential contributor to cognitive reserve. Cognitive reserve refers to the capacity of the brain to maintain effective functioning despite age-related neural decline or neuropathological damage. Through repeated engagement of language-control and executive networks, multilingual experience may promote neural efficiency, compensatory mechanisms, and resilience against cognitive deterioration.

This issue is particularly significant in relation to dementia and Alzheimer’s disease. Several clinical and epidemiological studies have suggested that lifelong bilingualism may be associated with a later manifestation of dementia-related symptoms. Importantly, multilingualism is not generally assumed to prevent neurodegenerative pathology itself. Rather, it may enable individuals to tolerate a greater degree of neural damage before clinical symptoms become evident. This distinction is essential because it positions bilingualism as a possible experiential factor contributing to cognitive reserve rather than as a direct medical treatment or protective guarantee. Despite growing interest in the neuroscience of multilingualism, the available evidence remains heterogeneous. Multilingualism is not a uniform condition, and individuals differ considerably in the number of languages spoken, proficiency level, age of acquisition, frequency of use, context of learning, language similarity, patterns of switching, and degree of immersion. Moreover, cross-sectional studies cannot always determine whether observed neural differences are caused by language learning or reflect pre-existing characteristics. Longitudinal research is therefore especially valuable because it enables investigators to examine changes in brain structure and cognition as individuals acquire and use an additional language over time.

Meta-analyses and systematic reviews have further contributed to the field by integrating findings across diverse

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populations and research designs. These approaches help distinguish robust patterns from study-specific effects and clarify the conditions under which multilingualism may influence cognition and neural organization. At the same time, inconsistencies across studies indicate the need for more precise theoretical models that treat bilingualism as a multidimensional and dynamic experience rather than a simple categorical distinction between bilingual and monolingual individuals. Against this background, the present paper reviews contemporary research on the neural and cognitive consequences of second language acquisition across human development. Drawing on evidence from neuroimaging investigations, longitudinal studies, clinical observations, and meta-analyses, the review addresses three interrelated areas. First, it examines structural and functional brain changes associated with learning and using a second language. Second, it evaluates the role of multilingual experience in executive functions, particularly attention switching, inhibitory control, cognitive flexibility, and working memory. Third, it considers the potential contribution of bilingualism to cognitive reserve and the delayed clinical onset of dementia. By integrating these areas, the paper seeks to provide a balanced account of multilingualism as a form of experience-dependent cognitive and neural adaptation.

The scientific understanding of multilingualism has changed substantially over recent decades. Earlier studies frequently treated bilingualism as a fixed categorical characteristic in which individuals were classified simply as either monolingual or bilingual. Contemporary research, however, increasingly conceptualizes multilingualism as a multidimensional and continuously changing experience. Bilingual speakers differ in age of second-language acquisition, proficiency, frequency of use, language-switching patterns, linguistic environment, immersion, and the social contexts in which their languages are employed. These variables influence the extent and nature of cognitive and neural adaptations associated with multilingualism.

This experience-based perspective is important because learning an additional language does not create one uniform neurological outcome. The brain changes associated with intensive classroom learning may differ from those produced by lifelong immersion or daily interaction in two languages. Similarly, simultaneous bilinguals who acquire two languages in early childhood may develop different neural organization from sequential bilinguals who begin learning another language during adolescence or adulthood. Consequently, recent scholarship emphasizes that the effects of bilingualism should be examined in relation to the intensity, duration, timing, and context of language use rather than through a simple bilingual–monolingual comparison. Evidence from recent studies also indicates that the timing of bilingual experience can influence both global and local functional brain organization.

The Adaptive Control Hypothesis provides one influential explanation for this variability. According to this approach, different communicative environments place different demands on language-control mechanisms. In a single-language context, speakers use one language in a particular setting and another language elsewhere. In a dual-language context, both languages are used in the same broader environment, but speakers must select the appropriate language according to the interlocutor. In dense code-switching contexts, elements from multiple languages may be combined within the same conversation. Each context is believed to recruit attention, monitoring, inhibition, planning, and switching processes differently. Research involving older bilingual adults and broader reviews of interactional contexts suggests that everyday patterns of language use may predict executive-function outcomes more accurately than bilingual status alone.

One of the most consistent conclusions of cognitive-neuroscience research is that acquiring and using an additional language can produce experience-dependent neuroplasticity. Neuroplasticity refers to the capacity of the nervous system to reorganize its structure, connectivity, and patterns of activation in response to learning and repeated experience. Since multilingual speakers must continuously acquire, retrieve, monitor, and regulate multiple linguistic systems, second-language learning provides a particularly valuable model for examining how intensive cognitive experience reshapes the human brain.

Structural magnetic resonance imaging studies have associated bilingual experience with changes in cortical and subcortical regions involved in language processing, memory, attention, and cognitive control. Frequently examined areas include the inferior frontal gyrus, inferior parietal lobule, anterior cingulate cortex, hippocampus, caudate nucleus, putamen, thalamus, and cerebellum. However, the reported direction of structural change is not always uniform. Some studies identify increases in gray-matter volume or cortical thickness, whereas others report reductions or redistribution in particular regions. Such differences should not automatically be regarded as contradictory because increases and decreases may represent different phases of learning, adaptation, specialization, or increased neural efficiency.

