

Научная статья | Original paper

Relationship of fluid intelligence with other indicators of neurocognitive development in children of senior preschool age

T.V. Zhilyaeva^{1,2} ✉, E.M. Tolstobrova¹, U.A. Nasonova¹,
O.S. Klekochko¹, Yu.M. Taraday¹, E.S. Romanova¹

¹ Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation

² V.M. Bekhterev National Research Medical Center for Psychiatry and Neurology, Saint-Petersburg, Russian Federation

✉ bizet@inbox.ru

Abstract

Context and relevance. The existing studies on the relationship between fluid intelligence (FI) and other neurocognitive functions, including in children, are contradictory: the relationship between fluid intelligence and short-term and long-term memory, attention, and fine motor development remains debatable, as does the question of the possibility of FI training through targeted development of individual cognitive skills. **Objective.** The aim of this study is to assess the associations of FI with a number of other indicators of neurocognitive development in older preschool children. **Hypothesis.** In older preschool children, FI is associated with indicators of working memory, short-term and long-term memory, attention, and fine motor skills. **Methods and materials.** The examination of the participants was conducted within the framework of the project “Study of neurobiological predictors of academic success in children” (Priority 2030) using the hardware and software system SHUHFRIED (Tower of London — Freiburg version, TOL-F; Motor Learning Skills test, short form according to Sturm and Büssing, Motor Learning Skills, MLS) and neuropsychological examination using the method of A.R. Luria adapted for older preschool children aged 6–7 years (Glozman, 2006). A total of 169 children were examined; 98 participants, 68 boys, 30 girls, completed all assessment procedures, median age 6,5 [6,0; 7,0] years. **Results.** FI has significant correlations with a number of neurocognitive development indicators, among which the closest and most significant are with dynamic, oral, and kinesthetic praxis; the ability to plan and create a copying strategy based on analytical and holistic components of perception (such as copying a three-dimensional image); hand movement coordination; fine motor skills; interaction of the afferent and efferent links of optical-constructive activity; acoustic gnosis; awareness of body schema; and spatial organization of movement. **Conclusions.** According to the data obtained, FI in senior preschool age has correlations with a wide range of neurocognitive development indicators, and, thus, it is not possible to single out only one target for FI training. To achieve results in the field of FI enhancement, more integrative approaches to training that cover a variety of cognitive functions and tasks should probably be considered.

Keywords: fluid intelligence, memory, attention, praxis, fine motor skills, senior preschool age

Funding. The study was carried out with the financial support of the Priority 2030 Program within the framework of the scientific project “Study of neurobiological predictors of academic success in children”.

Acknowledgements. The authors are grateful for assistance in organizing the study infrastructure O.V. Balandina and E.D. Bozhkova.

Дополнительные данные. Жиляева, Т.В., Толстоброва, Е.М., Насонова, У.А., Тарадай, Ю.М. (2025). База данных результатов обследования детей старшего дошкольного возраста с помощью нейропсихологической оценки, методики Leiter-3 и АПК SHUHFRIED: Набор данных. RusPsyData: Репозиторий психологических исследований и инструментов. Москва. <https://doi.org/10.48612/MSUPE/k7ka-nptk-3gfe>

For citation: Zhilyaeva, T.V., Tolstobrova, E.M., Nasonova, U.A., Klekocho, O.S., Taraday, Yu.M., Romanova, E.S. (2026). Relationship of fluid intelligence with other indicators of neurocognitive development in children of senior preschool age. *Psychological Science and Education*, 31(2), 39–53. (In Russ.). <https://doi.org/10.17759/pse.2026310203>

Связь флюидного интеллекта с другими показателями нейрокогнитивного развития у детей старшего дошкольного возраста

Т.В. Жиляева^{1, 2} ✉, Е.М. Толстоброва¹, У.А. Насонова¹,
О.С. Клекочко¹, Ю.М. Тарадай¹, Е.С. Романова¹

¹ Приволжский исследовательский медицинский университет Минздрава России, Нижний Новгород, Российская Федерация

² Национальный медицинский исследовательский центр психиатрии и неврологии им. В.М. Бехтерева, Санкт-Петербург, Российская Федерация

✉ bizet@inbox.ru

Резюме

Контекст и актуальность. Имеющиеся к настоящему времени исследования о связи флюидного интеллекта (ФИ) с другими нейрокогнитивными функциями, в том числе у детей, противоречивы: связь ФИ с кратковременной и долговременной памятью, вниманием, развитием мелкой моторики остается дискуссионной, так же как и вопрос о возможности тренировки ФИ путем таргетного развития отдельных когнитивных навыков. **Цель.** Оценка ассоциаций ФИ с рядом других показателей нейрокогнитивного развития в старшем дошкольном возрасте. **Гипотеза.** У детей старшего дошкольного возраста ФИ ассоциирован с показателями рабочей памяти, кратковременной и долговременной памяти, внимания и мелкой моторики. **Методы и материалы.** Обследование участников проводилось в рамках проекта «Исследование нейробиологических предикторов академической успешности детей» (Приоритет–2030) с помощью аппаратно-программной системы SHUHFRIED (методика Лондонский Тауэр, Фрейбургская версия, англ. Tower of London — Freiburg

