Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

EDUCATIONAL SCIENCES

Research article

UDC 159.9.07

doi

Performance on State Exams in the Russian Language and Indicators of Cognitive Development: A Cross-Cultural Analysis of Relationships

Yury P. Zinchenko[1], Igor V. Gaidamashko[2], Sergey B. Malykh[3], Tatiana N. Tikhomirova✉
[1, 3, 4] Psychological Institute, Russian Academy of Education, Moscow, Russian Federation
[1, 3, 4] Lomonosov Moscow State University, Moscow, Russian Federation
[2, 3, 4] Russian Academy of Education, Moscow, Russian Federation
[2] MIREA – Russian Technological University, Moscow, Russian Federation

✉ tikho@mail.ru

Abstract

Introduction. The relationship between indicators of cognitive development and the performance on state exams varies depending on whether or not the language of instruction is different from the student's native language, as well as the effectiveness of the national educational system. This study is a first attempt to examine universal and specific patterns of correlation between cognitive development and the success of learning the Russian language among native and non-native Russian-speaking students under different educational conditions. **Methods**. The study involved 899 public school graduates from the Kyrgyz Republic, the Republic of Moldova, and the Russian Federation. The language of instruction was Russian. The sample comprised native and non-native Russian-speaking students, of whom 63.7 % were females (mean age = 17.6 years, SD = 0.5). Statistical analysis was performed in the form of correlation analysis and ANOVA. **Results**. The findings indicated that the relationship between non-verbal intelligence and state exam performance is universal and manifests itself in various educational environments and language contexts. Along with intelligence, visuospatial working memory was only actualized in more favorable educational environments, when the student's native language was not different from the language of instructionat school. Information processing speed was of specific importance in the process of learning the Russian language by non-native Russian-speaking students, regardless of whether they were native speakers of Romance or Turkic languages. **Discussion**. The results were interpreted within the context of the resource theory of individual human achievements. The conclusion is drawn that the structure of the relationship between cognitive development and the performance in the Russian language state examinations differs for native and non-native Russian-speaking schoolchildren, even after eleven years of schooling in Russian.

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

Keywords
cognitive development, learning success, Russian language, native language, language of instruction, state exam, information processing speed, visuospatial working memory, non-verbal intelligence, high school education

Highlights
- Information processing speed was of specific importance in the process of learning the Russian language by non-native Russian-speaking students, regardless of whether they were native speakers of Romance or Turkic languages.
- Non-verbal intelligence was interrelated with the score on the Russian language state exam in various educational environments, with stronger relationships observed for schoolchildren, whose native language was different from the language of instruction at school.
- Visuospatial working memory was actualized in the structure of interrelationships with state exam performance only in more favorable educational environments.

Funding
The study was supported by the Russian Science Foundation, project no. 17-78-30028.

For citation
Zinchenko, Yu. P., Gaidamashko, I. V., Malykh, S. B., & Tikhomirova, T. N. (2022). Performance on state exams in the Russian language and indicators of cognitive development: A cross-cultural analysis of relationships. *Russian Psychological Journal*, *19*(1), 34–48. https://doi.org/10.21702/rpj.2022.1.3

Introduction
The study of performance in state examinations in the Russian language in various educational and cultural contexts is an urgent task aimed at solving the fundamental scientific problem of the relationship between development and learning, and is also associated with the socially significant task of teaching schoolchildren for whom Russian is a non-native language.

The present social situation makes relevant the scientific search for environmental conditions and individual resources that contribute to the successful education of non-native Russian-speaking schoolchildren as an integral part of global migration processes. However, it limits this search to the language context, as school education is conducted in Russian only in several countries, namely, the former republics of the Soviet Union (Verbitskaya, Zinchenko, Malykh, & Tikhomirova, 2017).

In these countries, as well as in the Russian Federation, the successful completion of the final Russian language exam is the most important educational stage in the life of a school graduate and determines his/her further educational trajectory (Verbitskaya, Malykh, Zinchenko, & Tikhomirova, 2015). Final exams in the Russian language, held in different countries, are standardized and, as a rule, are aimed at assessing the amount of school knowledge acquired by a graduate in accordance with the national educational standard.

Of all indicators of cognitive development that are important for successful learning of the Russian language, including as a non-native language, intelligence, information processing speed, and working memory are well studied (Zinchenko, Gaidamashko, Malykh, Kalmyk, & Tikhomirova,

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

2020; Tikhomirova, Malykh, & Malykh, 2020; Huettig & Janse, 2016; Linck, Osthus, Koeth, & Bunting, 2014; Kempe, Brooks, & Kharkhurin, 2010; etc.).

