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Standardization of the Five-Factor Model of the Maher Multifaceted Fluid Test of Intelligence (MMFTI) for Fourth to Sixth-Grade Students (first version) based on Metacognition Theory

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ABSTRACT

Objective: The research aimed to create a standardized version of the five-factor model of the Maher Multifaceted Fluid Test of Intelligence (MMFTI) for students in grades four to six, based on the theory of metacognition.

Methods and Materials: The study involved conducting the Maher Multifaceted Fluid Test of Children Intelligence (MMFTI) to standardize fluid intelligence in fourth to sixth-grade students (ages 10 to 12) in Tehran. The research used a descriptive and mixed exploratory method with a fundamental purpose. It is based on Cattle-Horn-Carroll (CHC) theories, successful intelligence theory, and superintelligence theory, or the intelligence of happiness, as a theoretical foundation. 800 students were selected from non-profit schools in 5 educational districts of Tehran using the staged cluster sampling method. The results of the exploratory factor analysis of 90 questions in the framework of a 5-factor model including perception (shape from context, shape recognition, visual completion, and perceptual sequence), reasoning (visual, maze, matrix, and mental calculations), attention (one-dimensional, multi-dimensional and geometric), memory (visual, auditory and numerical) and processing speed (visual processing, symbols, letter sequence) confirmed.

Findings: The results of the structural equation modeling and confirmatory factor analysis, confirmed that the 5-factor measurement model fit well. The factor loadings of the sub-variables on the 5-factor indicated that the sub-variables are appropriate measures for capturing the main factors. The Cronbach's alpha coefficients also indicated that these factors and their sub-variables demonstrated acceptable reliability.

Conclusion: The research findings indicate that this test may potentially supplant older tests and can provide more precise cognitive, meta-cognitive, and perceptual markers evaluations. This is achieved by prioritizing objectivity and keeping in mind the ultimate aim of the test, which is to promote happiness and well-being.

Keywords: *Successful intelligence, Superintelligence (happiness intelligence), Fluid intelligence, Perception, Reasoning, Attention, Memory, Processing speed*

Introduction

Intelligence has been a subject of extensive research and theoretical exploration, resulting in diverse conceptualizations and models. Traditional theories primarily focused on cognitive abilities, while contemporary frameworks incorporate a broader range of factors, including emotional and metacognitive dimensions. (Asdolahzadeh et al., 2021; Hasanpour et al., 2020)Robert J. Sternberg's Triarchic Theory of Intelligence revolutionized the understanding of intelligence by introducing a more holistic perspective.

This theory posits that intelligence comprises three interrelated components: analytical, creative, and practical intelligence. (Baramake et al., 2024; Kamkar et al., 2021). Sternberg's theory emphasizes that successful intelligence involves effectively integrating and utilizing these three components. This approach challenges the traditional focus on analytical abilities alone, advocating for a broader understanding of intelligence that includes creativity and practical application. (Kamkar et al., 2021)This theory has significant practical implications, as it suggests that educational programs should cultivate all three aspects to develop well-rounded individuals.

Howard Gardner's Theory of Multiple Intelligences expands the concept of intelligence by proposing that it is not a single, monolithic ability but a collection of distinct modalities. Gardner initially identified seven intelligences: linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, and intrapersonal, later adding naturalistic and existential intelligences. (Gooran Savadkohi et al., 2023; Miri Rami et al., 2022; Seadatee Shamir, 2024)This theory underscores that individuals possess unique combinations of these intelligences, which influence their learning and interaction with the world. Gardner's model has profound educational implications, advocating for a personalized approach to teaching that recognizes and nurtures each student's unique strengths. (Nejadi, 2022; Roghani & Afrokhte, 2023). Educators can create more inclusive and effective learning environments by acknowledging the diversity of intelligences.

The Cattell-Horn-Carroll (CHC) Theory represents a comprehensive model synthesizing the work of Raymond Cattell, John Horn, and John Carroll. This theory differentiates between fluid and crystallized intelligence, among other broad cognitive abilities. Fluid intelligence (Gf) is the capacity to solve novel problems and adapt to new situations, while crystallized intelligence (Gc) involves accumulating knowledge and skills. (Seadatee Shamir, 2024).