version, TOL-F; тест Навыки моторного обучения, краткая форма по Штурму и Бюссингу, англ. Motor Learning Skills, MLS) и нейропсихологического обследования с помощью методики А.Р. Лурии в адаптации для детей старшего дошкольного возраста 6–7 лет (Глозман, 2006). Всего обследовано 169 детей, полностью все процедуры оценки прошли 98 участников, 68 мальчиков, 30 девочек, медианный возраст — 6,5 [6,0; 7,0] лет. **Результаты.** ФИ имеет значимые корреляции с целым рядом показателей нейрокогнитивного развития, среди которых наиболее тесные и значимые — с динамическим, оральным и кинестетическим праксисом, возможностям планирования и создания стратегии копирования с опорой на аналитические и целостные компоненты восприятия (копирование трехмерного изображения), координацией движений рук, мелкой моторикой, взаимодействием афферентного и эфферентного звеньев оптико-конструктивной деятельности, акустическим гнозисом, осознанием схемы тела и пространственной организации движения. **Выводы.** Согласно полученным данным, ФИ в старшем дошкольном возрасте имеет корреляции с широким набором показателей нейрокогнитивного развития, и, таким образом, выделить только одну мишень для тренировок ФИ не представляется возможным. Для достижения результатов в области повышения ФИ, вероятно, следует рассматривать более интегративные подходы к тренировкам, которые охватывают разнообразные когнитивные функции и задачи.

Ключевые слова: флюидный интеллект, память, внимание, праксис, мелкая моторика, старший дошкольный возраст

Финансирование. Исследование выполнено при финансовой поддержке программы «Приоритет-2030» в рамках научного проекта «Исследование нейробиологических предикторов академической успешности детей».

Благодарности. Авторы благодарят за помощь в организации инфраструктуры для исследования О.В. Баландину, Е.Д. Божкову.

Дополнительные данные. Жилиева, Т.В., Толстоброва, Е.М., Насонова, У.А., Тарадай, Ю.М. (2025). База данных результатов обследования детей старшего дошкольного возраста с помощью нейропсихологической оценки, методики Leiter-3 и АПК SHUHFRIED: Набор данных. RusPsyData: Репозиторий психологических исследований и инструментов. Москва. <https://doi.org/10.48612/MSUPE/k7ka-nptk-3gfe>

Для цитирования: Жилиева, Т.В., Толстоброва, Е.М., Насонова, У.А., Клекочко, О.С., Тарадай, Ю.М., Романова, Е.С. (2026). Связь флюидного интеллекта с другими показателями нейрокогнитивного развития у детей старшего дошкольного возраста. *Психологическая наука и образование*, 31(2), 39–53. <https://doi.org/10.17759/pse.2026310203>

Introduction

Fluid intelligence (FI) is an important predictor of academic success. Research suggests that FI factors such as induction, deduction, classification, general sequential and quantitative thinking determine its important role in an individual's acquisition

of new skills and abilities (Rzhanova, Alekseeva, Burdukova, 2020; Johann, 2020; Li, 2021; Passolunghi, 2022; Vernucci, 2021).

According to Cattell, FI is an individual's ability to think logically and solve problems in new, non-standard situations, regardless of previously acquired knowledge (Cattell, 1987). The key tenet of Cat-

tell's theory is the presence of two main factors in the structure of intelligence: FI and crystallized intelligence (the latter is associated with the acquisition of knowledge, sociocultural experience, and the individual's educational environment) (Cattell, 1963). Subsequently, within the framework of Cattell-Horn-Carroll, FI began to be considered one of the key primary cognitive abilities, along with crystallized intelligence (McGrew, 2023).

The issue of the relationship between FI and other indicators of neurocognitive functioning in both adults and children is relevant, since the presence of associations with individual cognitive functions opens up opportunities for developing programs for the development of FI through targeted training of individual cognitive skills.

Particular attention is paid to the relationship between FI and working memory (WM). According to a number of researchers, WM is the most powerful predictor of FI (Luo, 2020). It is an active system that is responsible for storing a limited amount of information and the ability to operate on this information within a short period of time (Rzhanova, Alekseeva, Burdukova, 2020; Nisbett et al., 2012). Kyllonen and Christal were the first to show extremely high correlation coefficients (0,80–0,88) between WM and FI in adults (Kyllonen, Christal, 1990). A strong and stable relationship between WM and FI was confirmed by the results of other studies (Conway et al., 2002; Kane et al., 2004). The close relationship between FI and WM is also supported by the results of neurobiological studies: the same brain structures (prefrontal and parietal cortex) are activated when performing FI and WM tasks (Gray, Chabris, Braver, 2003; Luo, 2020).

Overall, the strong correlation between WM and FI in adults is recognized by the scientific community. The determinants of this relationship remain controversial.

Colom et al. (2005, 2006) found that individual differences in FI levels were significantly associated with both WM and short-term memory (STM). In some studies, STM was a stronger predictor of FI than WM, leading the researchers to conclude that the relationship between WM and FI was based on the volume of STM (Colom et al., 2008). However, other studies failed to confirm the mediating role of STM in the relationship between WM and FI (Cochrane, Green, 2021; Conway et al., 2002).

One of the versions explaining the observed relationship between WM and FI is the assumption of the determining role of attentional control mechanisms (Engle, 2010; Schroeders et al., 2016). In FI tasks, cognitive control is necessary for problem analysis, monitoring the solution process, and adapting the solution strategy in accordance with how successfully the subject copes with the task. Similarly, cognitive control is required in tasks assessing WM to maintain representations retrieved from memory in the field of consciousness when faced with interfering phenomena. Two independent studies confirmed the theory of attention as a determinant of the relationship between FI and WM (Colom et al., 2008; Jaeggi et al., 2011). The authors suggest that executive control, which is responsible for the distribution and concentration of attention during problem solving and its switching to more important tasks, plays a fundamental role in the relationship between FI and WM (Kane et al., 2004).

In children, the relationship between WM and FI has been studied significantly

less (Erostarbe-P rez, 2022). A number of studies have shown the influence of STM on the relationship between the studied variables (Hornung et al., 2011; Tillman, Nyberg, Bohlin, 2008). According to the study by Hornung et al. (Hornung et al., 2011; 160 children aged six years), it is the STM component that is associated with FI at this age stage. Other studies have demonstrated the opposite picture, that is, the absence of a significant effect of STM on the relationship between FI and WM (Bayliss et al., 2005; Engel de Abreu, Conway, Gathercole, 2010; Swanson, 2008).

