Neuromyths in Education: An Analysis of the Prevalence Among Faculties of Higher Educational Institutions

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Abstract

These days there is a rapid expansion of neuroscience in various spheres of society. Moreover, neuroscience results are being actively introduced into the education system, especially due to the digitalization of society. However, there are also started to appear neuromyths, which are misconceptions generated by misinterpretations of scientific facts related to the brain function. The prevalence of neuromyths entails a number of risks that can significantly affect the learning process. The study provides an analysis of various research results regarding the prevalence of neuromyths among school and university educators in different countries. The aim of this study was to explore the prevalence of belief in neuromyths among faculties of Russian higher educational institutions. The results of the study showed the need for further active implementation of neurobiological approaches among faculty members of educational organizations.

Keywords

neuromyths, neurobiology, educational neurobiology, brain function, university faculties.

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With the advancement of neurobiology, knowledge about the mechanisms and patterns of brain function came to be applied in various fields of science and practice, including education. Today's educators need this knowledge to develop and use educational resources, organize the learning process, and individualize learning [Karakus, Howard-Jones, Jay, 2015]. Educational neurobiology is a system of knowledge that brings together research in neurobiology, educational psychology, educational technology, and other disciplines. Interest in applying the data on brain function to educational practice increased drastically during the rapid development of neurobiology from 1990 to 2000 — a period designated the Decade of the Brain [Dekker et al., 2012]. However, along with accurate information, the so-called neuromyths — misconceptions resulting from misinterpreting scientific facts — became widespread.

Most neuromyths are based on proven scientific data but have been misinterpreted or oversimplified [Dekker et al., 2012; Howard-Jones, 2014; OECD, 2002]. For example, the most popular neuromyth — learning can be enhanced if children are classified according to their preferred learning style — is based on valid research findings. Visual, auditory, and kinesthetic information is indeed processed in different parts of the brain [Dekker et al., 2012; Howard-Jones, 2014]. However, these separate brain structures are highly interconnected. It is, therefore, incorrect to assume that only one sensory modality is involved in information processing. Although individuals have a preference for the way they receive information — either visual, auditory, or kinesthetic — there is no scientific evidence that the learning process designed according to the preferred learning style is more effective [Dekker et al., 2012; Howard-Jones, 2014]. Such neuromyths have become ingrained in the minds of people all over the world. Over time, it is getting increasingly challenging to dispel them as they have served as the basis for popular educational programs such as Brain Gym or the "preferred learning style" approach, the effectiveness of which, however, has not been scientifically confirmed [Dekker et al., 2012].

One of the reasons for the ever-growing belief in neuromyths may be the lack of scientific knowledge and skill to critically evaluate information coming from various sources [Torrijos-Muelas, González-Víllora, Bodoque-Osma, 2021; Bezrukikh, Ivanov, Orlov, 2021; Ferrero, Garaizar, Vadillo, 2016; Karakus, Howard-Jones, Jay, 2015; Dekker et al., 2012]. Another reason is the misinterpretation and misquoting of neurobiologists' statements and data from scientific publications by popular media and research papers written by non-specialists in this field [Ferrero, Garaizar, Vadillo, 2016; Karakus, Howard-Jones, Jay, 2015; Dekker et al., 2012]. It has been found that people are more likely to believe research results when they are accompanied by explanations from neurobiology and brain

images, even if those are flawed [Dekker et al., 2012]. Those who lack knowledge and experience in neurobiology are unable to recognize neuromyths about brain research presented in the popular media, which often oversimplify information. Inconsistency in the terminology used by neurobiologists and educators, the lack of close collaboration between them, and the popularity of commercial programs that promote pseudoscientific practices in teaching and learning also contribute to neuromyths [Ferrero, Garaizar, Vadillo, 2016].

Ignoring the existence of neuromyths would be unwise, as they might influence the effectiveness of the educational process. In the education systems of many countries, such as the UK, Netherlands, Turkey, Greece, Spain, USA, Australia, and China, research is already being conducted to assess the prevalence of neuromyths. These studies contribute to the adoption of evidence-based education standards by the education systems. A similar study has been conducted in Russia among preschool and school teachers. However, university teachers have rarely been the target audience in studies on the prevalence of neuromyths.

The purpose of this study was to assess to what extent Russian university teachers tend to believe in neuromyths. The hypothesis tested was as follows: in the Russian teaching community, the prevalence of belief in neuromyths is close to that among university teachers in foreign educational institutions.

1. History of Research on Neuromyths

The term “neuromyth” was proposed by neurosurgeon A. Crockard in the 1980s and was originally used in medical science and practice to describe misleading concepts about brain function [Torrijos-Muelas, González-Víllora, Bodoque-Osma, 2021; Howard-Jones et al., 2009].

In 2002, the Organization for Economic Cooperation and Development (OECD) launched the international project “Brain and Learning” [Torrijos-Muelas, González-Víllora, Bodoque-Osma, 2021; Howard-Jones, 2014; Howard-Jones et al., 2009]. Its main goal was to make neuroscience accessible to education professionals. Since then, neuromyths have also been analyzed in the context of education as “a misconception generated by a misunderstanding, a misreading, or a misquoting of facts scientifically established <by brain research> to make a case for use of brain research in education and other contexts” [OECD, 2002]. The OECD initiated the first study of non-specialists’ ideas about brain function and in 2009 published a list of common neuromyths, including those about critical periods of brain development, multilingualism, hemispheric asymmetry, as well as the popular belief that humans only use 10% of their brains [Torrijos-Muelas, González-Víllora, Bodoque-Osma, 2021; Howard-Jones et al., 2009].

