

Research article

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The Scale of Self-Perceived Ability – Spatial and Engineering: development, validation, reliability

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Abstract

Introduction. Current qualification requirements in scientific and technological practices emphasize the demand to take into account both engineering and spatial abilities when selecting students for advanced training in STEM disciplines. A comprehensive assessment of these abilities can improve the efficacy of education and increase the number of highly qualified specialists in the STEM sector. The aim of this study was to develop a valid and reliable scale for the measurement of self-perceived spatial and engineering abilities.

Methods. The sample consisted of 5062 students of higher educational institutions of Russia aged 18 to 25 years (average age 18.35 years). In order to evaluate psychometric properties of the scale, exploratory, confirmatory, and multigroup factor analysis were used. **Results.** Factor analysis revealed a four-factor structure of 10 items endorsed by excellent model fit indices. The identified factors of Orientation, Engineering, Rotation, and Visualization together explained 52% of the total variance. Factor loadings ranged from 0.72 to 0.98, confirming the high reliability of each scale item. Cronbach's alpha for the entire scale was 0.85, indicating high internal consistency. Comparative analysis of mean values for the top and bottom 27% of the sample demonstrated significant differences for all scale items. Analysis of mean values by gender groups revealed significant differences for four identified factors. Measurement invariance analysis showed that the scale corresponds to configural, metric, and scalar types of invariance. **Discussion.** The factor structure of the scale corresponds to the model of spatial abilities of "large" and "small" scale. The novelty of this study consists in the validation of the first Russian-language scale, providing a brief and comprehensive assessment of both spatial and engineering abilities important for educational and professional practice.

Keywords

spatial abilities, engineering abilities, students, gender, psychometric analysis

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Introduction

The ability to identify, manipulate and transform spatial information is crucial for human adaptation to the environment (Newcombe & Huttenlocher, 2000). Spatial skills are associated with key aspects of human cognitive and academic functioning, such as education achievement (Liu et al., 2021; Dvoinyin & Trotskaya, 2022), intelligence (Lohman, 1996, Karpov, 2012), creativity (Kell et al., 2013; Suh & Cho, 2020), scientific reasoning (Clements & Battista, 1992; Mayer et al., 2014). Notably, spatial skills are essential for successful education and career in STEM – science, technology, engineering and mathematics (Zavyalova et al., 2020; Wai et al., 2009; Miller & Halpern, 2013; Veurink & Sorby, 2017; Uttal & Cohen, 2012). In this particular case, the ability to effectively manipulate and interpret spatial information allows better understanding and solution of applied problems (Uttal et al., 2013).

Although spatial, mathematical, and verbal abilities are considered to be the foundation of students' cognitive abilities, assessment of spatial abilities has not received sufficient attention in STEM education (Uttal & Cohen, 2012; Sorby et al., 2013). It is particularly remarkable that spatial ability is considered an important and relatively accurate predictor of potential talent and success in STEM fields. (Lowrie et al., 2019; Stieff & Uttal, 2015; Uttal & Cohen, 2012; Wai et al., 2009). Furthermore, engineering abilities such as understanding the functioning principles of technical systems and devices require future STEM professionals to have a high level of spatial thinking in order to effectively develop the skills and competencies necessary to solve real-life problems in engineering practice (Uttal et al., 2013; Brotman & Moore, 2008). As a result the interaction between spatial and engineering abilities forms a firm basis for successful academic and professional activity in STEM.

Modern demands for professional activity in scientific and technical fields also emphasize the importance of considering not only engineering but also spatial abilities

when selecting students for advanced studies in STEM fields (Lubinski, 2010; Sorby et al., 2018; Yoon & Mann, 2017). The combined assessment will help maximize the effectiveness of training in these critical areas and lead to a significant increase in the number of highly skilled professionals in the STEM sector (Wai et al., 2009; Adya & Kaiser, 2005). In turn, isolated assessment of spatial and engineering abilities has a number of disadvantages. First of all, isolated assessment does not take into account the synergistic influence of spatial skills on solving engineering problems and vice versa (Uttal et al., 2013), which can manifest itself as underestimation of candidates with high spatial abilities but low scores on engineering criteria for engineering positions. Moreover, the lack of an interdisciplinary approach limits the interpretation: traditional tests of spatial abilities are insufficient to identify skills important for engineering design (Hegarty & Waller, 2004). This can lead to a skewed impression of actual competencies and hinder professional development in interdisciplinary fields such as architecture and mechanics which require synergy between different types of reasoning (Sorby, 2009). Therefore, comprehensive assessment of spatial and engineering abilities is essential for an accurate evaluation of professional skills.