Alekseeva et al. (2018) reported the results of a study examining the relationship between FI and other aspects of cognitive abilities in school-aged children using the Kaufman tests. The main findings highlight the link between FI and memory, both short-term and long-term (LTM), which may indicate the importance of a comprehensive approach to intelligence development.

Of great importance are the data from training experiments demonstrating the possibility of developing FI through WM training (Jaeggi et al., 2008, 2011). However, these data were not confirmed in other studies, including a randomized controlled trial (Redick et al., 2013; Thompson et al., 2013). The discussion about the possibility of influencing FI through WM training remains relevant. The possibility of such training was demonstrated in a meta-analysis of 20 studies (Au et al., 2015), but subsequently in two other studies, including a meta-analysis, these results were criticized and recognized as lacking a serious evidence base (Bogg, Lasecki, 2015; Melby-Lervåg, Hulme, 2016).

According to recent studies, fine motor skills and WM are the cognitive abilities

most closely associated with FI in samples of primary school children (Memisevic, Dedic, Malec, 2023). However, other studies have shown a relatively weak relationship between fine motor skills and intelligence in children (Jenni et al., 2013).

Thus, the studies available to date on the relationship between FI and other neurocognitive functions, including in children, are contradictory: the relationship between FI and STM and LTM, attention, fine motor skills remains debatable, as does the question of the possibility of training FI through targeted development of individual cognitive skills.

This inconsistency in the literature may be due to the fact that most studies focus on analyzing isolated associations between FI and specific cognitive functions (WM, attention, or motor skills) across different samples and age groups. A comprehensive analysis of a wide range of neurocognitive indicators in a single sample of older preschool-aged children has not previously been conducted, making it impossible to assess the relative contribution of various functions and their relationship with FI within a single diagnostic paradigm. This necessitated the study presented here, which was based on the following hypothesis: FI in older preschool-aged children is associated with indicators of WM, STM, LTP, attention, and fine motor development. The aim of the study was to evaluate the associations of FI with a number of other indicators of neurocognitive development in older preschool-aged children.

Materials and methods

The children were examined as part of the project “Study of neurobiological predictors of academic success in children.” Inclusion criteria: written voluntary consent

form a parent; child's age at inclusion: 5 years 10 months — 7 years 4 months; child's ability to understand and follow instructions. Exclusion criteria: previously diagnosed hearing, vision, and motor impairments; severe mental and neurological disorders diagnosed by a psychiatrist and/or neurologist; concussion within the last year, other traumatic brain injury, or neurosurgical intervention on the brain; paroxysmal activity on the EEG; alalia; severe chronic diseases, developmental defects, cachexia, hereditary diseases; chronic mental disorders, alcohol and/or drug addiction in parents.

The Leiter-3 International Performance Scale (4 core subtests of the cognitive block, K) was used to assess FI ($n = 169$) (Royd, 2014). The Leiter-3 test is designed to assess an individual's ability for abstract thinking, problem solving, and behavioral adaptation, independent of verbal or language skills. It consists primarily of visual-spatial tasks, which minimizes the impact of language barriers. The Leiter-3 demonstrates high validity and is actively used in clinical practice, education, and research (Giofrè et al., 2024; Lichtenstein et al., 2022).

The neuropsychological examination ($n = 130$) was based on the method of A.R. Luria, adapted for older preschool children aged 6–7 years (Glozman, 2006); the tests used are presented in the table in the Results section.

The assessment of WM, attention, and fine motor skills was conducted using the hardware and software complex (HSC) SHUHFRIED (Vienna Test System, Austria) ($n = 114$). Three subtests were analyzed:

1. The Tower of London Freiburg Version (TOL-F) test. The main variables assessed are planning ability (the ability to

cognitively model alternative solutions and evaluate the consequences of an action before it is performed), WM, and inhibitory control — components of executive functioning (EF) (Berg, Byrd, 2002). The validity of the TOL-F was confirmed in the study by Debelak et al. (2016).

2. The MLS test (Fine Motor Skills Assessment, Short Form according to Sturm and Büssing) includes 8 subtests — 4 for each hand and evaluates the following indicators: purposefulness of movements, calmness of the hands/tremor, precision of hand and wrist movements, dexterity of the hands and fingers, speed of hand and wrist movements, speed of wrist and finger movements.

3. To assess attention, the Determination Test was used: a test of reaction to several stimuli (presentation of color stimuli and sound signals), to which the respondent responds by pressing the corresponding buttons on the response panel and using the pedals. The test requires dividing attention between different stimulus modalities (visual and acoustic), as well as between different response options (pressing a button with the hand or using the pedal).

To date, data on the experience of using the SCHUHFRIED APCS in Russia for carrying out psychological and pedagogical research have been published (Yakimova, Perminov, 2020).

Ninety-eight study participants (68 boys and 30 girls, median age 6.5 [6,0; 7,0] years) completed all assessment procedures. All children were permanent residents of Nizhny Novgorod and Russian-speaking. The study was continuous and cross-sectional. Not all children had completed all planned assessment methods by the time of writing

this article (the study is ongoing), and some participants dropped out of the study due to parental refusal to participate. Therefore, the number of children assessed by different specialists varies. The database of children’s assessment results is published in the RusPsyDATA repository of psychological research and tools (Zhilyaeva et al., 2025).

Data analysis was performed using StatSoft Statistica 6.0. The data distribution was non-normal (Shapiro-Wilk test), and

Spearman’s rank correlation coefficient (ρ) was used to assess correlations between variables. Correlations were considered significant at $p < 0,05$.