There are many misconceptions about the brain among non-specialists, as S. Herculano-Houzel showed in 2002 in a survey of 2,193 people in Rio de Janeiro, where she asked them to evaluate the truth of 95 popular statements and neuromyths [Herculano-Houzel, 2002].

The first study of prospective educators' ideas about brain function was conducted in 2009 in Great Britain by P. Howard-Jones et al. [2009]. The authors asked 158 final-year students to rate the truth of 32 statements that represented neuromyths. Many respondents were found to believe that mental activity is determined by upbringing, education, and genetics, but not by biological brain functions; 82% of novice teachers believed in the effectiveness of delivering information in the student's preferred learning style; 60% believed in the hemispheric dominance as a possible cause of individual differences among learners. The authors conducted similar studies with groups of teachers in other countries, including the Netherlands, Greece, Turkey, Spain, and China.

In 2012, a similar study was conducted in selected regions of the United Kingdom and the Netherlands [Dekker et al., 2012]. A total of 242 primary and secondary school teachers were asked to assess 32 statements about brain function, some of which were neuromyths. On average, 49% of teachers believed in specific neuromyths, while about 70% of Dutch teachers had general knowledge about brain function. Teachers who read popular science magazines did better at evaluating the truth of the statements, whereas characteristics such as age, gender, and school type (primary or secondary) had no effect on belief in neuromyths. The most popular neuromyths were: the effectiveness of brain training (Brain Gym), more successful learning when course materials are provided in a student's preferred learning style, and left or right hemisphere dominance as a possible cause of individual differences. The prevalence of misconceptions was associated with the scope of programs in the country devoted to the study of brain activity. The same study investigated teachers' views on the role of genetics and the environment in learning. Teachers in both countries rated the influence of the environment on learning success much higher than that of genetics. In the UK (county of Dorset), teachers found that genetics determined only 22% of learning outcomes. A previous study of UK novice teachers yielded nearly the same result — 25% [Howard-Jones et al., 2009]. The authors concluded that possessing general knowledge of the brain did not protect teachers from believing in neuromyths.

To be able to compare the data with those obtained in the UK and the Netherlands, a study of 278 Turkish primary and secondary school teachers in 2015 was designed similarly [Karakus, Howard-Jones, Jay, 2015]. Most popular were the same neuromyths as in

other European countries. The average level of belief in neuromyths was 53%, with 97% of teachers thinking that learning is more effective when delivered in a student's preferred learning style, and 79% believing that left- or right-brain dominance can explain individual differences. In Turkey, the neuromyth about the connection between learning a second language and brain plasticity was found to be more common — 58.3%; in the Netherlands its prevalence was 36%, and in the UK it was only 7%. The authors explain this result by the cultural differences between the three countries and the positive attitude towards multilingualism in Turkey.

In Greece, just as in Great Britain and the Netherlands, most teachers believe in the effectiveness of instruction delivered in a student's preferred learning style (97%) and in left or right brain dominance being a possible cause of individual differences (71%) [Deligiannidi, Howard-Jones, 2015]. A total of 217 primary and secondary school teachers were surveyed in this country. This survey provided important insights into the effect of cultural factors on ideas about brain function. For example, it turned out that for Greek teachers, the relationship between mind and brain was more complex than for their peers in other countries: they considered it to be mediated by the soul. Furthermore, Greek teachers attributed learning successes and failures primarily to the child's genetics and believed in a biological limit to student achievement.

Research on the influence of national culture on the prevalence of neuromyths continued in 2016 in Spain. A total of 284 teachers from 15 regions of the country were surveyed on their belief in 12 neuromyths. The data obtained were compared with the results of ten studies conducted in the UK, the Netherlands, Greece, Turkey, Peru, Argentina, Chile, a group of Latin America countries, China, and Spain. Almost all the teachers surveyed were interested in patterns of brain function (98.5%) and considered this knowledge important in teaching (95.4%). At the same time, most read only popular magazines about education (42.6%) and far fewer teachers followed publications in scientific periodicals (29.5%). 49.1% of respondents did not recognize neuromyths among the statements presented to them, and 19.6% preferred not to answer. The most prevalent neuromyths among Spanish teachers concerned the effectiveness of stimulus-rich environments for learning (94%), instruction in a student's preferred learning style (91.1%), and using exercises that rehearse coordination of perceptual-motor skills to improve literacy (82%). However, unlike their Greek peers, Spanish teachers were less likely to believe the neuromyth about the effect of learning a second foreign language on brain plasticity. As in previous studies, teachers' age and years of work experience, as well as their participation in professional development, had no influence on belief in neuromyths. The study confirmed previous findings

[Dekker et al., 2012] that knowledge about brain function did not rule out belief in neuromyths; rather, those who know more about brain function made more mistakes. Regular reading of scientific journals reduced belief in neuromyths, while reading educational articles, on the contrary, strengthened it.

In a 2019 study in China, 253 primary and secondary school headmasters in the province of Gansu were asked to complete a questionnaire of 40 statements that included neuromyths and scientific facts [Zhang et al., 2019]. The majority of school principals were found to be interested in neurobiology and considered it advantageous to apply data from this field to education (88%). At the same time, more than half of the respondents rated neuromyths as true. The most popular neuromyths were those about the effectiveness of learning when delivered in a student's preferred learning style, and the influence of the environment and exercise to improve brain function on preschool children's development. In China, in contrast to the results from the European studies, teachers' level of education and the type of school in which they worked had a significant impact on their belief in neuromyths. The results of the study might have been affected by the specifics of Gansu province that has a lower level of economic development than most provinces in China.