The CHC theory further delineates multiple, broad, and narrow cognitive abilities, providing a detailed framework for understanding the complexity of human intelligence. This model has been instrumental in developing contemporary intelligence tests, guiding the creation of assessments that capture a wide range of cognitive functions. (Kamkar et al., 2021)The CHC theory's comprehensive approach ensures that intelligence assessments are nuanced and reflect the diverse nature of cognitive abilities.

Emotional intelligence (EI), popularized by Daniel Goleman, emphasizes the importance of emotional and social competencies in overall intelligence. EI involves recognizing, understanding, and managing one's emotions and those of others. This theory posits that emotional skills are critical for personal and professional success, influencing how individuals navigate social interactions and cope with challenges. (Roghani & Afrokhte, 2023).

Sternberg's theory of successful intelligence emphasizes the triarchic nature of intelligence, encompassing analytical, creative, and practical components (Kamkar et al., 2021). This model advocates for the inclusion of non-cognitive factors in intelligence assessment, aiming to provide a more holistic understanding of an individual's capabilities. The successful intelligence training package developed to reduce high-risk behaviors in teenagers illustrates the practical applications of this theory in educational interventions (Baramake et al., 2024).

Research indicates high emotional intelligence is associated with better mental health, academic performance, and interpersonal relationships. Teaching emotional intelligence skills in educational settings has been shown to reduce burnout and enhance student self-regulation. (Roghani & Afrokhte, 2023). Integrating EI into intelligence theories highlights the importance of considering emotional and social factors alongside cognitive abilities.

Metacognition, the awareness and regulation of one's cognitive processes, has emerged as a pivotal theoretical framework for understanding and enhancing human intelligence. The concept, deeply rooted in cognitive psychology, extends beyond mere knowledge acquisition, emphasizing the processes involved in monitoring, controlling, and reflecting on one's cognitive activities. (Elhamifar et al., 2019; Yeung & Summerfield, 2012). This framework has profound implications for educational practices and intelligence assessment, particularly in developing comprehensive and effective learning strategies. Metacognition encompasses two primary components: metacognitive knowledge and metacognitive regulation. Metacognitive knowledge refers to an individual's understanding of their cognitive processes, including knowledge about oneself as a

learner, the nature of different tasks, and strategies that can be employed for learning and problem-solving (Kokabi Rahman et al., 2023). Self-awareness is crucial for effective learning as it allows individuals to recognize their strengths and weaknesses and to plan accordingly. Metacognitive regulation, on the other hand, involves the monitoring and controlling of cognitive processes through activities such as planning, monitoring, and evaluating. Planning involves setting goals and selecting appropriate strategies, monitoring refers to the ongoing assessment of one's progress toward these goals, and evaluating entails reviewing the outcomes and the effectiveness of the strategies used. (Gooran Savadkohi et al., 2023). These regulatory processes are essential for adaptive learning and problem-solving, enabling learners to adjust their strategies based on feedback and performance outcomes.

Integrating metacognitive skills into educational curricula has demonstrated significant benefits across various age groups and educational levels. For instance, Karimi et al. (2023) developed and validated a model for teaching metacognitive skills based on quantum thinking, which effectively enhanced the cognitive abilities of student-teachers (Karimi et al., 2023). Similarly, metacognitive skills training has been found to increase the fluid intelligence of secondary students, highlighting its potential to foster cognitive development. (Gooran Savadkohi et al., 2023).

Emotional intelligence (EI), which involves recognizing, understanding, and managing emotions, is another crucial component of holistic intelligence. Research indicates that high EI is associated with better academic performance, social skills, and mental health h (Roghani & Afrokhte, 2023). Teaching emotional intelligence skills in educational settings has effectively reduced burnout and improved self-regulation among students with attention deficit disorders. (Alborzi & Khosh Lahjeh Sedgh, 2023; Amirinia, 2024; Khosh Lahje Sedq & Mohammadtahery, 2022; Miri Rami et al., 2022; Nejadi, 2022). Moreover, the relationship between emotional intelligence and other cognitive abilities, such as processing speed and organizational planning, underscores the interconnectedness of cognitive and emotional factors. Khorshidi et al. (2024) demonstrated that teaching metacognitive strategies improved processing speed and organizational planning in students with mathematical disorders, further emphasizing the integrated nature of cognitive and emotional development. (Khorshidi et al., 2024).