Results

The table presents the results of the analysis of correlations of the integral indicator FI — IQ — with the results of the assessment of other neurocognitive functions.

Table

Correlations (Spearman) of the fluid intelligence quotient with the results of assessment of other neurocognitive functions

Variable	Number of observations	Correlation coefficient	p
<i>Neuropsychological examination</i>			
Attention (proofreading test)	121	–0,19	0,036
Coordination of hand movements, fine motor skills (graphomotor test, "fence")	117	–0,41	< 0,0001
Dynamic praxis (execution of a complex motor program with a visual demonstration of a sample)	121	–0,46	< 0,0001
Possibilities of planning and creating a copying strategy based on analytical and holistic components of perception (copying a three-dimensional image)	121	–0,44	< 0,0001
Kinesthetic praxis (praxis of finger postures based on a visual model)	120	–0,30	0,00073
Kinesthetic organization of movements of speech organs (oral praxis)	118	–0,40	< 0,0001
Interaction of the afferent and efferent links of optical-constructive activity (copying a circle, square, triangle and rhombus, Denman figures)	121	–0,48	< 0,0001
Acoustic gnosia (reproduction of rhythmic structures based on an auditory pattern)	119	–0,43	< 0,0001
Awareness of the body scheme, spatial organization of movement (Head's test: copying a pose from a model; performing a hand pose according to verbal instructions)	121	–0,32	0,00031
Visual gnosia (recognition of noisy images)	121	–0,16	0,074
Operational (working) memory (memorization capacity at 1 presentation, 10-word test)	121	–0,10	0,26
Delayed (long-term) auditory memory (delayed recall in the 10-word test after interference)	120	–0,23	0,013
Mechanical memory (memorization by the 3rd–4th presentation in the 10-word test)	121	–0,22	0,014
Visual memory (remembering and recognizing two groups of three images of objects)	121	–0,35	< 0,0001

Variable	Number of observations	Correlation coefficient	p
Ability to categorize and generalize (4th odd one out test)	120	-0,34	0,00018
Understanding instructions (observation by a specialist)	121	-0,37	< 0,0001
Performance (observation by a specialist)	120	-0,26	0,0047
Perseverance (observation by a specialist)	121	-0,28	0,0020
Pace of activity (observation by a specialist)	121	-0,13	0,15
<i>HSC SCHUHFRIED, determination test (DT)</i>			
Number of incorrect reactions	113	-0,23	0,016
Speed of response	113	-0,17	0,071
Number of reactions	113	0,18	0,054
Number of correct reactions	113	0,26	0,0058
<i>HSC SCHUHFRIED, fine motor skills test (MLS)</i>			
Hits, Number of errors (Left hand)	113	-0,10	0,31
Hits, Error duration, seconds (Left hand)	113	-0,11	0,24
Hits, Total duration, seconds (Left hand)	113	0,09	0,36
Hits, Number of hits (Left hand)	113	0,16	0,090
Hits, Number of errors (Right hand)	113	-0,29	0,0020
Hits, Error duration, seconds (Right hand)	113	-0,29	0,0021
Hits, Total duration, seconds (Right hand)	113	0,04	0,66
Hits, Number of hits (Right hand)	113	0,09	0,36
Tracing lines, Number of errors (Left hand)	113	0,22	0,018
Tracing lines, Error duration, seconds (Left hand)	113	-0,06	0,54
Tracing lines, Total duration, seconds (Left hand)	113	0,19	0,041
Tracing lines, Number of errors (Right hand)	112	0,10	0,32
Tracing lines, Error duration, seconds (Right hand)	112	-0,05	0,64
Tracing lines, Total duration, seconds (Right hand)	112	0,26	0,0059
Stability, Number of errors (Left hand)	112	0,21	0,028
Stability, Error duration, seconds (Left hand)	112	-0,23	0,016
Stability, Number of errors (Right hand)	112	0,07	0,48
Stability, Error duration, seconds (Right hand)	112	-0,23	0,015
Tapping, Number of hits (Left hand)	113	0,20	0,034
Tapping, Number of hits (Right hand)	113	0,25	0,0089
<i>HSC SCHUHFRIED, Tower of London test (TOL)</i>			
Planning ability	113	0,07	0,45
Correctly solved tasks with 4 movements	113	0,02	0,82
Correctly solved tasks with 5 movements	113	0,05	0,61
Correctly solved tasks with 6 movements	113	0,10	0,32
Changes in decision	113	0,13	0,16
Selecting a locked ball	113	-0,15	0,12

Variable	Number of observations	Correlation coefficient	p
Selecting a locked rod	113	0,05	0,57
Selecting an invalid position	113	–0,11	0,24
Number of correct decisions	113	0,20	0,035

Note: HSC — hardware and software complex. The results of the neuropsychological assessment are coded in such a way: the more deviations from the norm, the higher the score. Therefore, the correlation coefficients of the neuropsychological battery indicators with the IQ are negative.

Discussion

According to the obtained results (see Table), in older preschool children, FI does not have significant associations with the working memory indicator (10-word test, memorization capacity at 1 presentation). The overwhelming majority of data on a close correlation between FI and WM were obtained in samples of adults (Conway et al., 2002; Engle, 2010; Gray, Chabris, Braver, 2003; Kane et al., 2004; Kyllonen, Christal, 1990). In the only published study we found on the relationship between WM and FI in children, the authors concluded that in childhood, the relationship between FI and WM is based on cognitive control mechanisms, but not STM (Engel de Abreu, Conway, Gathercole, 2010).