Thus, the development of a measurement tool for spatial and engineering abilities becomes a milestone step toward enhancing the quality of education and personnel recruitment within the STEM field. An integrated assessment will contribute to increase in the effectiveness of industry-specific education and candidates' competence development for engineering professions which is particularly vital in the context of rapidly advancing technologies. The cooperation between spatial and engineering abilities lays emphasis on the necessity of their joint assessment highlighting the importance of creating interdisciplinary instruments for practical assessment.

Spatial and Engineering abilities

The definition of spatial abilities remains a debatable question in psychometric research, as these abilities are not considered a single construct but rather a constellation of multiple components of spatial cognition (Aristova et al., 2018; Casey, 2013; Hegarty & Waller 2004, 2005; Lohman, 1996; Uttal & Cohen, 2012). One of the bases for the classification of spatial abilities is the scale of the subject in relation to the objects of space (Aristova et al., 2018).

The literature distinguishes between local (small-scale) and global (large-scale) spatial abilities (Jansen, 2009; Aristova et al., 2018). The "small scale" group of spatial abilities includes skills related to the manipulation of specific objects: the main abilities of this group include the transformation of objects (Zacks et al., 2000), mental rotation (Blajenkova et al., 2005), and object manipulation (Kozhevnikov & Hegarty, 2001). Within the context of "large-scale" abilities, spatial orientation and the mental representation of object locations relative to the observer are distinguished. This group of abilities encompasses the judgement on direction and distance (Jansen, 2009); specifically, it

includes navigation (Kozhevnikov et al., 2006), the «sense of direction» (De Beni et al., 2006), spatial orientation (Kozhevnikov & Hegarty, 2001), and perspective-taking (Hegarty & Waller, 2004). Furthermore, psychological and neuropsychological research provides evidence of a partial dissociation between abilities related to "small-scale" and "large-scale" spatial cognition (Morris & Parslow, 2004; Wang et al., 2014).

Conversely, engineering abilities can be defined as the aggregate of knowledge, skills, and personal qualities necessary for the successful resolution of engineering problems and effective performance in technical and applied field (Miller, 2017; Anufrieva, 2023). These abilities encompass both technical skills and social competencies (Groeneveld et al., 2020), as well as general cognitive abilities (Frank, 2006; Ackerman et al., 2013). Cognitive abilities that play a crucial role in engineering competencies include analytical thinking (Hidayat et al., 2023), critical thinking (Ahern et al., 2019), creative thinking (Cromptley, 2016), and spatial reasoning (Lubinski, 2010).

The interplay between spatial and engineering abilities warrants particular attention due to their significance for achieving success in STEM fields. The ability to visualize objects and their interrelationships within three-dimensional space becomes essential for design and analysis as it facilitates the comprehension of abstract concepts (Hegarty & Waller, 2004; Lee et al., 2010; Ha & Fang, 2016). This confirms the fact that spatial reasoning is a key component of engineering thinking and can be effectively transformed into practical skills (Buckley et al., 2018; Buckley et al., 2022).

Self-Perceived Ability – Spatial and Engineering Scale

Currently, there are several Russian-language assessment tools designed to evaluate various components of spatial abilities (Trotskaya, 2017; Likhanov et al., 2020; Batova, 2021). However, the assessment of both spatial and engineering abilities can be demanding. Given the relevance of screening methods for individual differences measurement, there is a need to develop a brief self-assessment scale for spatial and engineering abilities. For scale development, a series of statements from the Bricks questionnaire aimed at evaluating both "large-scale" and "small-scale" spatial abilities adolescents were utilized (https://datadictionary.teds.ac.uk/studies/webtests/18yr_bricks_qnr.htm) from Twins Early Development Study (TEDS) project. Additionally, three specific statements were developed to measure engineering abilities reflecting the combination of spatial and engineering skills involved in the successful execution of tasks related to understanding and designing objects, devices, and mechanisms.

We hypothesize that the factor structure of the self-assessment scale for spatial abilities will be divided into two theoretically justified interconnected components: spatial and engineering. The main **aim** of this study is to evaluate the theoretical and psychometric validity of the developed scale.