Research almost unanimously reports on the paramount importance of intelligence in the formation of individual differences in schooling, including the Russian language (Verbitskaya, Malykh, & Tikhomirova, 2017; Deary, Strand, Smith, & Fernandes, 2007; and others). These data were confirmed in studies involving Russian schoolchildren and their Kyrgyz peers who study in Russian throughout their entire school period (Verbitskaya et al., 2017). It is noted that it is nonverbal intelligence, which is associated with the effective solution of tasks based on abstract stimuli that contributes to higher achievements in learning Russian as both a native and non-native language (Verbitskaya et al., 2017).

Working memory, according to studies and their meta-analyses, is important for the acquisition and improvement of oral and written skills both in the native language and in the study of a second language (Verbitskaya et al., 2020; Linck et al., 2014; Kempe et al., 2010; etc.). It was shown that a more developed visuospatial memory, which is associated with the ability to retain small fragments of information about the shape of stimuli and their localization in space, leads to more success in the acquisition of skills and the accumulation of knowledge related to language (Verbitskaya et al., 2020; Frenken et al., 2016).

Controversial results were obtained for information processing speed as an indicator of cognitive development in the context of its interrelationship with the learning success. On the one hand, the importance of individual reaction time during processing of syntactic units of language, the speed of retrieval from long-term memory, and further understanding of the meaning of this syntactic unit is postulated (Huettig & Janse, 2016). On the other hand, only indirect relationship between reaction time and overall academic success through higher-order cognitions are reported (Tikhomirova et al., 2020).

Formulation of the problem

However, the strength, and in some cases, the direction of the relationship between indicators of cognitive development and the learning success at school can change (based on teacher assessments and on individual results of standardized tasks in subjects). The effectiveness of the national educational system (Verbitskaya et al., 2020; Nisbett et al., 2012; Brouwers, Van de Vijver, & Van Hemert, 2009) and the coincidence of the students' native language with the language of instruction at school (Zinchenko et al., 2020; Verbitskaya et al., 2017; Oh, 2016) are cited as the main modulators of the correlation between cognitive development and learning success in school disciplines, including languages.

The quality of the national education system can lead to differences in the relationship between cognitive indicators and learning success, including learning language (Tikhomirova & Malykh, 2017; Tucker-Drob & Bates, 2016). Thus, according to a meta-analysis involving more than 240,000 respondents from 45 countries, such cross-cultural differences are associated with the specifics of national education systems to an even greater extent ($r = 0.25$ vs. $r = 0.16$; $p < 0.001$) than with social – economic status (Brouwers et al., 2009). Moreover, in studies involving Russian schoolchildren, it was shown that indicators of cognitive development turn out to be "sensitive" to varying degrees to the characteristics of the educational environment: from high educational influences on non-verbal intelligence to a minimum influence on information processing speed (Tikhomirova & Malykh, 2017). At the same time, the higher efficiency of the national education system and its

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

uniformity lead to an increase in the role of the cognitive development of the student in the success of mastering the educational programs (Tucker-Drob & Bates, 2016).

Whether a student's native language does or does not coincide with the language of instruction at school plays an important role in shaping the relationship between cognitive development and academic success (Verbitskaya et al., 2017). Studies related to the specifics of learning Russian as a non-native language report a large increase in cognitive resources necessary to achieve academic success by schoolchildren for whom Russian is not their native language (Zinchenko et al., 2020). These data are explained in the context of the resource theory of individual human achievements, according to which the tightness and number of interrelations of cognitive development indicators determine the power of a person's cognitive resource (Druzhinin, 2007).

This study aims to assess the specifics of the relationship between cognitive development and the performance in Russian language state exams in various educational systems and language contexts. The analysis is carried out on samples of eleventh-graders with Russian as both native and non-native language from public schools in Kyrgyzstan, Moldova and Russia.

The choice of these countries is due to the similarities in the organization of educational process and differences in the effectiveness of the functioning of the national educational system. According to the international rating of the United Nations Development Program 2020, based on the achievements of the states in three areas of development – health, education, and living conditions – Russia is included in the group of countries with a very high level of human development (52nd place), and Kyrgyzstan with an average level (120th place). It should be emphasized that in Moldova this study was conducted in schools in the city of Tiraspol on the territory of the unrecognized Pridnestrovian Moldavian Republic, which is characterized by a very low socio-economic status and, as a result, the low efficiency of the national education system.