Moreover, we obtained a highly significant correlation between visual memory and FI ($\rho = -0,199$; $p = 0,000094$). It is likely that visual working memory is most involved in completing the Leiter-3 tasks. Verbal working memory, which has a different neurobiological basis, apparently does not contribute to the FI indicator in older preschool age. At the same time, the verbal mechanical and LTM indicators in our study correlate with FI, albeit weakly. This is con-

sistent with the data of other researchers (Alekseeva, Rzhanova, Burdukova, 2018; Hornung et al., 2011; Tillman, Nyberg, Bohlin, 2008).

Significant correlations of attention indices with FI, obtained using both neuropsychological assessment and the SCHUHFRIED HSC (determination test), are consistent with each other, as well as with the data of other researchers who have demonstrated a connection between attention indices and FI (Colom et al., 2008; Engle, 2010; Jaeggi et al., 2011; Schroeders et al., 2016). The authors of the cited studies explain the connection between attention and FI in the context of a close relationship between attention and IF. In our study, IF was tested using the TOL test of the SCHUHFRIED HSC, and the number of correct decisions in this test also correlated with FI ($\rho = 0,20$; $p = 0,035$).

Thus, the results obtained in this study indicate the existence of a relationship between various components of memory (except verbal working memory), attention, EF and FI, previously presented in the literature.

However, it is noteworthy that the relationship between FI and other indica-

tors of children's neurocognitive development is closer and more significant. Thus, FI has significant correlations (see table) with dynamic praxis, the ability to plan and create a copying strategy based on analytical and holistic components of perception, hand coordination, fine motor skills, the interaction of the afferent and efferent links of optical-constructive activity, the kinesthetic organization of speech movements, acoustic gnosis, awareness of body schema, spatial organization of movement, kinesthetic praxis, as well as comprehension of instructions, performance, and perseverance. Furthermore, a large number of significant weak correlations were obtained between FI and fine motor skills, assessed by the MLS test of the SCHUHFRIED HSC. While conflicting data on the relationship between fine motor skills and FI in children are presented in the literature (Jenni et al., 2013; Memisevic, Dedic, Malec, 2023), there is no data on the relationship between FI and other indicators of neurocognitive functioning described above in the available sources.

Conclusions

According to the data obtained in our study, FI in older preschool children correlates with a wide range of neurocognitive development indicators, including

various types of praxis, gnosis, visuospatial functions, and fine motor skills. However, significant links with verbal working memory are absent, which may indicate the leading role of visuospatial systems in the implementation of FI at this age. Thus, it is not possible to single out a single target for FI training, which is consistent with the concept of FI as a complex dynamic system based on the interaction of various cognitive processes and neural networks. To achieve results in improving FI in older preschool children, it is likely necessary to consider integrative training approaches encompassing a wide range of cognitive functions.

Limitations. The associations obtained in this cross-sectional study cannot be interpreted as cause-and-effect relationships, nor can it be concluded that the development of neurocognitive traits associated with FI will contribute to the development of FI. A reverse relationship cannot be ruled out: children with more developed FI have higher scores on other tests due to their more highly developed FI. However, the obtained results create the basis for further prospective experimental studies that will be able to confirm or refute the hypothesis that FI can be developed through comprehensive training of several neurocognitive development indicators.