Metacognitive therapy (MCT), which focuses on modifying dysfunctional metacognitive beliefs, has shown promise in treating various psychological disorders. Studies have documented its effectiveness in reducing anxiety, rumination, and worry among obsessive-compulsive patients. (Nematollahi et al., 2023). Additionally, MCT has been beneficial in improving communication skills and reducing anxiety in secondary school girls. (Atayi et al., 2023). The broader implications of metacognitive therapy extend to enhancing overall cognitive and emotional functioning. Okati et al. (2023) found that MCT effectively addressed the relationship between obsessive-compulsive disorder (ROCD) and experiential avoidance, suggesting its potential to improve relational and cognitive outcomes. These findings align with the growing recognition of the interplay between metacognitive processes and emotional regulation in fostering mental health and cognitive resilience. (Okati et al., 2023).

Traditional intelligence tests, such as those developed by Wechsler, Binet, and Simon, primarily focus on cognitive abilities. However, these tests often fail to capture the multifaceted nature of intelligence, which includes emotional and metacognitive dimensions. The need for more comprehensive assessment tools has led to the development of integrated models that consider various aspects of intelligence. (Stanovich & West, 2014; Tahmasebiboldaji, 2022; Tsalas et al., 2017).

Intelligence assessment must also account for cultural and contextual factors influencing cognitive and metacognitive processes. For example, the strategic intelligence of education district managers in Tehran is shaped by specific cultural and organizational contexts, necessitating tailored models for effective management. (Miri Rami et al., 2022). Similarly, the influence of Taekwondo martial arts on emotional intelligence in high school boys highlights the cultural specificity of specific interventions. (Nejadi, 2022).

Integrating metacognitive and emotional factors into intelligence assessment significantly advances educational psychology. Studies have shown that metacognitive training enhances emotional intelligence and adaptive cognitive strategies, improving academic and life outcomes. (Amirinia, 2024). This holistic approach to intelligence recognizes the importance of

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self-regulation, emotional management, and cognitive flexibility in achieving success and well-being. For instance, the relationship between spiritual intelligence, self-efficacy, and self-compassion illustrates the complex interplay between cognitive and emotional factors in academic settings. (Tahmasebiboldaji, 2022). Teaching methods based on metacognitive strategy theory have proven effective in promoting autonomous learning and academic success. (Li, 2018). In the Iranian context, diverse cultural backgrounds necessitate the development of norm scores that reflect the population's unique characteristics. (Bilač et al., 2024; Boltivets, 2023; Rostami & Navabinejad, 2023). This approach ensures the validity and reliability of intelligence assessments, facilitating their application in educational and psychological settings. Future research should aim to extend these findings across different provinces and age groups to establish comprehensive normative data.

The theoretical challenges and fundamental criticisms of existing intelligence tests and the evolving perspectives of intelligence theorists like Sternberg on measuring intelligence have set the stage for further research in this field. This includes comparing existing tests and evaluating their effectiveness. This field was found to have shortcomings in theory, research, and practice. The gaps were often caused by the existing tests not being compatible with the social and local conditions of Iran. The next step is consolidating all tests into one comprehensive test, enhancing the precision and effectiveness in pursuing practical goals. After designing the preliminary model of the multifaceted Maher Fluid Intelligence Test (MMFTI) children's version, the second primary purpose of this research was to determine:

1. Whether the model designed, the content, and the extracted factors are meaningful and have appropriate factor loadings on the overall structure of the research, and if they fit with the data collected from the native sample.

2. Whether the sub-components developed for each factor are suitable criteria for measuring the related factor.

3. Finally, can this test cover the theoretical and practical gaps of the previous tests?

Methods and Materials

Study Design and Participants

The research was conducted using a descriptive and correlational method. The research's objective was fundamental. The target population of the tool was the students in the second year of elementary school, aged 10 to 12 years. The working method involved obtaining approval from the education department and school principals for student participation in the test on Thursdays and Fridays. The test was administered by 10 multifaceted fluid intelligence experts (MMFTI) who had previously been trained individually and using pencil and paper. After completing the first three components, the subject takes a 15-minute rest before proceeding with the following three components.