The Dynamic Restructuring Model developed by Pliatsikas explains these variable findings by proposing that bilingual neuroplasticity develops through successive stages. During initial exposure to a second language, the brain may show expansion in regions responsible for lexical learning, language control, and effortful processing. As proficiency and experience increase, structural reorganization may become more selective, reflecting the strengthening of frequently used networks. With prolonged and efficient bilingual practice, some regions may demonstrate cortical consolidation or renormalization, while white-matter pathways become more efficient. Thus, bilingualism-related neuroplasticity is not a linear process of continuous brain-volume increase; rather, it involves dynamic restructuring determined by the quantity and quality of language experience.

Longitudinal investigations provide particularly strong evidence because they measure participants before and after a period of language instruction. Legault and colleagues found that second-language learners demonstrated changes in cortical thickness compared with control participants and that these changes were associated with individual differences in language performance and functional connectivity. Earlier intensive-training research similarly documented growth in language-related cortical areas and hippocampal regions following sustained foreign-language study. Such findings support the interpretation that at least some structural differences identified in bilingual populations result from language learning itself rather than from pre-existing individual characteristics.

Subcortical structures are especially important because multilingual language control requires the selection of the

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intended language and the suppression of competing alternatives. The basal ganglia, particularly the caudate nucleus and putamen, contribute to language selection, procedural learning, and switching. Recent research has demonstrated that bilingual experience is associated with dynamic subcortical adaptations and that these changes correspond to general principles of experience-based neuroplasticity. The variability in subcortical findings appears to reflect differences in immersion, proficiency, language-switching habits, and duration of bilingual use.

White-matter connectivity represents another important dimension of bilingual neuroplasticity. White-matter tracts connect cortical and subcortical regions and support rapid communication across distributed neural networks. Research has examined bilingualism-related differences in pathways such as the arcuate fasciculus, superior longitudinal fasciculus, inferior fronto-occipital fasciculus, corpus callosum, and anterior thalamic radiation. These pathways contribute not only to language comprehension and production but also to attention, working memory, and cognitive control. Nevertheless, findings concerning white-matter integrity remain heterogeneous. Age, age of acquisition, language similarity, daily use, proficiency, and analytical methods may all affect observed results. A systematic investigation published in 2024 emphasized the importance of examining bilingual experience together with age and second-language onset rather than interpreting white-matter differences as a universal bilingual signature.

Functional neuroimaging research demonstrates that bilingualism influences not only brain anatomy but also the organization and recruitment of neural networks. During speech production, both languages of a bilingual individual may remain active to some degree, even when only one is required. This parallel activation creates competition and requires the speaker to select the target language while controlling interference from the non-target language. These demands engage a distributed bilingual language-control network that overlaps with domain-general executive-control systems.

The anterior cingulate cortex is associated with conflict monitoring, while dorsolateral and inferior frontal regions contribute to goal maintenance, response selection, and inhibition. The basal ganglia support language selection and switching, whereas parietal regions assist attentional orientation and the representation of language-specific task demands. The cerebellum, traditionally associated with motor coordination, is also increasingly recognized as contributing to language prediction, sequencing, automatization, and cognitive control.

Functional adaptations may appear as either increased or reduced activation. At early stages of second-language learning, increased activity may reflect the greater effort required for vocabulary retrieval, grammatical processing, and language selection. As proficiency develops, activation in some regions may decrease because processing becomes more automatic and efficient. At the same time, connectivity among language, attention, executive-control, salience, and cerebellar networks may become more coordinated. A 2024 functional-connectivity study found that the timing of bilingual language learning was associated with altered global and local brain-network organization, particularly through connectivity between association networks and the cerebellum.

Functional neural differences may also occur in the absence of clear behavioral advantages. For example, bilingual and monolingual individuals may achieve similar accuracy and response times while relying on different patterns of neural recruitment. Research on selective attention has shown that bilingualism can modify neural processing even when behavioral performance does not consistently differ between groups. This distinction is methodologically significant because conventional cognitive tasks may not fully capture latent neural efficiency or compensatory mechanisms associated with bilingual experience.

Language similarity may further affect functional organization. Speakers of typologically similar languages may experience greater cross-linguistic competition in some domains because lexical, phonological, or grammatical representations overlap more strongly. In contrast, typologically distant languages may require different control strategies. These observations indicate that the neurological consequences of multilingualism depend not only on how many languages an individual speaks but also on the relationships between those languages and the manner in which they are used.

The cognitive-reserve literature offers promising evidence that lifelong bilingualism may delay the clinical expression of dementia. Yet, this should not be interpreted as proof that multilingualism prevents neurodegenerative disease. More longitudinal research is required to separate the effects of bilingualism from education, occupational complexity, immigration, social engagement, and other reserve-enhancing factors.

Future investigations should use continuous and multidimensional measures of multilingualism, including age of acquisition, proficiency in each language, frequency of use, switching patterns, immersion, and interactional context. Larger longitudinal samples, preregistered designs, standardized executive-function batteries, and multimodal neuroimaging are also needed. Such approaches will support a more precise understanding of how, when, and for whom second-language learning influences brain organization, cognitive control, and resilience across the lifespan.

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