Methods

Sample

The study involved 5,062 students from four Russian higher education institutions. Of these, 14.3% completed the assessment instrument in a careless manner, as identified through analysis of individual response variability and response sequence length. For the following analysis, a sample of 4,336 participants was selected, including 1,236 males (28.51%). The mean age of the participants was 18.35 years (range: 18–25 years; SD = 0.9).

Self-Perceived Ability - Spatial and Engineering Scale

The Self-Perceived Ability - Spatial and Engineering Scale comprised 11 statements. Of these, 8 items pertain to the assessment of spatial abilities, while items 9–11 are aimed at the evaluation of engineering abilities (Table 1). Participants are asked to indicate their level of agreement with each statement on a Likert scale ranging from 1 (Strongly agree) to 5 (Strongly disagree). Statements 4, 6, and 8 are reverse-coded (negative). For subsequent analysis, responses to all items, except the reverse-coded ones, were re-coded in the opposite direction: "strongly agree" as 5 points, "agree" as 4 points, and so on. The total score for the scale was calculated by summing the individual item scores.

Table 1

Content of the Self-Perceived Ability - Spatial and Engineering scale's items.

Nº	Item Content
1	Я хорошо ориентируюсь на местности.
2	Я хорошо представляю, как 2D объекты выглядят в 3D.
3	Я хорошо запоминаю ориентиры, когда гуляю где-то в первый раз.
4	Мне трудно представить, как будут выглядеть объекты с другого ракурса.***
5	Я редко теряюсь, когда гуляю где-то в первый раз.
6	Мне сложно мысленно вращать объекты.***
7	У меня хорошие пространственные способности.
8	Обычно я не знаю, где нахожусь относительно ближайших ориентиров.***
9	Я легко понимаю принцип работы приборов, механизмов или устройств.
10	Если понадобится, то я смогу разобрать и собрать обратно бытовой прибор или механизм.
11	Для меня не составляет труда собирать модели из бумаги или конструировать из кубиков Лего.

Note. *** – reverse-coded statements

Statistical Analysis

To evaluate the validity of the theoretical construct and to identify the underlying factor structure of the Self-Perceived Ability – Spatial and Engineering scale (SPA-SAE), participants' responses were analyzed using structural equation modeling. The sample was evenly divided into two parts to conduct Exploratory Factor Analysis (EFA) prior to performing Confirmatory Factor Analysis (CFA). The first 2,168 participants were used for EFA, while the remaining 2,168 participants were selected for CFA. The initial EFA was conducted using the psych package (Revelle, 2025) in R version 4.3.1 to determine the factor clustering of the data. Based on the results of the EFA, CFA was performed using promax rotation to assess the fit of the observed data to the proposed factor structure. The confirmatory factor analysis was carried out using JASP software version 0.18.1.

Subsequently, an assessment of the internal consistency and stability of the SPA-SAE scale was conducted. This analysis included the calculation of Spearman's rank correlation coefficients (ρ) between individual items and the total scale score. For each subscale, Cronbach's alpha (α) was computed to determine the internal reliability of the items. This analysis was performed using R version 4.3.1.

Finally, a test of measurement invariance across different gender groups was conducted using Multigroup Confirmatory Factor Analysis (MCFA). Within this framework, three models were analyzed to assess configural invariance, metric invariance (factor loadings), and scalar invariance (thresholds). The multigroup confirmatory factor analysis was performed using JASP software version 0.18.1.

Results

Descriptive statistics

Table 2 presents the distribution characteristics of raw scores for the scale items. The normality analysis of the total score distribution for the entire sample was conducted using the Shapiro-Wilk test and indicated a significant deviation from a normal distribution ($W = 0.99$, $p < 0.001$). Following this, non-parametric criteria were employed for subsequent analyses.

Table 2

Descriptive statistics of data distribution of scale's statements and total score.