This method has been utilized because standardizing tests necessitates examining the correlation between items, the correlation between each item, the total correlation, and the repeatability of test scores. The qualitative part of the research included 6 experts in psychometrics of intelligence and talent, selected using purposeful sampling. The quantitative research focused on the entire population of male and female students in fourth to sixth grade at non-government schools in Tehran. The population size was 16,000, according to the Education Department. The cluster sampling method was used to select the participants. 5 regions of Tehran (1, 3, 6, 5, 18), including northern, central, southern, eastern, and western regions, were randomly selected. Then, 6 schools from each region (3 boys' schools and 3 girls' schools) were chosen. In the next stage, 3 grades (1st, 2nd, and 3rd) were selected from each school, resulting in a total of 800 students. The criterion for selecting the sample size was the number of factors in the proposed model. Based on the model's 27 factors and Kerlinger's theory (1984), which suggests selecting between 15 and 30 people for each factor, 30 individuals were chosen for each factor after considering the conditions and feedback from qualitative research experts.

$$N = \text{factors} * 30 \rightarrow 27 * 30 = 810$$

According to the given formula, 810 people were calculated for the sample size, and at the end, after the sample size was reduced, 800 people were included in the analysis.

Data Collection Tools

In order to compile and construct the Maher Multifaceted Fluid Intelligence (MMFTI) test, first of all, the existing theories and tests such as Sternberg's theory of successful intelligence, Gardner's theory of mind, Renzulli's talent theory, Cattell-horn and Carroll's theory (CHC), etc. Various tests from Among the tests of Raven, Cattell, Binet and Simon, Wechsler, N Beck, Riding's notebook, Frosting test, Wisconsin cards, Woodcock-Johnson test, Stroop attention, CHC, etc. Were studied, and a combination of these tests with Natives was chosen**.** Then, the extracted questions were sorted according to the importance of the components. In the next step, they were sent to six professors who were experts in this field to check the content validity using the Delphi method. The initial 11 components were narrowed down to 6 based on expert opinions. Then, 143 questions were confirmed using the Delphi method and tested on a group of 50 people. Each of the five factors had 2 questions, except for the attention factor, which had three questions removed **.**The remaining questions were placed under five components and 27 sub-components, which were 1- Perception (shape from context, shape recognition, visual completion, and perceptual sequence), 2- Reasoning (visual, maze, matrix, and mental calculations), 3- Attention (one-dimensional, multi-dimensional and geometric) 4- Memory (visual, auditory and numerical) and 5- Processing speed (visual processing, symbols, letter sequence)**.**

Perception and reasoning variables each have 4 sub-components, and each component has 5 questions. The test consists of 20 questions covering various aspects such as shape recognition, visual completion, perceptual sequence, maze, matrix, and mental calculations. The time allotted for each question ranges from 30 seconds (for the first to third question) to 40 seconds (for the fourth question) and 45 seconds (for the fifth question). The scoring method is as follows: the first three questions have 3 marks each, the third question has 4 marks, and the fifth question has 5 marks. This section has a total of 72 points for each variable. For each sub-component in this section, one question is provided to explain how to perform the test for the subject. These questions are for guidance only and do not carry a score.

In the variables of attention, memory, and processing speed, each variable has 15 questions, and the subvariables have 5 questions each. In total, the section has a total of 54 marks. The raw score of Maher's multifaceted fluid intelligence test (MMFTI) is 333, and the highest IQ obtained in this test is 160. The method for calculating IQ scores is as follows: First, raw scores are obtained based on age groups, starting from 10 years and 3 months, with subsequent age groups at 10 years and 6 months, 10 years and 9 months, 10 years and 11 months, and so on for 11 and 12 years. These raw scores are then converted into scaled scores using a scoring table, which are further converted into IQ scores. The confidence interval is defined for each IQ point, which is 2 points lower and 2 points higher than the final IQ of the person. Finally, the percentage rank of each person is determined; that is, the order of each person's score is determined in comparison with others.

Table 1

Introduction of Maher Multifaceted Fluid Intelligence Test (MMFTI)

	Perception	Reasoning	Attention	Memory	Processing speed
Subcomponents	4	4	4	3	3
Questions	20	20	20	15	15
Maximum raw score	72	72	72	57	57
Efforts	4	4	4	3	3
Time (minutes)	12	12	12	9	
Scoring indicators	Raw score	Balance score	IQ	Percentage rank	Confidence interval
Total	Questions	Time	Attempts	The total score	IQ
	90	54 minutes	21	333	160

Data analysis

The data was analyzed using SPSS 23 software, and exploratory factor analysis was performed using maximum likelihood and varimax rotation. Moreover, the correlation between 5 factors of fluid intelligence (the latent variables) was investigated using the Lisrel 8.80 software.