These cross-cultural similarities and differences, as well as the inclusion of students with Russian as their native and non-native languages, made it possible to formulate universal and specific patterns of correlation between cognitive development and the success of learning Russian as a native and non-native language under different educational conditions.

Methods

Sample

The study involved 899 public school graduates from the Kyrgyz Republic, the Republic of Moldova, and the Russian Federation, with Russian as the language of instruction.

During the whole schooling period, the participants were instructed in the Russian language in one Russian school (Moscow region), one Kyrgyz school (Bishkek) and two Moldovan schools (Tiraspol), which were similar in terms of the qualifications of the teaching staff, the compliance of curricula in the Russian language, rating positions in the region, etc. (for more details, see Verbitskaya et al., 2020).

Samples from Kyrgyzstan and Moldova were formed in such a way that they included both students for whom Russian was their native language and, accordingly, coincided with the language of instruction at school, and students for whom Russian was a non-native language (Kyrgyz or Moldovan), but from the first grade, these children were taught in Russian. The sample from Russia was formed only from Russian-speaking eleventh-graders.

Thus, the sample of participants from the Kyrgyz Republic (Bishkek) included 169 Russian-speaking schoolchildren (mean age = 17.6 years; SD = 0.6 years; 66.5 % of girls) and 196 Kyrgyz-speaking

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

schoolchildren (mean age = 17.8 years; SD = 0.5 years; 64.3 % of girls).

The sample of participants from Moldova (Tiraspol, unrecognized Pridnestrovian Moldavian Republic) comprised 152 Russian-speaking students (mean age = 17.3 years; SD = 0.6 years; 68 % of girls) and 151 Moldovan-speaking students (mean age = 17.6 years; SD = 0.4 years; 61.3 % of girls).

The sample from Russia comprised 231 Russian-speaking schoolchildren (mean age = 17.6 years; SD = 0.4 years; 58.4 % of girls).

Course of study

The study of cognitive development was conducted at the end of the eleventh grade, and the state exam performance was assessed two months later. The informed consent of parents and representatives of the school administration was obtained for the participation of schoolchildren. Data collection was carried out in the computer science class of an educational institution strictly according to the developed protocol under the supervision of a researcher. Data analysis was carried out using depersonalized data.

Methods

Cognitive development

Indicators of cognitive development – information processing speed and visuospatial working memory – were measured using computerized tasks grouped into a test battery (Tikhomirova & Malykh, 2017). Non-verbal intelligence was assessed using the Standard Progressive Matrices test in printed form (Raven, Kurt, Raven, 2009).

Information processing speed was assessed using the Choice Reaction Timetest with 4 possible answers (Tikhomirova, Kuzmina, & Malykh, 2020). During the test, the numbers 1, 2, 3, 4 appeared on the computer screen 40 times with random intervals ranging from 1 to 3 seconds. The task of the participant was to press the key, which corresponded to the number shown on the screen as quickly and as accurately as possible. The participants had 8 seconds to provide an answer. The accuracy of the answer (correctly or incorrectly pressed key) and the reaction time for each answer were recorded. Correct answers were included into the statistical analysis as scores for reaction time.

Assessment of visuospatial working memory was carried out using the Sequences test, based on the classic Corsi Block-Tapping Test (Tikhomirova, 2017). Sequences of cubes were presented on the computer screen, which 'lighted up' one after the other with an interval of 1 second. The minimum number of elements in the sequence was 4, the maximum was 9. The participant's task was to repeat the order in which cubes 'lighted up' using a computer mouse. The total number of correct answers was included into the statistical analysis.

Non-verbal intelligence was assessed using the Standard Progressive Matrices test in printed form (Raven et al., 2009). The test consisted of 60 tasks grouped into 5 series. Tasks became progressively more difficult within each series, as well as from series to series. The task of the participant was to choose the missing element of the matrix from 6 or 8 proposed options. The number of correct answers for the entire test was included into the statistical analysis.

Performance on the Russian language state examination

The test scores on the state exam were used as indicators of performance – the Unified State Exam for Russian graduates, the National Testing for Kyrgyz graduates and the Unified State Exam

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

for school graduates in the territory of the unrecognized Pridnestrovian Moldavian Republic.

The Unified State Examination in Russia (USE) is a set of standardized test tasks, which assess the graduate's level of knowledge of school material, according to the federal state educational standard of Russia. The USE Russian language exam is mandatory for all graduates of Russian schools.