Nº Item	Mean	Median	SD	Min	Max	Skewness	Kurtosis
1	3,59	4	1,12	1	5	-0,43	2,35
2	3,54	4	1,08	1	5	-0,37	2,39
3	3,71	4	1,08	1	5	-0,54	2,54
4	3,56	4	0,96	1	5	-0,65	3,02

Nº Item	Mean	Median	SD	Min	Max	Skewness	Kurtosis
5	3,29	3	1,18	1	5	-0,19	2,09
6	3,92	4	1,09	1	5	-0,47	2,51
7	3,43	3	1,02	1	5	-0,18	2,34
8	3,44	4	1,11	1	5	-0,61	2,49
9	2,85	3	1,07	1	5	0,24	2,41
10	2,61	2	1,22	1	5	0,37	2,15
11	3,33	3	1,53	1	5	-0,27	2,08
Total Score	36,76	37	7,45	11	55	-0,13	3,05

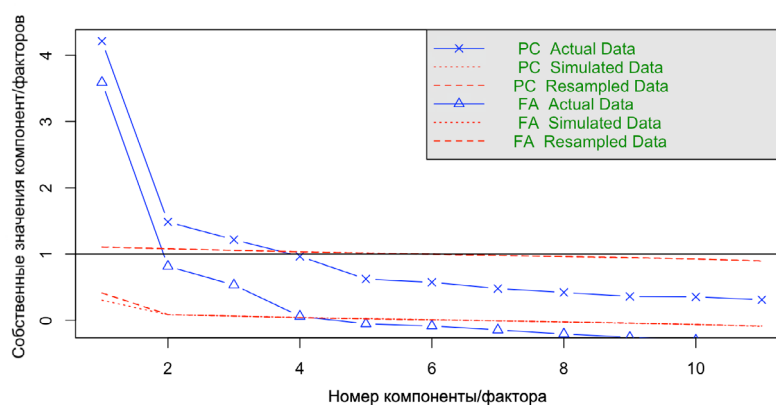
Exploratory Factor Analysis

To determine the factor structure of the scale exploratory factor analysis was conducted on the first half of the sample (N = 2,168). Prior to this the feasibility of the sample for further analysis was assessed. The Kaiser-Meyer-Olkin (KMO) measure was calculated and found to be 0.85. The results of Bartlett's test of sphericity were significant ($\chi^2 = 17,676.79$, $p < 0.001$) indicating that the data are multivariate normally distributed and meet the criteria for factor analysis.

To determine the number of latent factors a parallel analysis was conducted. The scree plot (Figure 1) indicated the presence of three components with eigenvalues exceeding 1. However, the acceleration coefficient analysis suggested the presence of four factors. Based on these results, a four-factor structure was selected for subsequent exploratory factor analysis.

Figure 1

Graphical estimation of the number of components and factors in the exploratory factor analysis model



An EFA was conducted to determine the factor loadings of the items within the proposed factor model. The number of factors was set to four corresponding to the previously identified structure, and oblique promax rotation was applied to facilitate a more reliable interpretation of the factor loadings. The results indicated that the four identified factors explained 18%, 15%, 13%, and 6% of the total variance, respectively, cumulatively accounting for 52%. In the next stage, the degree of correspondence between each statement and its respective factor was assessed. When interpreting the pattern of factor loadings an item was considered significantly loaded onto a factor if its loading value was 0.3 or higher based on widely accepted guidelines regarding the minimum threshold for item loadings. Item 8 did not meet this criterion and was therefore removed from the scale. The factor loadings for each statement are presented in Table 3.

Table 3

Factor loadings of scale's items based on Confirmatory Factor Analysis

		Factor loadings after rotation			
Item					
Nº	Item content	1	2	3	3
1	Я хорошо ориентируюсь на местности	0,839			
3	Я хорошо запоминаю ориентиры, когда гуляю где-то в первый раз.	0,772			
5	Я редко теряюсь, когда гуляю где-то в первый раз.	0,645			
9	Я легко понимаю принцип работы приборов, механизмов или устройств		0,731		
10	Если понадобится, то я смогу разобрать и собрать обратно бытовой прибор или механизм		0,923		
11	Для меня не составляет труда собирать модели из бумаги или конструировать из кубиков лего		0,521		
4	Мне трудно представить, как будут выглядеть объекты с другого ракурса.			0,791	
6	Мне сложно мысленно вращать объекты.			0,828	
2	Я хорошо представляю, как 2D объекты выглядят в 3D				0,602
7	У меня хорошие пространственные способности.				0,379

Note. Amount of explained variance: 51,895%, Factor 1: 18,128%, Factor 2: 15,221%, Factor 3: 12,747%, Factor 4: 5,799%

Based on the analysis of the patterns of factor loadings and the theoretical content of the statements, it was determined that statements 1, 3, and 5 form a factor related to spatial orientation and navigation abilities. Consequently, this factor was named "Orientation." Statements 9, 10, and 11, which assess engineering abilities, form the "Engineering" factor. The theoretical content of statements 4 and 6 is categorized as mental rotation skills; this factor was referred to as "Rotation". The fourth factor comprising statements 2 and 7 focused on evaluating spatial visualization abilities, and was named "Visualization".