Список источников / References

1. Алексеева, О.С., Ржанова, И.Е., Бурдукова, Ю.А. (2018). Флюидный интеллект в структуре когнитивных характеристик. *Психология. Журнал Высшей школы экономики*, 15(1), 185–197. Alekseeva, O.S., Rzhanova, I.E., Burdukova, Yu.A. (2018). Fluid intelligence in the structure of cognitive characteristics, 15(1), 185–197.
2. Глозман, Ж.М., Потанина, А.Ю., Соболева, А.Е. (2006). Нейропсихологическая диагностика в дошкольном возрасте. М.: Питер. Gluzman, Zh.M., Potanina, A.Yu., Soboleva, A.E. (2006). Neuropsychological diagnostics in preschool age. Moscow: Piter (In Russ.)
3. Жилияева, Т.В., Толстоброва, Е.М., Насонова, У.А., Тарадай, Ю.М. (2025). База данных результатов обследования детей старшего дошкольного возраста с помощью нейропсихологической оценки, методики Leiter-3 и АПК SHUHFRIED: Набор данных. RusPsyData: Репозиторий психологических исследований и инструментов. Москва. <https://doi.org/10.48612/MSUPE/k7ka-nptk-3gfe> Zhilyaeva, T.V., Tolstobrova, E.M., Nasonova, U.A., Taradaj, Yu.M. (2025). Database of results of examination of senior preschool children using neuropsychological assessment, Leiter-3 method and SHUHFRIED APC: Data set. RusPsyData: Repozitorij psihologicheskikh issledovanij i instrumentov. Moscow. <https://doi.org/10.48612/MSUPE/k7ka-nptk-3gfe>
4. Ржанова, И.Е., Алексеева, О.С., Бурдукова, Ю.А. (2020). Успешность в обучении: взаимосвязь флюидного интеллекта и рабочей памяти. *Психологическая наука и образование*, 25(1), 63–74. DOI: <https://doi.org/10.17759/pse.2020250106>. Rzhanova, I.E., Alekseeva, O.S., Burdukova, Yu.A. (2020). Successful Learning: Relationship Between Fluid Intelligence and Working Memory. *Psychological Science and Education*, 25(1), 63–74. DOI: <https://doi.org/10.17759/pse.2020250106> (In Russ., abstr. in Engl.).
5. Ройд, Г.Х., Миллер, Л.Дж., Помплан, М, Кох, К. (2014) Международные шкалы продуктивности Leiter-3, третье издание. Руководство. Русская версия под ред. А. Сорокина. Giunti Psychometrics. Roid, G.H., Miller, L.J., Pomplun, M., Koch, C. (2013) Leiter international performance scale-third edition. Wood Dale, IL: Stoelting Company.
6. Ушаков, Д. (2022). *Психология интеллекта и одаренности*. Litres. Ushakov, D. (2022). *Psychology of intelligence and giftedness*. Litres.
7. Якимова, О.В., Перминов, В.А. (2020). Опыт применения аппаратно-программного комплекса «Шуфрид» в ФКУ «ГБ МСЭ по Томской области» Минтруда России. *Медико-социальные проблемы инвалидности*, 1, 11–15. Iakimova, O.V., Perminov, V.A. (2020). Experience of using the Shufrid hardware and software complex at the Federal State Institution “State Bureau of Medical and Social Expertise for Tomsk Oblast” of the Ministry of Labor of the Russian Federation. *Mediko-sotsial'nye problemy invalidnosti*, 1, 11–15. (In Russ.).
8. Au, J., Sheehan, E., Tsai, N., Duncan, G.J., Buschkuhl, M., Jaeggi, S.M. (2015). Improving fluid intelligence with training on working memory: a meta-analysis. *Psychonomic bulletin & review*, 22(2), 366–377. <https://doi.org/10.3758/s13423-014-0699-x>.
9. Bayliss, D.M., Jarrod, C., Baddeley, A.D., Gunn, D.M., Leigh, E. (2005). Mapping the developmental constraints on working memory span performance. *Developmental Psychology*, 41(4), 579–597.
10. Berg, W.K., Byrd, D.L. (2002). The Tower of London spatial problem-solving task: Enhancing clinical and research implementation. *J. Clin. Exp. Neuropsychol*, 24, 586–604.
11. Blair, C. (2006). How similar are fluid cognition and general intelligence? A developmental neuroscience perspective on fluid cognition as an aspect of human cognitive ability. *Behavioral Brain Science*, 29(2), 109–125. doi: 10.1017/S0140525X06009034.
12. Bogg, T., Lasecki, L. (2015). Reliable gains? Evidence for substantially underpowered designs in studies of working memory training transfer to fluid intelligence. *Frontiers in psychology*, 5, 1589. <https://doi.org/10.3389/fpsyg.2014.01589>
13. Cattell, R.B. (1987). *Intelligence: Its structure, growth and action*. New York: Elsevier.
14. Cattell, R.B. (1963). The theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology*, 54(1), 1–22.
15. Cochrane, A., Green, C.S. (2021). Trajectories for performance change indicate multiple dissociable links between working memory and fluid intelligence. *NPJ science of learning*, 6(1), 33. <https://doi.org/10.1038/s41539-021-00111-w>.
16. Colom, R., Abad, F.J., Quiroga, M.A., Shih, P.C., Flores-Mendoza, C. (2008). Working memory and intelligence are highly related constructs, but why? *Intelligence*, 36(6), 584–606. doi:10.1016/j.intell.2008.01.002.
17. Colom, R., Abad, F.J., Rebollo, I., Shih, P.C. (2005). Memory span and general intelligence: A latent-variable approach. *Intelligence*, 33(6), 623–642. doi:10.1016/j.intell.2005.05.006.