The Unified State Examination in Tiraspol (USE) is analogous to the Russian USE and is designed to assess the level of graduate's mastery of basic educational programs of state's educational standard. The language test in USE is mandatory, but the graduate can choose between Russian, Moldovan or Ukrainian languages. The study analyzed the results of the Unified State Examination in the Russian language, taken by both Russian-speaking and Moldovan-speaking schoolchildren.

The Republic-Wide Test is a series of standardized test tasks aimed at identifying the most capable high school students for further education at universities in Kyrgyzstan. A graduate can choose to take the test in Russian, Kyrgyz or Uzbek languages. The study analyzed the score on the main test in Russian, taken by both Russian-speaking and Kyrgyz-speaking students.

Statistical analysis

In the first phase of the analysis, descriptive statistics were calculated based on the measurements of indicators of cognitive development and the level of performance in the Russian language state exams in the studied groups of school graduates.

During the second phase, a one-way analysis of variance was carried out to understand the differences in indicators of cognitive functioning between all the studied groups of school graduates: 1) Russian speakers from Kyrgyzstan, 2) Kyrgyz speakers from Kyrgyzstan, 3) Russian speakers from Moldova, 4) Moldovan speakers from Moldova and 5) Russian speakers from Russia. The Bonferroni correction was applied during the comparison between different groups. Analysis of variance was also carried out within the groups of Kyrgyz and Moldovan schoolchildren to assess the differences in the performance on the Russian language state exam, depending on whether or not the language of instruction was different from their native language.

During the third phase, a correlation analysis was carried out between the indicators of cognitive development and the score on the Russian language state exam in order to study general and specific patterns in these relationships.

Results

The study analyzed indicators of cognitive development (non-verbal intelligence, information processing speed, and visuospatial working memory) and performance on the Russian language state exam in groups of school graduates from Russia, Kyrgyzstan and Moldova.

Descriptive statistics

Table 1 presents the mean values and standard deviations (in brackets) of indicators of cognitive development and performance on the state exam in groups of Russian-, Moldovan- and Kyrgyz-speaking school graduates who studied for the entire school period in Russia, Moldova or Kyrgyzstan.

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

Table 1
Descriptive statistics of indicators of cognitivedevelopment and the Russian language state exam scores

	Moldova		Kyrgyzstan		Russia
	R	M	R	K	R
Non-verbal intelligence	48.55 (5.83)	47.02 (6.79)	48.67 (6.13)	46.82 (7.33)	52.17 (4.91)
Information processing speed	0.74 (0.17)	0.82 (0.17)	0.74 (0.19)	0.80 (0.19)	0.71 (0.24)
Visuospatial working memory	5.30 (1.93)	5.23 (2.16)	4.73 (2.51)	4.74 (2.41)	5.43 (2.05)
State exam score	38.30 (9.99)	37.72 (10.43)	173.31 (26.71)	162.91 (29.86)	72.08 (12.02)

Note: R – Russian-speaking schoolchildren, *M* – Moldovan-speaking schoolchildren, *K* – Kyrgyz-speaking schoolchildren.

Table 1 shows the average score for non-verbal intelligence and visuospatial working memory, which correspond to the number of correctly completed tasks on the Standard Progressive Matrices and the Sequences tests, respectively. Non-verbal intelligence test scores ranged from 0 to 60; working memory test scores ranged from 0 to 12. Information processing speed score was calculated as the average value of the reaction time for correct answers only in the Choice Reaction Time test. Lower reaction time corresponds to higher information processing speed.

According to Table 1, the average values for non-verbal intelligence and information processing speed appear to be somewhat higher in schoolchildren with Russian as their native language, when compared with non-native Russian-speaking students, regardless of the country in which the student studied. No such tendency was observed for working memory scores. However, Russian-speaking students studying in Russia, on average, scored higher than their peers from Moldova and Kyrgyzstan on all tests – Standard Progressive Matrices, Choice Response Time, and Sequences. Significant differences were assessed using the analysis of variance.

Possible state exams scores range from 0 to 100 for USE in Russia, 0 to 231 for the Republic-Wide Test in Kyrgyzstan and 0 to 57 for USE in Moldova.

Results of analysis of variance

One-way ANOVA was used to assess differences in non-verbal intelligence, information processing speed, and visuospatial working memory between the five analyzed groups of school graduates.

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

Table 2 presents the results of the analysis of variance, where different groups of schoolchildren were used as a categorical factor: 1) Russian speakers from Kyrgyzstan, 2) Kyrgyz speakers from Kyrgyzstan, 3) Russian speakers from Moldova, 4) Moldovan speakers from Moldova and 5) Russian speakers from Russia. Results of Levene's test showed the absence of differences in the distribution of all analyzed cognitive indicators for the compared groups ($p > 0.05$).