Findings and Results

The fluid intelligence variable was investigated using confirmatory factor analysis. In this method, each question was an indicator or observed variable, and each of the 5 variables was entered into the equation as a latent variable. In order to check each of these models, the fit of the initially developed model was checked in the first step. Then, using correction indices, the initial model was revised by adding some error covariances, and the fit of the modified model was checked**.** Next, the researcher investigated the descriptive statistics of the demographic variables of the research. In this study, the students were divided into two groups, boys and girls, and they were between 10 and 12 years old.

Table 2

Description of the variables

Variables	Groups	Frequency	Percent	Sample size	Mode
Gender	Boy	411	51.4	800	1
	Girl	389	48.6		
Age	10	128	16.0	800	3
	11	305	38.1		
	12	367	45.9		

The correlation matrix is presented in Table 3.

Table 3

The results of examining the correlation between the 5 dimensions of fluid intelligence

Variables	1	2	3	4	5	6
1-Perception	0.78**	1				
2- Reasoning	0.63**	0.60**	1			
3- Attention	0.48**	0.44**	0.61**	1		
4-Memory	0.78**	0.69**	0.53**	0.42**	1	
5-Processing speed	0.79**	0.59**	0.65**	0.54**	0.69**	1

As can be seen in Table 3, all variables of fluid intelligence have a medium to high significant correlation with each other. Based on this, the highest correlation is related to the correlation between perception and knowledge (0.81), and the lowest correlation is related to the correlation between attention and knowledge ()0.43. the researcher checked the reliability in Table 4.

Table 4

The results of the reliability check of the components of fluid intelligence

Variables	Number of questions	Internal consistency reliability (alpha)	Composite Reliability Index (CRI)
1-Perception	20	0.78	0.94
2- Reasoning	20	0.90	0.93
3- Attention	15	0.88	0.87
4-Memory	15	0.82	0.88
5-Processing speed	15	0.80	0.96

The results of composite reliability analysis for five factors show that this coefficient is in the range of 0.87 to 0.95, which indicates good reliability for these factors. Also, the results of the internal homogeneity of these 5 sub-variables show that this composite reliability index is in the range of 0.78 to 0.96, which indicates good reliability for these factors. In the next step, Figure 1 shows the indicators of the factor analysis related to the fluid intelligence model. These indicators are presented graphically.

According to the findings of the multivariate covariance analysis presented in Table 4, the P-value for the Between-Subjects Effects in the variable of Suicidal ideation was statistically significant during both the Post-test and Follow-up phases ($p<0.001$). This indicates a notable difference between the research groups while controlling for the effects of the Pre-test stage. In the same way, the P-value for the Between-Subjects Effects in the Emotional Security variable was significant in both the Post-test and Follow-up phases ($p<0.001$), indicating a notable distinction between the study groups. Table 5 was utilized to assess and contrast the different stages of the research procedure.