In 2019, U.S. education researchers conducted a large-scale international online survey of 929 instructors, instructional designers, and professional development administrators in higher education [Betts et al., 2019]. The majority of respondents reported an interest in learning more about brain function and considered the impact of neuromyths on learning to be important. The proportion of correct evaluations of the 23 statements that included neuromyths and general information about brain function ranged from 11 to 94%. The proportion of correct evaluations of the 28 statements that represented practices from pedagogy and neurobiology ranged from 26 to 99%. The following neuromyths were the most frequently rated as true by respondents: "Listening to classical music increases reasoning ability"; "A primary indicator of dyslexia is seeing letters backwards"; "Individuals learn better when they receive information in their preferred learning styles." Among statements describing practices from pedagogy and neurobiology, respondents were most likely to evaluate the following as true: "Emotions can affect human cognitive processes, including attention, learning and memory, reasoning, and problem-solving"; "Explaining the purpose of a learning activity helps engage students in that activity"; "Maintaining a positive atmosphere in the classroom helps promote learning." Correct responses about neuromyths, brain function and educational practices were more likely to be given by respondents who regularly read scholarly articles on neurobiology, psychology, and pedagogy, and by those who participated in professional development.

In Russia, the prevalence of neuromyths has so far been measured only among school teachers [Bezrukikh, Ivanov, Orlov, 2021]. The sample consisted of 150–200 preschool and primary school teachers and 300–350 secondary school teachers in each of the 10 regions of Russia. Most teachers, regardless of the stage of education and professional training, believe in neuromyths concerning the dominance of the right or left hemisphere as a possible cause of individual differences between people (85%), the effectiveness of instruction based on a student's preferred learning style (90–94%), training of fine motor skills as a way to improve speech development, and using special exercises to enhance the integration of the right and left hemispheres of the brain (90–95%). Similar to respondents in foreign studies, Russian teachers expressed interest in learning about brain development and functioning (82.3–90.8%) and believed that this knowledge could contribute to the effectiveness of learning (73.2–85.7%). The study found that belief in neuromyths did not depend on teachers' level of education, work experience, and age. Teachers of biology and physical education, whose professional training includes studying brain function patterns, did not differ from teachers of other disciplines in their evaluation of neuromyths.

Applying knowledge about the brain to the organization of learning can improve its effectiveness [Aleksandrova et al., 2021; Zhang et al., 2019; Ferrero, Garaizar, Vadillo, 2016; Dekker et al., 2012]. At the same time, belief in neuromyths can have an adverse effect on educational practice [Dekker et al., 2012]. However, no empirical evidence of the impact of neuromyths on learning effectiveness has been found [Horvath et al., 2018]: the researchers assessed belief in 15 neuromyths among internationally recognized teachers and those with professional awards and compared their findings with previously published data on belief in neuromyths among teachers without professional distinction and prospective teachers. The comparison showed no significant differences. The authors suggest that the idea that neuromyths negatively affect learning may itself be a neuromyth.

Most researchers of neuromyths emphasize the importance of interdisciplinary collaboration between neurobiologists and teachers: it will help teachers develop critical thinking and find opportunities to optimize instruction.

2. Methodology

The present study used empirical data from an online survey conducted in November-December 2021 by the Institute of Online Education at the Financial University under the Government of the Russian Federation. There was no time limit for filling out the questionnaire. The survey could be completed only once.

The survey participants were 147 Russian university teachers of humanities, natural, social, and engineering sciences, with the largest group including faculty and administrators at medical universities (34.7% of respondents). The predominant group was teachers with more than 20 years of work experience (39.5%). The sample included academic administrators of different levels (vice-rectors, deans, heads of departments) and faculty members holding different positions (professors, associate professors, senior lecturers, and lecturers).

The adapted questionnaire consisted of 25 statements about brain function: 16 scientific facts from educational neurobiology and 9 neuromyths. The questionnaire was based on data obtained in the Netherlands, UK, Turkey, Greece, Spain, USA, and China: we used the wording of the neuromyths and scientific facts about brain function that were given the highest number of incorrect evaluations by foreign respondents [Betts et al., 2019; Zhang et al., 2019; Ferrero, Garaizar, Vadillo, 2016; Karakus, Howard-Jones, Jay, 2015; Deligiannidi, Howard-Jones, 2015; Dekker et al., 2012; Howard-Jones et al., 2009] (Appendix 1).

The questionnaire consisted of three parts: general information about the respondents (level of education, years of work experience, scientific field); 25 statements about brain function, which the respondents were asked to rate as true or false; the respondents' self-assessment of their awareness of educational neurobiology and neurotechnologies.

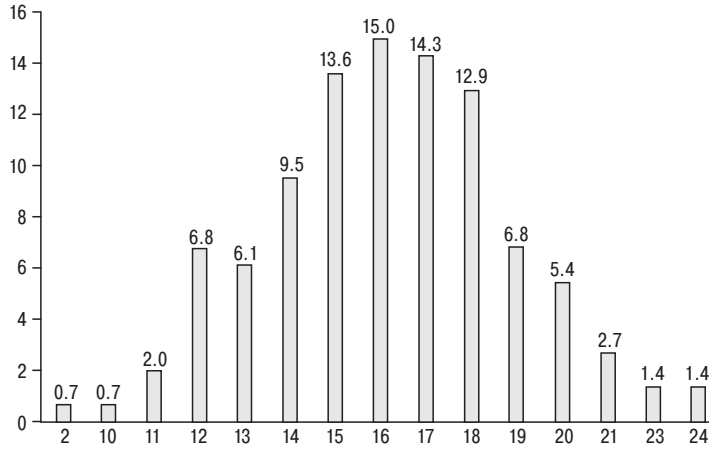
The results of the survey are presented as descriptive statistics. We analyzed the number of correct responses in groups of academics differing by the level of education, work experience, and scientific field. Among the 25 statements, we identified those to which the participants had most frequently responded incorrectly and examined the evaluations of these statements by different categories of respondents. The results obtained were compared with the data of foreign and Russian studies on the prevalence of neuromyths in education.