Table 2
Cognitive functioning differences among groups

	Sum of squares (SS)	Fisher's criterion (F)	Significance level (p)	Effect size (η^2)
Non-verbal intelligence	3125.08	19.59	0.000	0.09
Information processing speed	1.28	8.16	0.000	0.04
Visuospatial working memory	79.18	3.96	0.01	0.02

According to Table 2, statistically significant differences among the analyzed groups of school graduates were obtained for all indicators of cognitive development ($p < 0.01$).

The largest effect size of belonging to a group was found for non-verbal intelligence ($\eta^2 = 0.09$; $p = 0.000$). The results of multiple Bonferroni-corrected comparisons showed differences between schoolchildren studying in Russia and their peers studying in Kyrgyzstan and Moldova ($p < 0.001$). At the same time, no differences in intelligence were found between native and non-native Russian-speaking schoolchildren within individual countries. In particular, the average values of non-verbal intelligence of Russian-speaking and Kyrgyz-speaking schoolchildren who study for the entire school period in Kyrgyzstan do not differ ($p > 0.05$). A similar tendency is also observed when comparing the non-verbal intelligence of Russian-speaking and Moldovan-speaking graduates of schools in Moldova ($p > 0.05$).

Information processing speed differs among the analyzed groups of schoolchildren with an effect size of 4 % ($p = 0.000$). The results of multiple comparisons showed statistically significant differences between native and non-native Russian speaking schoolchildren, regardless of the country ($p < 0.05$). For example, the reaction time of Russian-speaking schoolchildren from Moldova (average reaction time of 0.74 seconds) is significantly higher than that of their Moldovan-speaking peers (average value of 0.82). At the same time, no differences were found among Russian-speaking schoolchildren from Russia, Kyrgyzstan and Moldova ($p > 0.05$). The average value of the reaction time of Russian-speaking graduates of Russian, Kyrgyz, and Moldovan schools was 0.71, 0.74, and 0.74 seconds, respectively.

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

Visuospatial working memory differs the least in the analyzed groups of schoolchildren (η^2 = 0.02; p < 0.05). Bonferroni-adjusted results of multiple comparisons showed insignificant differences only between schoolchildren from Russia and Kyrgyzstan, regardless of their native language (p < 0.05).

One-way ANOVA was carried out for performance on the Russian language state exam on samples of Kyrgyz and Moldovan schoolchildren, depending on whether or not the language of instruction was different from their native language. The results showed slight, but statistically significant, differences in the exam scores between native and non-native Russian-speaking students from Kyrgyzstan (model characteristics: SS = 9601.23; F = 11.85; p = 0.001; η^2 = 0.02). However, Russian-speaking and Moldovan-speaking schoolchildren studying in Moldova demonstrated no differences in scores on the Russian language exam (p > 0.05), which may be explained by the specifics of the national exam's test tasks.

Results of correlation analysis

Correlation analysis was used for each of the five analyzed groups of schoolchildren to study the relationship between the indicators of cognitive development – information processing speed, visuospatial working memory, and non-verbal intelligence – and Russian language state examination scores.

Table 3 shows the Spearman correlation coefficients between indicators of cognitive development and state examination scores in groups of native and non-native Russian-speaking schoolchildren from Kyrgyzstan, Moldova, and Russia (* p < 0.05; ** p < 0.01).

Table 3
Relationships between indicators of cognitive development and performance on the Russian language state exam

	Native language	Non-verbal intelligence	Information processing speed	Working memory
Kyrgyzstan	Russian	0.33**	0.01	0.08
	Kyrgyz	0.39**	–0.17*	0.07
Moldova	Russian	0.19*	–0.02	0.08
	Moldovan	0.21*	–0.12*	0.06
Russia	Russian	0.26**	–0.08	0.19*

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

According to Table 3, there are weak and moderate correlations between the indicators of cognitive development and final Russian language exam scores in all analyzed groups of schoolchildren ($0.39 > | r | > 0.12$; $p < 0.05$).

Of all indicators of cognitive development, non-verbal intelligence is correlated with exam scores the most. This relationship is typical for graduates of schools in Kyrgyzstan, Moldova, and Russia, regardless of their native language. The correlation is even higher in schoolchildren, whose native language does not coincide with the language of instruction at school. In particular, in a sample of Kyrgyz-speaking schoolchildren who study in Russian for the entire school period in Kyrgyzstan, the correlation coefficient of an examination score with non-verbal intelligence reaches a value of 0.39 at $p < 0.01$.