18. Colom, R., Rebollo, I., Abad, F.J., Shih, P.C. (2006). Complex span tasks, simple span tasks, and cognitive abilities: A reanalysis of key studies. *Memory and Cognition*, 34(1), 158–171.
19. Conway, A.R., Cowan, N., Bunting, M.F., Theriault, D.J., Minkoff, S.R. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence*, 30(2), 163–183. doi:10.1016/S0160-2896(01)00096-4.
20. Debelak, R., Egle, J., Köstering, L., Kaller, C.P. (2016). Assessment of planning ability: Psychometric analyses on the unidimensionality and construct validity of the Tower of London Task (TOL-F). *Neuropsychology*, 30(3), 346–360. <https://doi.org/10.1037/neu0000238>.
21. Engel de Abreu, P.M., Conway, A.R., Gathercole, S.E. (2010). Working memory and fluid intelligence in young children. *Intelligence*, 38(6), 552–561. doi:10.1016/j.intell.2010.07.003.
22. Engle, R.W. (2010). Role of working memory capacity in cognitive control. *Current Anthropology*, 51, 1.
23. Erostarbe-Pérez, M. (2022). Executive functions and their relationship with intellectual capacity and age in schoolchildren with intellectual disability. *Journal of Intellectual Disability Research*, 66(1-2), 50–67. <https://doi.org/10.1111/jir.12885>.
24. Giofrè, D., Toffalini, E., Esposito, L., Cornoldi, C. (2024). Sex/gender differences in general cognitive abilities: an investigation using the Leiter-3. *Cognitive processing*, 25(4), 663–672. <https://doi.org/10.1007/s10339-024-01199-9>.
25. Gray, J.R., Chabris, C.F., Braver, T.S. (2003). Neural mechanisms of general fluid intelligence. *Natural Neuroscience*, 6(3), 316–322. doi: 10.1038/nn1014.
26. Hornung, C., Brunner, M., Reuter, R., Martin, R. (2011). Children's working memory: Its structure and relationship to fluid intelligence. *Intelligence*, 39, 210–221.
27. Jaeggi, S.M., Buschkuhl, M., Jonides, J., Perrig, W.J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, 105(19), 6829–6833.
28. Jaeggi, S.M., Buschkuhl, M., Jonides, J., Shah, P. (2011). Short- and long-term benefits of cognitive training. *Proceedings of the National Academy of Sciences*, 108, 10081–10086.
29. Jenni, O.G., Chaouch, A., Caffisch, J., Rousson, V. (2013). Correlations between motor and intellectual functions in normally developing children between 7 and 18 years. *Developmental neuropsychology*, 38(2), 98–113. <https://doi.org/10.1080/87565641.2012.733785>.
30. Johann, V. (2020). The unique contribution of working memory, inhibition, cognitive flexibility, and intelligence to reading comprehension and reading speed. *Child Neuropsychology*, 26(3), 324–344. <https://doi.org/10.1080/09297049.2019.1649381>
31. Kane, M.J., Hambrick, D.Z., Tuholski, S.W., Wilhelm, O., Payne, T.W., Engle, R.W. (2004). The generality of working memory capacity: A latent-variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology. General*, 133(2), 189–217. doi:10.1037/0096-3445.133.2.189.
32. Kyllonen, P.C., Christal, R.E. (1990). Reasoning ability is (little more than) working-memory capacity?! *Intelligence*, 14(4), 389–433. doi:10.1016/S0160-2896(05)80012-1.
33. Li, D. (2021). Fluid intelligence, trait emotional intelligence and academic performance in children with different intellectual levels. *High Ability Studies*, 32(1), 51–69. <https://doi.org/10.1080/13598139.2019.1694493>.
34. Lichtenstein, J., Niemczak, C., Bowers, C., Magohe, A., Fellows, A., Ealer, C., Massawe, E., Moshi, N., Buckey, J. (2022). Nonverbal Neurocognitive Assessment during the Coronavirus Disease of 2019 Pandemic: the Effect of Personal Protective Equipment. *Archives of clinical neuropsychology: the official journal of the National Academy of Neuropsychologists*, 37(7), 1628–1632. <https://doi.org/10.1093/arclin/acac044>.
35. Luo, W. (2020). Can Working Memory Task-Related EEG Biomarkers Measure Fluid Intelligence and Predict Academic Achievement in Healthy Children? *Frontiers in Behavioral Neuroscience*, 14, Article 2. <https://doi.org/10.3389/fnbeh.2020.00002>.
36. Margari, L., Palumbi, R., Lecce, P.A., Craig, F., Simone, M., Margari, M., Seccia, S.M.C., Buttiglione, M. (2018). Non-Verbal Cognitive Abilities in Children and Adolescents Affected by Migraine and Tension-Type Headache: An Observational Study Using the Leiter-3. *Frontiers in neurology*, 9, 78. <https://doi.org/10.3389/fneur.2018.00078>.
37. McGrew, K.S. (2023). Carroll's Three-Stratum (3S) Cognitive Ability Theory at 30 Years: Impact, 3S-CHC Theory Clarification, Structural Replication, and Cognitive-Achievement Psychometric Network Analysis Extension. *Journal of Intelligence*, 11(2), 32. <https://doi.org/10.3390/jintelligence11020032>.
38. Melby-Lervåg, M., Hulme, C. (2016). There is no convincing evidence that working memory training is effective: A reply to Au et al. (2014) and Karbach and Verhaeghen (2014). *Psychonomic bulletin & review*, 23(1), 324–330. <https://doi.org/10.3758/s13423-015-0862-z>.

39. Memisevic, H., Dedic, A., Malec, D. (2023). The Relative Strengths of Relationships Between Fine Motor Skills, Working Memory, Processing Speed and Fluid Intelligence in Early Elementary School Children. *Perceptual and motor skills*, 130(4), 1386–1399. <https://doi.org/10.1177/00315125231181297>
40. 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. doi:10.1037/a0026699
41. Passolunghi, M.C. (2022). The role of working memory updating, inhibition, fluid intelligence, and reading comprehension in explaining differences between consistent and inconsistent arithmetic word-problem-solving performance. *Journal of Experimental Child Psychology*, 224, Article 105512. <https://doi.org/10.1016/j.jecp.2022.105512>
42. Redick, T.S., Shipstead, Z., Harrison, T.L., Hicks, K.L., Fried, D.E., Hambrick, D.Z., Kane, M.J., Engle, R.W. (2013). No evidence of intelligence improvement after working memory training: a randomized, placebo-controlled study. *Journal of experimental psychology. General*, 142(2), 359–379. <https://doi.org/10.1037/a0029082>
43. Schroeders, U., Schipolowski, S., Zettler, I., Golle, J., Wilhelme, O. (2016). Do the smart get smarter? Development of fluid and crystallized intelligence in 3rd grade. *Intelligence*, 59, 84–95.
44. Swanson, H.L. (2008). Working memory and intelligence in children: What develops? *Journal of Educational Psychology*, 100(3), 581–602.
45. Thompson, T.W., Waskom, M.L., Garel, K.L., Cardenas-Iniguez, C., Reynolds, G.O., Winter, R., Chang, P., Pollard, K., Lala, N., Alvarez, G.A., Gabrieli, J.D. (2013). Failure of working memory training to enhance cognition or intelligence. *PLoS one*, 8(5), e63614. <https://doi.org/10.1371/journal.pone.0063614>
46. Tillman, C.M., Nyberg, L., Bohlin, G. (2008). Working memory components and intelligence in children. *Intelligence*, 36(5), 394–402.
47. Vernucci, S. (2021). Working memory and fluid intelligence predict reading comprehension in school-age children: A one-year longitudinal study. *Applied Cognitive Psychology*, 35(4), 1115–1124. <https://doi.org/10.1002/acp.3841>
48. Welsh, M.C., Satterlee-Cartmell, T., Stine, M. (1999). Towers of Hanoi and London: contribution of working memory and inhibition to performance. *Brain and cognition*, 41(2), 231–242. <https://doi.org/10.1006/brcg.1999.1123>

Information about the authors

Tatyana V. Zhilyaeva, Doctor of Sciences (Medicine), Associate Professor, Psychiatrist of the Mental Health Center, Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation; Leading Researcher of the Department of Social Neuropsychiatry, V.M. Bekhterev National Research Medical Center for Psychiatry and Neurology, St. Petersburg, Russian Federation, ORCID: <https://orcid.org/0000-0001-6155-1007>, e-mail: bizet@inbox.ru