Confirmatory Factor Analysis

Following the EFA, confirmatory factor analysis (CFA) was conducted on the second half of the sample ($N = 2,168$) to verify whether the derived factors accurately represent the theoretical framework of spatial and engineering abilities. Scale's factor structure was derived in the previous stage of analysis based on the results of the EFA. Consequently, all identified factors were explicitly defined and comprised 2 to 3 items. The model's fit was evaluated using standard fit indices: chi-square (χ^2), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR). An acceptable model fit was confirmed by RMSEA values below 0.08 and CFI and TLI values ranging from 0.90 to 0.95 (Hu & Bentler, 1999).

The four-factor CFA model demonstrated an excellent data fit ($\chi^2(283) = <0.001$; CFI = 0.971; TLI = 0.956; RMSEA = 0.064; SRMR = 0.038). Moreover, the factor loadings ranged from 0.72 to 0.98 (see Figure 2). The factor correlation matrix indicated moderate to high correlations among all four factors, ranging from 0.36 to 0.80 (see Figure 2). These findings provide reasonable evidence supporting the construct validity of the SPA-SAE scale.

Reliability

To estimate the reliability of the identified factors a correlation analysis was conducted on the full sample ($N = 4,336$) using Spearman's rho coefficient. Spearman's rho correlations were calculated to examine the relationships between four factors and the total score (see Table 4). The four factors and the total scale score were positively correlated. The Cronbach's alpha coefficients for internal consistency of the four scale factors ranged from 0.70 to 0.79 (see Table 4). These results further support the multidimensionality of the scale and confirm the presence of four distinct factors.

Picture 2

Factor structure diagram of the Self-Perceived Ability - Spatial and Engineering scale.

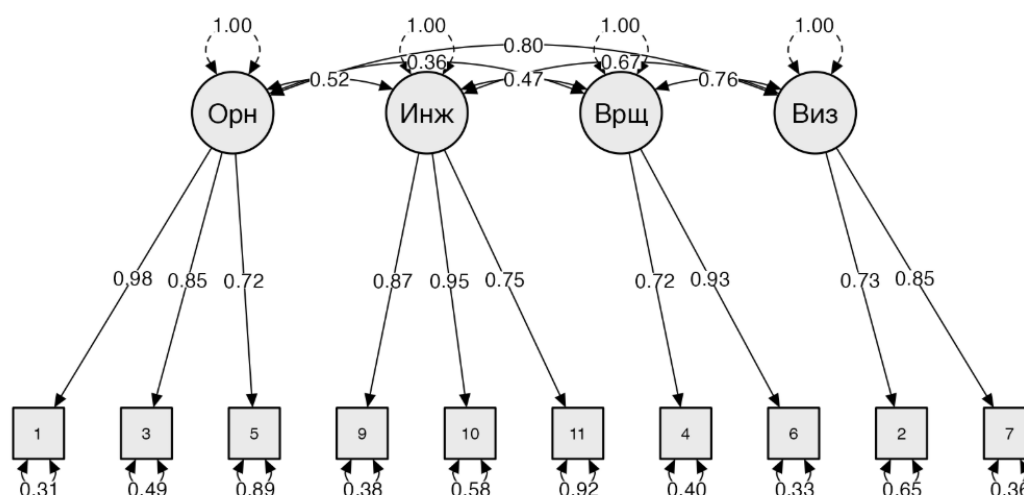


Table 4

Coefficients of internal consistency for the factors and correlation coefficients between the factors and the total score

	Orientation	Engineering	Rotation	Visualisation	Total score
Orientation					0,768***
Engineering	0,396***				0,783***
Rotation	0,272***	0,362***			0,657***
Visualisation	0,569***	0,505***	0,572***		0,830***
α Cronbach	0,79	0,78	0,78	0,70	0,85

Note. *** – p -value $< 0,001$

To evaluate the discriminative capacity of the items, corrected correlations between each item and the total score were calculated for sample groups comprising the lowest 27% ($N = 1,217$) and highest 27% ($N = 1,236$) of scores. The differences between the mean scores of the lower and upper groups were analyzed using the Mann-Whitney U test, a non-parametric independent test. The corrected correlations between each item and the total score for scale items ranged from 0.573 to 0.768 (see Table 5). All values were positive and high, confirming the internal consistency of each item with the total score. For all items, the differences in mean scores between the lower and upper 27% groups were statistically significant ($p < 0.001$) (see Table 5). These findings provide compelling evidence of the items' discriminative ability and scale's internal consistency.