Visuospatial working memory is directly related to the exam scores in only one group of schoolchildren – native Russian-speaking graduates of Russian schools.

Information processing speed has a relationship with examination scores only in groups of non-native Russian-speaking graduates from Kyrgyz and Moldovan schools. In particular, in the group of Kyrgyz-speaking and Moldovan-speaking schoolchildren, the reaction time is inversely proportional to the state exam score – the longer the reaction time, and, accordingly, the slower the student, the lower the state exam score is. However, we should notethat the correlation analysis does not give grounds to assume the direction of the relationship between cognitive development and learning outcomes, which will be taken into account when interpreting the results.

In general, the largest number of relationships with the exam scores was obtained for non-verbal intelligence (all groups of schoolchildren), the smallest – for visuospatial working memory (only in the group of Russian schoolchildren). The relationship between information processing speed and the examination scores turned out to be unique for the groups of Moldovan- and Kyrgyz-speaking schoolchildren, whose native language is different from the language of instruction at school.

Discussion

Of all indicators of cognitive development, non-verbal intelligence varied the most among the groups of school graduates from different countries, regardless of their native language. This result is consistent with data on the directly proportional effect of the quality of national education on individual results on the Standard Progressive Matrices intelligence test (Tikhomirova & Malykh, 2017; von Stumm & Plomin, 2015; Nisbett et al., 2012). An indirect confirmation of this conclusion is the absence of differences in intelligence within country groups – between Russian- and Kyrgyz-speaking schoolchildren from Kyrgyzstan, between Russian- and Moldavian-speaking schoolchildren from Moldova.

Slight differences were observed in the analyzed groups for information processing speed, but of a fundamentally different nature. The differences were observed not among different country groups, but between cross-cultural groups – between schoolchildren with Russian as their native and non-native language. At the same time, native Russian-speaking schoolchildren performed better on the 4-choice reaction time task, regardless of their country of residence. Similar results were obtained in other studies, including those involving Kyrgyz-speaking high school students (Zinchenko et al., 2020; Leonard et al., 2007; Rose, Feldman, & Jankowski, 2011). These findings may indicate specific characteristics of the cognitive sphere of schoolchildren when studying in a non-native language, especially since differences were also observed in state exam

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

scores between native and non-native Russian-speaking graduates in favor of Russian-speaking eleventh-graders.

In the structure of the relationship between cognitive development and the state exam scores, both similarities and differences were obtained for groups of native and non-native Russian-speaking schoolchildren who studies in Kyrgyzstan, Moldova, and Russia.

The main similarity for all analyzed cross-cultural groups of schoolchildren, regardless of their native language, turned out to be a directly proportional relationship between non-verbal intelligence and the Russian language state exam score. Indeed, studies have repeatedly emphasized the leading role of intelligence in the formation of individual differences in academic success, based on standardized and expert assessments (Zinchenko et al., 2020; Verbitskaya et al., 2017; Deary et al., 2007; etc.). Thus, in the model of the relationship between the cognitive sphere and general academic success, it is non-verbal intelligence that is the central link between basic cognitive processes and a child's academic performance during all stages of the schooling process (Tikhomirova et al., 2020).

Differences in the relationship between the cognitive sphere and performance on the Russian language state exam were analyzed through the prism of the effects of the national education system and the student's native language and its coincidence with the language of instruction at school.

The effects of the quality of public education were manifested in the relationship between working memory and performance on the Russian language state examination. Thus, in more favorable educational environments, along with the usual role of intelligence, the role of visuospatial memory is emphasized. According to studies, the function of visuospatial working memory in the successful completion of test tasks is related to the reproduction of available information that is relevant to the completion of the task at hand (Wai et al., 2009). As a rule, most of the exam tasks are based on school material and high-quality education leads to better material retention and its availability for extraction at the right time (Verbitskaya et al., 2017).

The relationship between information processing speed and performance on the Russian language exam depended on whether or not the language of instruction was different from students' native language. In particular, this relationship turned out to be typical only for groups of non-native Russian-speaking schoolchildren. Information processing speed is probably the cognitive resource that can be used to optimize the process of learning a second language (for example, Huettig & Janse, 2016).

Conclusion

The study showed universal and specific patterns of correlation between cognitive development and the success of learning Russian as a native and non-native language under different educational conditions.