3. Results

The largest group of respondents (15% of the sample) included those who correctly assessed 16 statements out of 25 (Appendix 2). Sixteen people (11%) gave correct answers to 20 or more questions. In particular, 21 correct answers were given by four respondents (2.7%), 23 and 24 correct answers were given by two respondents each (1.4%), but no one answered all 25 questions correctly (Figure 1).

Table 1 shows the average number of correct answers in the groups of respondents differing by education level, work experience, and scientific field (the discipline they teach). The results

Figure 1. **Distribution of the Number of Correct Answers (sample proportion, %)**



of teachers with different levels of education differ only slightly: 17.2 is the average number of correct answers given by teachers with two or more university degrees, 16.4 is the average for teachers with one university degree, and 15.8 is the average for teachers holding a Candidate of Sciences (PhD) or Doctor of Sciences degree. The average number of correct answers given by teachers with up to 3 years of work experience (17.6) is higher than that among more experienced teachers: 11 to 20 years of work experience — 16.3 correct answers on average, over 20 years — 15.8, from 4 to 10 years — 15.7. There are no significant differences in the results by scientific field in which the teacher works. Humanities teachers gave slightly more correct answers — the average number was 17.1, while social and medical sciences teachers on average gave 16.4 and 16.1 correct answers, respectively. Teachers of engineering and natural sciences gave the least number of correct answers — 15.4 and 15.3, respectively.

Table 1. **Average Number of Correct Answers in Groups of Respondents**

Groups of respondents		Average Number of Correct Answers
Education level	One university degree	16.4
	Two or more university degrees	17.2
	Candidate/Doctor of Sciences	15.8
Work experience	Up to 3 years	17.6
	4–10 years	15.7
	11–20 years	16.3
	Over 20 years	15.8

Groups of respondents		Average Number of Correct Answers
Scientific field	Medical sciences	16.1
	Humanities	17.1
	Engineering sciences	15.4
	Natural sciences	15.3
	Social sciences	16.4

3.1. The Most Popular Neuromyths

Respondents' evaluation of established scientific facts was mostly correct, and their evaluation of claims representing neuromyths was more often incorrect. Since these statements were false, by agreeing with them, respondents showed their belief in neuromyths. If they disagreed with the false statements, the answer was considered correct. Some statements proved particularly difficult to evaluate, with many respondents preferring not to answer. The most difficult questions turned out to be those about classical music (24.5%), multitasking (19.7%), storage locations for memories (16.3%), using only 10% of the brain, and left/right hemisphere dominance (14.3%) (Table 2).

Table 2. **Questions Most Frequently Answered Incorrectly by Respondents, %**

	Agree	Disagree	No answer
5. Individuals learn better when learning material is delivered in their preferred way to receive information (visual, auditory, or kinesthetic learner)	80.3	13.6	6.1
6. Differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners	69.4	16.3	14.3
10. Listening to classical music increases reasoning ability	59.2	16.3	24.5
3. Memory is stored in the brain as in a computer, that is, each memory goes into a tiny piece of the brain	55.1	28.6	16.3
4. In normal life, we only use 10% of our brains	44.9	40.8	14.3
17. Multitasking while studying increases productivity	38.1	42.2	19.7

Many respondents (80.3%) believed that individuals learn better when learning material is delivered in their preferred way to receive information (visual, auditory, or kinesthetic). There is no scientific evidence for the effectiveness of instruction delivered in students' preferred learning styles. Processes in different regions of the brain are so interconnected that when a person sees the word "bell" written, the auditory cortex is also activated in the brain. Moreover, it is difficult to imagine learning with only one — visual, auditory, or tactile — system in practice, in particular in disciplines such as physics or mathematics where memorization of formulas plays an important role [OECD, 2002].

The assertion that differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners is also false. Meanwhile, 69.4% of respondents believed in it and 14.3% could not decide and chose not to answer. There is indeed a concept of specialization of each brain hemisphere in particular ways of information processing and on this basis, it is concluded that the dominance of the left or right hemisphere determines an individual's way of thinking and personality [OECD, 2002]. In reality, however, brain activity at any given moment engages all regions of the brain to some extent. Most everyday tasks, including learning, require many regions in both hemispheres to work together [Howard-Jones, 2017].

There is solid scientific evidence that listening to classical music has no impact on reasoning ability. In our survey, only 16.3% of respondents evaluated this statement correctly, with 24.5% choosing not to answer. Several studies have found an association between learning to play musical instruments in childhood and the plasticity of the brain at a more mature age. Learning to play a musical instrument has also been shown to improve cognitive skills in the long run. However, studies from the 2000s have found no significant effect of listening to music on performance, nor have they supported the assumption that Mozart's music can improve spatial reasoning abilities in children and adults [Pietschnig, Voracek, Formann, 2010; Waterhouse, 2006; McKelvie, Low, 2002]. The results of the meta-analysis clearly show the invalidity of all theories claiming that musical training improves cognitive skills or academic achievement in a particular scientific field [Sala, Gobet, 2019].