Table 5

Correlation between scale's statements and total score, and mean values comparison between groups of lower and upper 27 % scores

Factor	Nº	Total score correlation	Gr.	Mean	SD	Mann-Whitney, p-value	Rank-Biserial, Correlation
Orientation	1	0,709***	L	2,607	0,952	<0,001	-0,864
			U	4,515	0,657		
	3	0,657***	L	2,843	1,038	<0,001	-0,791
			U	4,520	0,668		
	5	0,573***	L	2,491	0,998	<0,001	-0,712
			U	4,092	1,005		
Engineering	9	0,683***	L	2,035	0,783	<0,001	-0,822
			U	3,788	0,901		
	10	0,639***	L	1,778	0,863	<0,001	-0,786
			U	3,666	1,088		
	11	0,636***	L	2,402	1,060	<0,001	-0,796
			U	4,290	0,853		
Rotation	4	0,580***	L	2,895	0,975	<0,001	-0,668
			U	4,151	0,716		
	6	0,610***	L	2,562	1,051	<0,001	-0,727
			U	4,109	0,791		
Visualisation	2	0,690***	L	2,608	0,947	<0,001	-0,813
			U	4,358	0,758		
	7	0,768***	L	2,467	0,755	<0,001	-0,898
			U	4,315	0,675		

Note. *** – p-value <0,001; L – lower 27% group; U – upper 27% group.

Measurement invariance

As a result of the comparative analysis of mean scores between male (N = 1,236) and female (N = 3,100) groups, significant differences were observed in favor of the male gender (see Table 6).

Table 6

Comparative analysis of mean values in female and male gender groups.

Factor	Gr.	Mean	SD	Mann-Whitney, p-value	Rank-Biserial, Correlation
Orientation	M	11,587	2,653	<0,001	0,283
	F	10,201	2,846		
Engineering	M	10,204	2,827	<0,001	0,384
	F	8,231	2,771		
Rotation	M	7,330	1,778	<0,001	0,170
	F	6,803	1,872		
Visualisation	M	7,576	1,681	<0,001	0,270
	F	6,725	1,846		
Total score	M	36,697	6,647	<0,001	0,392
	F	31,961	6,997		

Note. *M – male gender group; F – female gender group.*

Measurement invariance implies that the scale provides equivalent measurement of the same constructs across different groups. To assess the satisfaction of invariance conditions multigroup confirmatory factor analysis (MCFA) is frequently employed in practice (Vandenberg & Lance, 2000; van de Schoot et al., 2012). In order to evaluate the reproducibility of the factor loadings pattern across two gender groups, a configural model based on four factors (Orientation, Engineering, Rotation, and Visualization) was utilised. The configural model was compared with a model that assumes invariance of factor loadings (metric invariance) and with a model that assumes invariance of both factor loadings and thresholds (scalar invariance). The results of the MCFA are presented in Table 7.

Table 7

Results of the Multigroup Confirmatory Factor Analysis and invariance models comparison.

Model	χ^2	df	p-value	CFI	RMSEA	SRMR
Model 1					0,065	
configural	582,61	58	<0,001	0,968	95% CI (0,060; 0,069)	0,041
Model 2				0,967	0,062 $\Delta = -0,003$	0,042
metric	600,32	64	<0,001	$\Delta = -0,001$	95% CI (0,058; 0,067)	$\Delta = 0,001$
Model 3				0,965	0,061 $\Delta = -0,001$	0,041
scalar	631,16	70	<0,001	$\Delta = -0,002$	95% CI (0,057; 0,065)	$\Delta = -0,001$

Based on widely accepted guidelines regarding acceptable model fit decline in invariance testing ($\Delta CFI \geq -0.01$, $\Delta RMSEA \geq 0.015$, and $\Delta SRMR \geq 0.03$), we can conclude that configural invariance and metric invariance are confirmed for this sample (Chen, 2007). Similarly, using corresponding criteria for scalar invariance ($\Delta CFI \geq -0.01$, $\Delta RMSEA \geq 0.015$, and $\Delta SRMR \geq 0.01$), the conditions for verification of this type of invariance are also met. Therefore, the primary types of measurement invariance for the self-assessment scale of spatial and engineering abilities are confirmed.