Of all analyzed indicators of cognitive development, non-verbal intelligence is directly proportional to the score on the state examination in the Russian language among school graduates in various educational and language environments.

The relationship between cognitive development and performance on the final exam in the Russian language can change depending on the educational conditions and whether or not the language of instruction is different from students' native language. In more favorable educational environments, when the native language is not different from the language of instruction, the

importance of working memory for performance on the state exams is emphasized along with the usual importance of intelligence.

The study showed that the structure of the relationships between indicators of cognitive development and performance on state examinations in the Russian language differs between native and non-native Russian-speaking groups of schoolchildren, even after eleven years of schooling in Russian. Information processing speed was observed to have a unique role in the process of learning Russian as a non-native language, regardless of whether students are native speakers of Romance or Turkic languages.

References

Brouwers, S. A., Van de Vijver, F. J., & Van Hemert, D. A. (2009). Variation in Raven's Progressive Matrices scores across time and place. *Learning and Individual Differences*, *19*(3), 330–338. https://doi.org/10.1016/j.lindif.2008.10.006

Deary, I. J., Strand, S., Smith, P., &Fernandes, C. (2007). Intelligence and educational achievement. *Intelligence*, *35*(1), 13–21. https://doi.org/10.1016/j.intell.2006.02.001

Druzhinin, V. N. (2007). *Psychology of general abilities*. St. Petersburg: Piter. (in Russ.).

Frenken, H., Papageorgiou, K. A., Tikhomirova, T., Malykh, S., Tosto, M. G., & Kovas, Y. (2016). Siblings' sex is linked to mental rotation performance in males but not females. *Intelligence*, *55*, 38–43. https://doi.org/10.1016/j.intell.2016.01.005

Huettig, F., & Janse, E. (2016). Individual differences in working memory and processing speed predict anticipatory spoken language processing in the visual world. *Language, Cognition and Neuroscience*, *31*(1), 80–93. https://doi.org/10.1080/23273798.2015.1047459

Kempe, V., Brooks, P. J., & Kharkhurin, A. (2010). Cognitive predictors of generalization of Russian grammatical gender categories. *Language Learning*, *60*(1), 127–153. https://doi.org/10.1111/j.1467-9922.2009.00553.x

Leonard, L. B., Weismer, S. E., Miller, C. A., Francis, D. J., Tomblin, J. B., & Kail, R. V. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech, Language, and Hearing Research*, *50*(2), 408–428. https://doi.org/10.1044/1092-4388(2007/029)

Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review*, *21*, 861–883. https://doi.org/10.3758/s13423-013-0565-2

Nisbett, R. E., Aronson, J., Blair, C., Dickens, W., Flynn, J., Halpern, D. F., & Turkheimer, E. (2012). Intelligence: New findings and theoretical developments. *American Psychologist*, *67*(2), 130–159. https://doi.org/10.1037/a0026699

Oh, E. (2016). Comparative studies on the roles of linguistic knowledge and sentence processing speed in L2 listening and reading comprehension in an EFL tertiary setting. *Reading Psychology*, *37*(2), 257–285. https://doi.org/10.1080/02702711.2015.1049389

Raven, J. C., Court, J. H., & Raven, J. E. (2009). *Manual for Raven's progressive matrices and vocabulary*

scales: Section 2: The Coloured progressive matrices. Moscow: Kogito-Tsentr. (in Russ.).

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2011). Modeling a cascade of effects: The role of speed and executive functioning in preterm/full-term differences in academic achievement. *Developmental Science*, *14*(5), 1161–1175. https://doi.org/10.1111/j.1467-7687.2011.01068.x

Tikhomirova, T. (2017). Spatial thinking and memory in Russian high school students with different levels of mathematical fluency. *Procedia – Social and Behavioral Sciences*, *237*, 1260–1264. https://doi.org/10.1016/j.sbspro.2017.02.204

Tikhomirova, T. N., & Malykh, S. B. (2017). *Cognitive foundations of individual differences in learning success.* St. Petersburg: Nestor-Istoriya. (in Russ.).

Tikhomirova, T., Malykh, A., & Malykh, S. (2020). Predicting academic achievement with cognitive abilities: Cross-sectional study across school education. *Behavioral Sciences, 10(10)*, 158. https://doi.org/10.3390/bs10100158

Tikhomirova, T. N., Kuz'mina, Yu. V., & Malykh, S. B. (2020). Trajectories in development of information processing speed across primary school years: A longitudinal study. *Psikhologicheskii zhurnal*, *41*(2), 26–38. https://doi.org/10.31857/S020595920008507-3 (in Russ.).