More than half of respondents (55.1%) agreed with the statement that each memory is stored in an individual tiny piece of the brain. This is a neuromyth because complex cognitive abilities, such as memory and attention, as well as learning in a specific domain, for instance, languages or mathematics, are distributed across all regions of the brain as complex networks [Battaglia et al., 2011].

The idea that in normal life, we only use 10% of our brains is believed by 44.9% of university teachers, and almost as many (40.8%) evaluate it as false. This assertion is not supported by any scientific evidence. Instead, research has clearly shown that we use 100% of our brains. No region in the brain can be damaged without impairing a person's mental or physical functions. Studies using electrical stimulation of different brain regions prove that no brain region is completely inactive, even during sleep [OECD, 2002].

The idea of multitasking while learning is still alive, with 38.1% of our respondents believing that performing multiple tasks simultaneously while studying increases productivity. However, constantly shifting attention from one task to another requires increased mental effort, potentially incurring a loss of information on the pre-

vious task in working memory. Thus, a person performs two tasks worse than one [Sousa, 2011].

We analyzed the respondents' evaluations of the six statements that were most frequently rated incorrectly within groups of respondents differing by education level, work experience, and scientific field, and identified the proportion of those who answered correctly out of the total number of respondents in each group (Appendix 3). Correct answers were most often given by respondents with up to 3 years of work experience, incorrect answers — by teachers with 4 to 10 years of work experience. Those who held two or more university degrees made mistakes least often, while respondents holding a Candidate or Doctor of Sciences degree gave incorrect answers more often than others. However, all the abovementioned differences can be considered insignificant. No differences in belief in neuromyths between professionals from different scientific fields were revealed.

The study participants chose the "No answer" option relatively often: more than 20% of natural and engineering sciences teachers answered this way when evaluating the most popular neuromyths. This is a meaningful choice, as it indicates the difficulty of making a decision and suggests a de facto larger proportion of respondents who believe in particular neuromyths. The neuromyths about multitasking and classical music were the most difficult to evaluate for respondents from all scientific fields (Appendix 4).

3.2. Respondents' Self-assessment of Awareness of Educational Neurobiology and Neurotechnologies

Most respondents believed that university teachers need to know how the brain develops and functions ("strongly agree" — 31.3%, "agree" — 43.5%). In their opinion, knowledge about brain function could help to effectively organize the learning process ("strongly agree" — 32%, "agree" — 44.9%).

Assessing their own knowledge in educational neurobiology and neurotechnologies, 6.1% of respondents indicated that they had experience in this field, the majority (72.8%) had only a cursory idea of it, and 21.1% did not have any experience in this field at all. According to their self-assessments, respondents with medical education, Candidate or Doctor of Sciences degrees, and over four years of work history most often had experience in educational neurobiology and neurotechnologies. A cursory idea of educational neurobiology and neurotechnologies was mostly reported by social sciences teachers, while humanities teachers had no experience in this field at all (Appendix 5).

The majority of respondents (89.1%) had never used programs and neurotechnologies for brain training, such as Wikium, Cognifit, Lumosity, Elevate, or games with the Neuroplay headset. They were used by some medical sciences teachers (10.2%); users of these tools were most likely to be found among respondents who

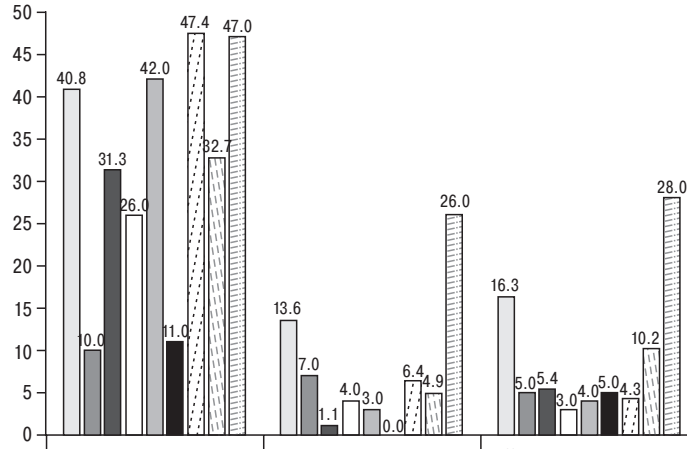
had one university degree or a Candidate/Doctor of Sciences degree, regardless of work experience.

When asked about their willingness to gain additional knowledge about neurotechnologies and learn how to apply them in professional practice, 79.6% of the respondents answered positively and 12.9% chose not to answer.

3.3. Comparing Data on Belief in the Most Popular Neuromyths from Different Studies

The results of Russian and foreign studies conducted between 2009 and 2021 show a high prevalence of neuromyths among educators in different countries. Most often, respondents fail to correctly assess the following three neuromyths: "differences in hemispheric dominance can help explain individual differences among learners"; "in normal life, we only use 10% of our brains"; "individuals learn better when learning material is delivered in their preferred way to receive information" (Figure 2). In the international study of 2019, 28% of respondents correctly rated the assertion about left/

Figure 2. **Comparison of the Evaluations of Three Neuromyths by Russian and Foreign Educators**