Discussion

In the present study a series of statements constituting a brief scale was developed for the rapid self-assessment of spatial and engineering abilities in students (Self-Perceived Ability - Spatial and Engineering, SPA-SAE). This scale was evaluated using a representative sample of students enrolled in Russian higher education institutions, enabling a comprehensive analysis of its psychometric quality. Various diagnostic methods were employed to evaluate the scale, including analyses of internal consistency and construct validity, and measurement invariance across gender groups. The results demonstrated the high quality of the proposed scale, confirming its theoretical foundation and appropriateness for use in assessing students' core spatial and engineering abilities.

Factor structure of the scale

A factor analysis was conducted to ensure the validity of the theoretical construct and to identify the psychometric structure underlying the self-assessment scale of spatial and engineering abilities. The results of the exploratory factor analysis indicated that scale's statements related to spatial navigation, engineering skills, mental rotation, and spatial visualization, loaded onto distinct but correlated factors (Orientation, Engineering, Rotation, and Visualization, respectively). Confirmatory factor analysis further validated the four-factor structure.

These findings are in congruence with the conceptualization of spatial ability components as classified into "large-scale" and "small-scale" groups (Jansen, 2009). Thus, the "Orientation" factor can be considered as representing "large-scale" spatial abilities as the items associated with this factor pertain to tasks that require spatial orientation and the mental representation of object locations relative to the observer. Conversely, the "Rotation" and "Visualization" factors are associated with "small-scale" spatial abilities, with the statements referring to mental representation of objects in space, object's transformation tracking, and performing mental manipulations.

Thus, the identified factor structure of the proposed scale is in line with existing conceptualizations of spatial abilities and their relationship with engineering skills, thereby supporting the theoretical validity of the scale's structure.

Reliability and Validity

According to the results, the "Engineering" factor demonstrated moderate correlations with both the "Orientation" factor, and the "Rotation" factor, and "Visualization" factor. These findings are in congruence with the notion that the development of advanced engineering skills requires well-developed spatial abilities (Berkowitz & Stern, 2018; Sorby et al., 2018). Furthermore, spatial visualization emerges as a primary and the most strongly intercorrelated factor within the structure of spatial and engineering abilities, exhibiting the greatest connections with the other spatial factors, as well as the "Engineering" factor. The relationships between the scale's factors confirm the association between engineering and spatial abilities, which are crucial for specialized tasks such as solving spatial problems or working with technical documentation. Additionally, these results denote the justified need for combined assessment approaches for profiling in educational and career guidance contexts.

Measurement invariance in gender groups

Comparisons of mean scores across the identified factors as well as the total score revealed significant differences between male and female gender groups. Gender differences in spatial abilities are well-documented in numerous studies. Specifically, males tend to outperform females on several spatial tests (Maeda & Yoon, 2013; Uttal et al., 2013), as

well as in engineering skills (Halpern et al., 2007; Ceci & Williams, 2010; Charlesworth & Banaji, 2019; Antoshchuk, 2021). Research attributes these differences to various factors, including evolutionary (Silverman et al., 2007), strategic (Heil & Jansen-Osmann, 2008; Weiss et al., 2003), and hormonal influences (Heil & Jansen-Osmann, 2008; Vuoksimaa et al., 2010). The detection of gender-based differences within this sample confirms the scale's sensitivity to individual variations in spatial and engineering abilities.

The invariance analysis across gender groups demonstrated that the scale with its four-factor structure satisfied the conditions for configural, metric, and scalar types of invariance. This result indicates the scale's reliability in comparison of latent factor means and structural model components, as well as the invariance of threshold parameters across the examined gender groups. Based on these findings, it can be concluded that scale's estimates are highly comparable and that the interpretations of the scale statements are consistent across gender groups.

Conclusions

The developed self-assessment scale of spatial and engineering abilities constitutes a theoretically valid and reliable instrument ready for application in Russian-language research and practice. We offer a practical tool that can be effectively employed in educational institutions to identify and evaluate key spatial and engineering skills among students, and it can serve as a basis for further investigations in STEM fields.

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Conflict of Interest Information

The authors have no conflicts of interest to declare.