Tucker-Drob, E. M., & Bates, T. C. (2016). Large cross-national differences in gene × socioeconomic status interaction on intelligence. *Psychological Science*, *27*(2), 138–149. https://doi.org/10.1177/0956797615612727

Verbitskaya, L. A., Malykh, S. B., Zinchenko, Yu. P., & Tikhomirova, T. N. (2015). Cognitive predictors of success in learning Russian. *Psychology in Russia: State of the Art*, *8*(4), 91–100. https://doi.org/10.11621/pir.2015.0408

Verbitskaya, L. A., Malykh, S., & Tikhomirova, T. (2017). Cognitive predictors of success in learning Russian in native and non-native speakers at high school age. *Procedia – Social and Behavioral Sciences*, *237*, 1236–1241. https://doi.org/10.1016/j.sbspro.2017.02.195

Verbitskaya, L. A., Zinchenko, Y. P., Malykh, S. B., Gaidamashko, I. V., Kalmyk, O. A., & Tikhomirova, T. N. (2020). Cognitive predictors of success in learning Russian among native speakers of high school age in different educational systems. *Psychology in Russia: State of the Art*, *13*(2), 2–15. https://doi.org/10.11621/pir.2020.0201

Verbitskaya, L. A., Zinchenko, Yu. P., Malykh, S. B., & Tikhomirova, T. N. (2017). Cognitive foundations of success in Russian language learning: Cross-cultural research. *Voprosy psikhologii*, 1, 26–40. (in Russ.).

von Stumm, S., & Plomin, R. (2015). Socioeconomic status and the growth of intelligence from infancy through adolescence. *Intelligence*, *48*, 30–36. https://doi.org/10.1016/j.intell.2014.10.002

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), 817–835. https://doi.org/10.1037/a0016127

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

Zinchenko, Yu. P., Gaidamashko, I. V., Malykh, S. B., Kalmyk, O. A., & Tikhomirova, T. N. (2020). Cognitive predictors of successful learning Russian as a non-native language: Cross-cultural analysis. *Teoreticheskaya i eksperimental'naya psikhologiya (Theoretical and experimental psychology)*, *13*(1), 6–22. (in Russ.).

Received: December 06, 2021
Revision received: February 10, 2022
Accepted: March 18, 2022

Author Contribution

Yu. P. Zinchenko supervised the study.

I. V. Gaidamashko contributed to the literature research.

S. B. Malykh contributed to the study conception, coordinated the data collection in the Russian Federation, the Kyrgyz Republic, and the Republic of Moldova, and interpreted the findings of the study.

T. N. Tikhomirova contributed to research methodology, research database, statistical data analysis, and prepared the manuscript for publication.

Author Details

Yury Petrovich Zinchenko – Academician, Russian Academy of Education, Dr. Sci. (Psychology), Professor, Director, Psychological Institute of the Russian Academy of Education, Lomonosov Moscow State University, Moscow, Russian Federation; Scopus Author ID: 26655128800, ResearcherID: F-4021-2012, SPIN: 1038-7720; e-mail: director@pirao.ru

Igor Vyacheslavovich Gaidamashko – Academician, Russian Academy of Education, Dr. Sci. (Psychology), Professor, Vice-President, Russian Academy of Education, Moscow, Russian Federation; Scopus Author ID: 57192274957, ResearcherID: I-7523-2018, SPIN: 3082-9761; e-mail: gaydamashko_rao@mail.ru

Sergey Borisovich Malykh – Academician, Russian Academy of Education, Dr. Sci. (Psychology), Professor, Head of Laboratory, Psychological Institute of the Russian Academy of Education, Lomonosov Moscow State University, Russian Academy of Education; Moscow, Russian Federation; Scopus Author ID: 6701707734, ResearcherID: I-3697-2013, SPIN: 1396-8088; e-mail: malykhsb@mail.ru

Russian Psychological Journal, 2022, Vol. 19, No. 1, 34-48. **doi**: 10.21702/rpj.2022.1.3

Tatiana Nikolaevna Tikhomirova – Corresponding Member, Russian Academy of Education, Dr. Sci. (Psychology), Leading Researcher, Psychological Institute of the Russian Academy of Education, Lomonosov Moscow State University, Russian Academy of Education, Moscow, Russian Federation; Scopus Author ID: 37116054100, ResearcherID: N-3016-2014, SPIN: 9735-5507; e-mail: tikho@mail.ru

The authors declare no conflicts of interest.