Ekaterina M. Tolstobrova, Master, Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation, ORCID: <https://orcid.org/0009-0004-4668-7220>, e-mail: katerinka-7778@mail.ru

Ulyana A. Nasonova, Psychologist of the Mental Health Center, Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation, ORCID: <https://orcid.org/0000-0002-1734-6003>, e-mail: unasonova@yandex.ru

Olesya S. Klekochko, Assistant of the Department of General and Clinical Psychology, Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation, ORCID: <https://orcid.org/0009-0006-8910-4640>, e-mail: olesya-klekochko@mail.ru

Yuri M. Taraday, Assistant of the Department of General and Clinical Psychology, Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation, ORCID: <https://orcid.org/0009-0009-6938-2514>, e-mail: taraday97@yandex.ru

Elena S. Romanova, Master's Student in the Specialization "Clinical Psychology", Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation, ORCID: <https://orcid.org/0009-0007-4573-5966>, e-mail: HelenSR@yandex.ru

Информация об авторах

Татьяна Владимировна Жилияева, доктор медицинских наук, доцент, врач-психиатр Центра ментального здоровья, Приволжский исследовательский медицинский университет Минздрава России

(ФГБОУ ВО ПИМУ Минздрава РФ), Нижний Новгород, Российская Федерация, ведущий научный сотрудник отделения социальной нейropsychиатрии, Национальный медицинский исследовательский центр психиатрии и неврологии им. В.М. Бехтерева (ФГБУ НМИЦ ПН им. В.М. Бехтерева), Санкт-Петербург, Российская Федерация, ORCID: <https://orcid.org/0000-0001-6155-1007>, e-mail: bizet@inbox.ru

Екатерина Михайловна Толстоброва, магистр, Приволжский исследовательский медицинский университет Минздрава России (ФГБОУ ВО ПИМУ Минздрава РФ), Нижний Новгород, Российская Федерация, ORCID: <https://orcid.org/0009-0004-4668-7220>, e-mail: katerinka-7778@mail.ru

Ульяна Алексеевна Насонова, психолог Центра ментального здоровья, Приволжский исследовательский медицинский университет Минздрава России (ФГБОУ ВО ПИМУ Минздрава РФ), Нижний Новгород, Российская Федерация, ORCID: <https://orcid.org/0000-0002-1734-6003>, e-mail: uasonova@yandex.ru

Клекочка Олеся Сергеевна, ассистент кафедры общей и клинической психологии, Приволжский исследовательский медицинский университет Минздрава России (ФГБОУ ВО ПИМУ Минздрава РФ), Нижний Новгород, Российская Федерация; ORCID: <https://orcid.org/0009-0006-8910-4640>, e-mail: olesya-klekocho@mail.ru

Юрий Михайлович Тарадай, ассистент кафедры общей и клинической психологии, Приволжский исследовательский медицинский университет Минздрава России (ФГБОУ ВО ПИМУ Минздрава РФ), Нижний Новгород, Российская Федерация; ORCID: <https://orcid.org/0009-0009-6938-2514>, e-mail: taraday97@yandex.ru

Елена Сергеевна Романова, магистрант по профилю «Клиническая психология», Приволжский исследовательский медицинский университет Минздрава России (ФГБОУ ВО ПИМУ Минздрава РФ), Нижний Новгород, Российская Федерация, ORCID: <https://orcid.org/0009-0007-4573-5966>, e-mail: HelenSR@yandex.ru

Contribution of the authors

Zhilyaeva T.V. — editing, participation in writing and design of the manuscript; research planning; research supervision, coordination of the researchers' work, application of statistical methods for data analysis.

Tolstobrova E.M. — data collection, database formation, participation in writing the “Methods and materials” section.

Nasonova U.A. — monitoring the study, participation in data collection, participation in hypothesis formation, writing the research protocol, coordination of the researchers' work.

Klekocho O.S. — data collection, database formation.

Taraday Yu.M. — participation in data collection, database formation, participation in writing the “Discussion of results” section.

Romanova E.S. — participation in hypothesis formation, participation in writing the “Introduction” section.

All authors took part in the discussion of the results and agreed on the final text of the manuscript.

Вклад авторов

Жиляева Т.В. — редактирование, участие в написании и оформлении рукописи; планирование исследования; контроль за проведением исследования, координация работы исследователей, статистическая обработка результатов.

Толстоброва Е.М. — сбор данных, формирование базы данных, участие в написании раздела «Методы и материалы».

Насонова У.А. — мониторинг проведения исследования, участие в сборе данных, участие в формировании гипотезы, написание протокола исследования, координация работы исследователей.

Клекочко О.С. — сбор данных, формирование базы данных.

Тарадай Ю.М. — участие в сборе данных, формировании базы данных, участие в написании раздела «Обсуждение результатов».

Романова Е.С. — участие в формировании гипотезы, участие в написании раздела «Введение».

Все авторы приняли участие в обсуждении результатов и согласовали окончательный текст рукописи.

Conflict of interest

The authors declare no conflict of interest.

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Ethics statement

The study was reviewed and approved by the Ethics Committee of Privolzhsky Research Medical University (Report No. 7, 2024/17/05).

Декларация об этике

Исследование было рассмотрено и одобрено Этическим комитетом ФГБОУ ВО «Приволжский исследовательский медицинский университет» (протокол №7 от 17.05.2024 г.).

Поступила в редакцию 17.06.2025

Поступила после рецензирования 27.08.2025

Принята к публикации 23.03.2026

Опубликована 30.04.2026

Received 2025.06.17.

Revised 2025.08.27.

Accepted 2026.03.23.

Published 2026.04.30.