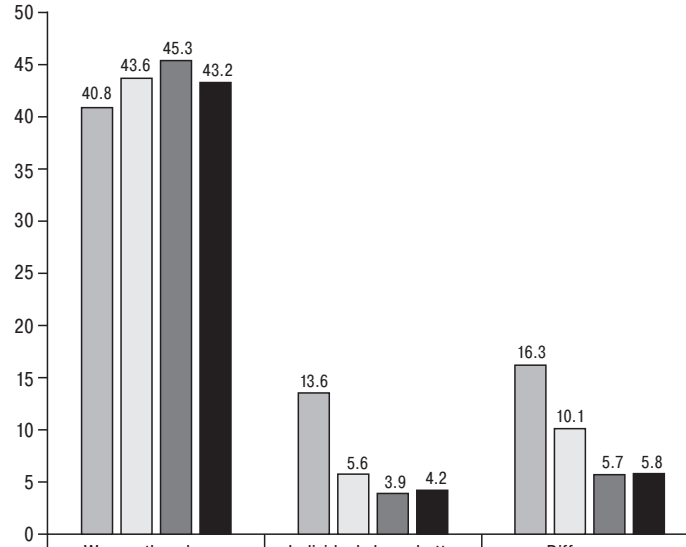


	We mostly only use 10% of our brains	Individuals learn better when they receive information in their preferred learning style (VAK)	Differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners
Results of this study	40.8	13.6	16.3
UK (2009)	10.0	7.0	5.0
Turkey (2014)	31.3	1.1	5.4
Dorset, UK (2012)	26.0	4.0	3.0
Netherlands (2012)	42.0	3.0	4.0
Greece (2014)	11.0	0.0	5.0
China (2019)	47.4	6.4	4.3
Spain (2016)	32.7	4.9	10.2
International study (2019)	47.0	26.0	28.0

right hemisphere dominance as a possible explanation of individual differences between learners, 47% — the myth about using only 10% of the brain, and 26% — the myth about receiving information in the preferred learning style. The least number of correct answers about using only 10% of our brains were given by novice teachers in the UK (10%), about hemispheric dominance — by teachers in Greece (0%), and about receiving information in the preferred learning style — by UK teachers in the county of Dorset (3%). The university teachers participating in our study showed relatively high results: the statement about using only 10% of the brain was correctly classified as a neuromyth by 40.7% of respondents, the statement about the hemispheric dominance as a cause of individual differences was correctly rated by 16.3%, and the statement about receiving information in the preferred learning style — by 13.6%.

In a recent study on neuromyths in education, Russian preschool, primary school, and secondary school teachers were asked to evaluate several statements from neurobiology [Bezrukikh, Ivanov, Orlov, 2021]. Figure 3 compares the results of our study conducted

Figure 3. **Comparison of the Evaluations of Three Neuromyths by Russian University, School and Preschool Teachers**



	We mostly only use 10% of our brains	Individuals learn better when they receive information in their preferred learning style (VAK)	Differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners
Results of this study	40.8	13.6	16.3
Preschool teachers	43.6	5.6	10.1
Primary school teachers	45.3	3.9	5.7
Secondary school teachers	43.2	4.2	5.8

among university teachers with the results of a survey of school and preschool teachers. No significant difference was found in the number of correct answers about using only 10% of our brains between teacher groups. When evaluating the other two neuromyths, faculty members gave more correct answers than school and preschool teachers. Regardless of the education level, both university faculty and school and preschool teachers were most often wrong when evaluating assertions about hemispheric dominance as a possible cause of individual differences and about the effectiveness of receiving information in the preferred learning style. The results of Russian school teachers are similar to those obtained in foreign studies.

4. Conclusion and Discussion

The relevance of the study stems from the rapid spread of neuromyths in the education system. The purpose of the study was to analyze to what extent Russian university teachers tend to believe in neuromyths. The review of previous studies has shown that neuromyths are ingrained in the minds of a significant part of university teachers from different countries. The survey of Russian university teachers confirmed our hypothesis: in the Russian teaching community, the prevalence of belief in neuromyths is close to that among university teachers in foreign educational institutions.

Research shows that basic knowledge of brain function helps to recognize neuromyths. Meanwhile, a lack of general understanding of brain function patterns and a lack of critical thinking when reading the scientific literature predisposes one to believe in neuromyths.

When evaluating the truthfulness of various statements about brain function, university teachers most often made mistakes when it came to neuromyths. They were more confident when rating statements based on valid scientific research and more hesitant to choose an answer when rating neuromyths, thus demonstrating critical thinking skills. Correctly evaluating a neuromyth is problematic due to its wording, as a neuromyth is a misinterpreted finding from scientific research. The respondent's ability to recognize its falsity depends on their experience in applying scientific research in practice, and on their awareness of neurobiology.

Researchers' opinions on the effect of the spread of neuromyths in education on learning are contradictory. Assessing the impact of university teachers' belief in specific neuromyths on the effectiveness of the educational process is one of the promising research directions. The results of various surveys show that teaching practice already incorporates techniques and methods based on the neuromyths of hemispheric dominance as a possible cause of individual differences between learners and the effectiveness of receiving information in the preferred learning style. The use of these tech-

niques and methods without conducting scientific research on their impact on learning outcomes cannot be considered reasonable.

The findings on the prevalence of neuromyths suggest the need to disseminate scientific information dispelling them, widely publicize findings from educational neurobiology and information about its impact on learning, and enhance the professional competence of teachers in this field.

Appendix 1 Questions Adapted for This Study

Adapted Questions	Questions from Foreign Studies	Neuromyth/ Fact	Authors
1. We use our brains 24 hours a day	We use our brains 24 hours a day	Fact	Howard-Jones et al., 2009; Dekker et al., 2012; Deligiannidi, Howard-Jones, 2015; Ferrero, Garaizar, Vadillo, 2016; Betts et al., 2019
2. To learn how to do something, it is necessary to pay attention to it	To learn how to do something, it is necessary to pay attention to it	Fact	Howard-Jones et al., 2009; Deligiannidi, Howard-Jones, 2015; Betts et al., 2019
3. Memory is stored in the brain as in a computer, that is, each memory is goes into a tiny piece of the brain	Memory is stored in the brain much like as in a computer. That is, each memory goes into a tiny piece of the brain	Neuromyth	Howard-Jones et al., 2009; Deligiannidi, Howard-Jones, 2015
4. In normal life, we only use 10% of our brains	We mostly only use 10% of our brains	Neuromyth	Howard-Jones et al., 2009; Dekker et al., 2012; Karakus, Howard-Jones, Jay, 2015; Deligiannidi, Howard-Jones, 2015; Ferrero, Garaizar, Vadillo, 2016; Zhang et al., 2019; Betts et al., 2019
5. Individuals learn better when learning material is delivered in their preferred way to receive information (visual, auditory, or kinesthetic learner)	Individuals learn better when they receive information in their preferred learning style (e.g. visual, auditory, kinaesthetic)	Neuromyth	
6. Differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners	Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners	Neuromyth	
7. Problems associated with the development of brain functions cannot be fixed by education	Learning problems associated with developmental differences in brain function cannot be improved by education	Neuromyth	
8. Physical exercise can improve mental function	Vigorous exercise can improve mental function	Fact	Howard-Jones et al., 2009; Dekker et al., 2012; Deligiannidi, Howard-Jones, 2015; Ferrero, Garaizar, Vadillo, 2016
9. Production of new connections in the brain can continue into old age	Production of new connections in the brain can continue into old age	Fact	Howard-Jones et al., 2009; Dekker et al., 2012; Deligiannidi, Howard-Jones, 2015; Ferrero, Garaizar, Vadillo, 2016; Betts et al., 2019

Adapted Questions	Questions from Foreign Studies	Neuromyth/ Fact	Authors
10. Listening to classical music increases reasoning ability	Listening to classical music increases reasoning ability	Neuromyth	Dekker et al., 2012; Betts et al., 2019
11. Normal development of the human brain involves the birth and death of brain cells	Normal development of the human brain involves the birth and death of brain cells	Fact	
12.Rereading course materials is an effective strategy for learning	Rereading course materials is an effective strategy for learning	Neuromyth	Betts et al., 2019
13. Testing knowledge tends to distract from learning	Testing, in general, tends to detract from learning	Neuromyth	
14. Human brains are as unique as fingerprints	Human brains are relatively as unique as fingerprints	Fact	
15. Out of large amounts of information, the brain helps us choose and focus on what is important	The brain acts as a filter to help us to pay attention to what is important	Fact	
16. Graphical representation of course materials can enhance learning	Decorative graphics can enhance learning when applied to course materials	Fact	
17. Multitasking while studying increases productivity	Multitasking while studying increases productivity	Neuromyth	
18. You can train certain parts of the brain to improve their functioning	You can train certain parts of the brain to improve their functioning	Fact	
19. Metacognition plays an important role in learning	Metacognition plays a role in learning	Fact	
20. Repeated rehearsal of learned material will help to consolidate it in long-term memory	Repeated practice and rehearsal of learned material or a skill will help to consolidate it in long-term memory	Fact	
21. Meaningful feedback accelerates learning	Meaningful feedback accelerates learning	Fact	
22. Stress can impair the ability of the brain to encode and recall memories	Stress can impair the ability of the brain to encode and recall memories	Fact	
23. A positive atmosphere in the classroom is important for learning	Maintaining a positive atmosphere in the classroom helps promote learning	Fact	
24. Explaining the purpose of a learning activity helps engage students in that activity	Explaining the purpose of a learning activity helps engage students in that activity	Fact	
25. Emotions can affect human cognitive processes, including attention, memory, reasoning, and problem-solving	Emotions can affect human cognitive processes, including attention, learning and memory, reasoning, and problem-solving	Fact	

Appendix 2 Statistics of Respondents' Answers

Question	Neuromyth/Fact	Proportion of correct answers (%)
We use our brains 24 hours a day	Fact	61.9
To learn how to do something, it is necessary to pay attention to it	Fact	84.4
Memory is stored in the brain as in a computer, that is, each memory goes into a tiny piece of the brain	Neuromyth	28.6
In normal life, we only use 10% of our brains	Neuromyth	40.8
Individuals learn better when learning material is delivered in their preferred way to receive information (visual, auditory, or kinesthetic learner)	Neuromyth	13.6
Differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners	Neuromyth	16.3
Problems associated with the development of brain functions cannot be fixed by education	Neuromyth	51.0
Physical exercise can improve mental function	Fact	89.0
Production of new connections in the brain can continue into old age	Fact	78.9
Listening to classical music increases reasoning ability	Neuromyth	16.3
Normal development of the human brain involves the birth and death of brain cells	Fact	66.7
Rereading course materials is an effective strategy for learning	Neuromyth	12.2
Testing knowledge tends to distract from learning	Neuromyth	67.3
Human brains are as unique as fingerprints	Fact	88.4
Out of large amounts of information, the brain helps us choose and focus on what is important	Fact	83.0
Graphical representation of course materials can enhance learning	Fact	85.7
Multitasking while studying increases productivity	Neuromyth	42.2
You can train certain parts of the brain to improve their functioning	Fact	76.2
Metacognition plays an important role in learning	Fact	61.9
Repeated rehearsal of learned material will help to consolidate it in long-term memory	Fact	84.4
Meaningful feedback accelerates learning	Fact	95.2
Stress can impair the ability of the brain to encode and recall memories	Fact	87.8
A positive atmosphere in the classroom is important for learning	Fact	96.6
Explaining the purpose of a learning activity helps engage students in that activity	Fact	91.8
Emotions can affect human cognitive processes, including attention, memory, reasoning, and problem-solving	Fact	95.2

Appendix 3 Evaluations of Six Neuromyths in Groups of Respondents Differing by Scientific Field, Education Level, and Work Experience (proportion of correct answers, %)

Statement	Scientific field					Education level			Work experience			
	Medical sciences	Humanities	Engineering sciences	Natural sciences	Social sciences	One university degree	Two or more university degrees	Candidate/ Doctor of Sciences	Up to 3 years	4–10 years	11–20 years	Over 20 years
3. Memory is stored in the brain as in a computer, that is, each memory goes into a tiny piece of the brain	27.5	30.3	36.4	19.2	33.3	30.0	39.1	25.5	41.7	25.0	28.9	27.6
4. In normal life, we only use 10% of our brains	29.4	54.5	50.0	38.5	40.0	40.0	56.5	37.2	66.7	28.1	53.3	32.8
5. Individuals learn better when learning material is delivered in their preferred way to receive information (visual, auditory, or kinesthetic learner)	5.9	21.2	18.2	11.5	20.0	13.3	30.4	9.6	25.0	9.4	8.9	17.2
6. Differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners	9.8	24.2	18.2	7.7	33.3	16.7	26.1	13.8	41.7	9.4	15.6	15.5
10. Listening to classical music increases reasoning ability	5.9	18.2	50.0	7.7	13.3	26.7	17.4	12.8	41.7	21.9	8.9	13.8
17. Multitasking while studying increases productivity	33.3	51.5	36.4	30.8	80.0	30.0	60.9	41.5	58.3	37.5	40.0	43.1

Appendix 4 Distribution of the Three Response Types in the Evaluations of Neuromyths by Respondent Groups Differing by Scientific Field (%)

Statements	Responses	Medical sciences	Humanities	Engineering sciences	Natural sciences	Social sciences
3. Memory is stored in the brain as in a computer, that is, each memory goes into a tiny piece of the brain	Agree	60.8	54.5	45.5	57.7	46.7
	Disagree	27.5	30.3	36.4	19.2	33.3
	No answer	11.8	15.2	18.2	23.1	20.0

Statements	Responses	Medical sciences	Humanities	Engineering sciences	Natural sciences	Social sciences
4. In normal life, we only use 10% of our brains	Agree	51.0	42.4	40.9	38.5	46.7
	Disagree	29.4	54.5	50.0	38.5	40.0
	No answer	19.6	3.0	9.1	23.1	13.3
5. Individuals learn better when learning material is delivered in their preferred way to receive information (visual, auditory, or kinesthetic learner)	Agree	90.2	72.7	72.7	80.8	73.3
	Disagree	5.9	21.2	18.2	11.5	20.0
	No answer	3.9	6.1	9.1	7.7	6.7
6. Differences in hemispheric dominance (left brain or right brain) can help explain individual differences among learners	Agree	74.5	69.7	59.1	73.1	60.0
	Disagree	9.8	24.2	18.2	7.7	33.3
	No answer	15.7	6.1	22.7	19.2	6.7
7. Problems associated with the development of brain functions cannot be fixed by education	Agree	31.4	27.3	36.4	38.5	40.0
	Disagree	56.9	54.5	40.9	46.2	46.7
	No answer	11.8	18.2	22.7	15.4	13.3
10. Listening to classical music increases reasoning ability	Agree	76.5	54.5	18.2	57.7	73.3
	Disagree	5.9	18.2	50.0	7.7	13.3
	No answer	17.6	27.3	31.8	34.6	13.3
13. Testing knowledge tends to distract from learning	Agree	23.5	18.2	22.7	11.5	26.7
	Disagree	70.6	69.7	63.6	65.4	60.0
	No answer	5.9	12.1	13.6	23.1	13.3
17. Multitasking while studying increases productivity	Agree	47.1	36.4	40.9	34.6	13.3
	Disagree	33.3	51.5	36.4	30.8	80.0
	No answer	19.6	12.1	22.7	34.6	6.7

Appendix 5 Respondents' Self-assessment of Awareness of Educational Neuroscience and Neurotechnologies (%)

Scientific field	Total	Education level			Work experience			
		One university degree	Two or more university degrees	Candidate/Doctor of Sciences	Over 20 years	11–20 years	4–10 years	Up to 3 years
Have experience in this field								
Medical sciences	11.8			11.8	3.9	3.9	3.9	
Engineering sciences	9.1			9.1	4.5	4.5		
Natural sciences	3.8			3.8			3.8	
Have a cursory idea								
Medical sciences	70.6	13.7		56.9	23.5	27.5	13.7	5.9
Engineering sciences	63.6	27.3	9.1	27.3	18.2	18.2	18.2	9.1
Natural sciences	73.1	19.2	15.4	38.5	42.3	15.4	15.4	

Scientific field	Total	Education level			Work experience			
		One university degree	Two or more university degrees	Candidate/Doctor of Sciences	Over 20 years	11–20 years	4–10 years	Up to 3 years
Humanities	75.8	12.1	30.3	33.3	27.3	24.2	18.2	6.1
Social sciences	86.7		20.0	66.7	26.7	40.0	13.3	6.7
Have no experience in this field								
Medical sciences	17.6	2.0	2.0	13.7	9.8	3.9	3.9	
Engineering sciences	27.3	18.2		9.1	4.5	9.1	4.5	9.1
Natural sciences	23.1	3.8	3.8	15.4	15.4		3.8	3.8
Humanities	24.2	6.1	3.0	15.2	12.1	6.1	3.0	3.0
Social sciences	13.3		6.7	6.7	6.7		6.7	

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