Table 5

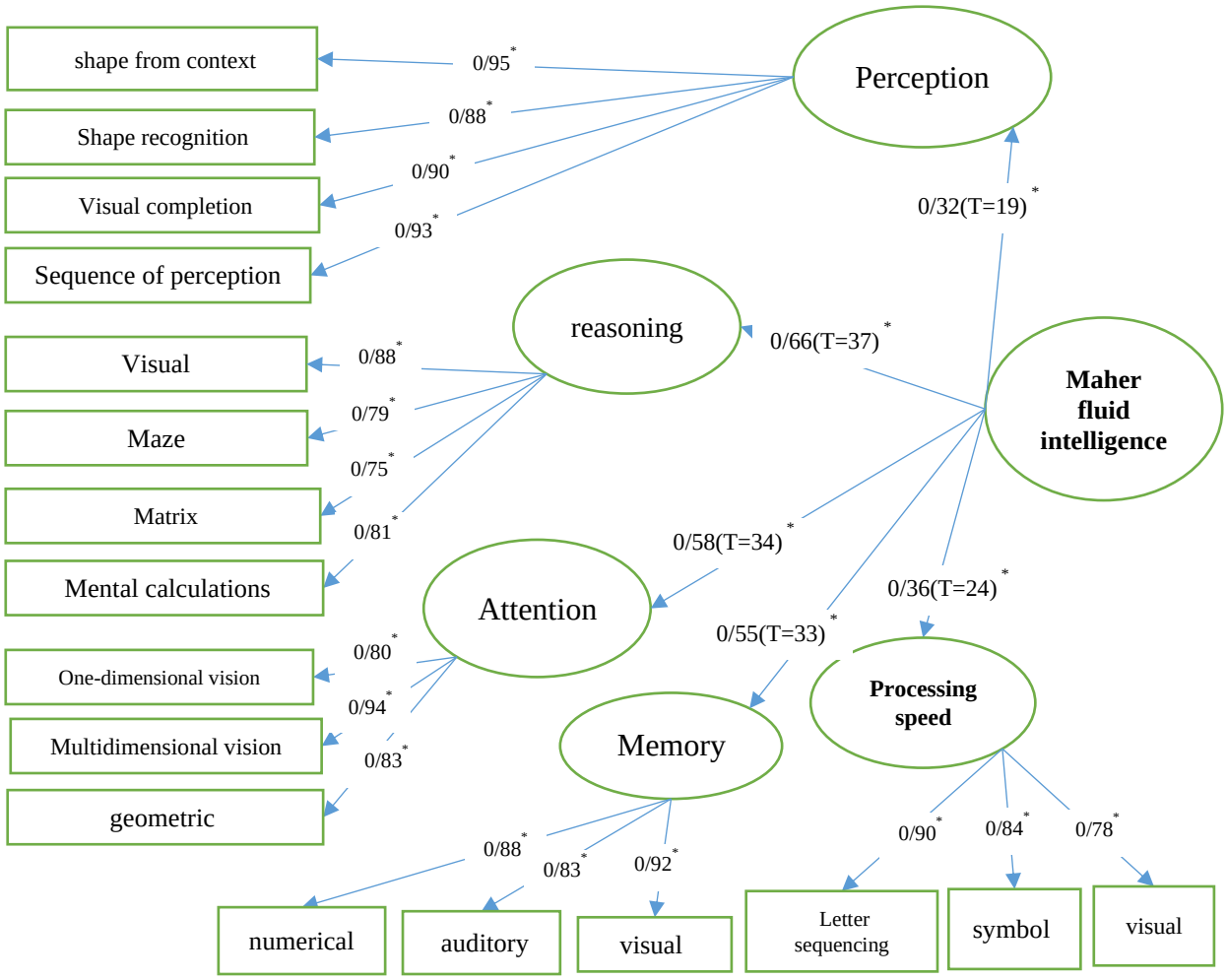
Mean, standard deviation, and correlation coefficients of perception subtest questions with total score and Cronbach's alpha coefficients

Question	Mean	Standard deviation	Correlation with the whole	Alpha	Question	Mean	Standard deviation	Correlation with the whole	Alpha
Shape from context					Visual completion				
1	1.90	91.0	0.54	0.71	1	2.70	92.0	0.21	0.89
2	1.66	1.66	0.37	0.71	2	2.60	1.14	0.88	0.72
3	1.90	.860	0.76	0.77	3	2.31	1.12	0.31	0.89
4	1.68	1.16	0.67	0.82	4	2.33	.862	0.88	0.76
5	1.55	86.0	0.23	0.80	5	3.43	871.	0.31	0.81
Shape recognition					Sequence of visual perception				
1	1.30	1.76	0.16	0.80	1	2.90	1.32	0.22	0.72
2	1.66	.880	0.54	0.81	2	2.04	1.38	0.61	0.82
3	1.69	78.0	0.74	0.98	3	2.01	1.43	0.25	0.75
4	1.75	90.0	0.53	0.81	4	2.41	1.53	0.45	0.78
5	1.81	0.75	0.61	0.85	5	1.37	1.26	0.32	0.79
Visual					Maze				
1	1.84	90.0	0.68	0.71	1	2.70	93.0	0.22	0.86
2	1.88	1.78	0.17	0.80	2	2.80	1.81	0.23	0.85
3	1.70	90.0	0.70	0.80	3	2.40	1.44	0.75	0.89
4	1.80	1.35	0.28	0.88	4	2.97	0.90	0.60	0.77
5	2.30	79.0	0.27	0.86	5	3.23	19.0	0.58	0.86
Matrix					Mental calculations				
1	2.89	1.39	2.89	0.81	1	2.93	1.35	0.29	0.86
2	2.90	1.60	2.90	0.80	2	2.91	1.58	0.55	0.77
3	2.01	1.76	2.01	0.83	3	2.91	1.88	0.65	0.71
4	2.89	1.39	2.89	0.90	4	2.48	1.59	0.74	0.89
5	2.17	1.05	0.27	0.93	5	1.47	1.52	0.78	0.89
					6	0.87	0.77	2.67	1.04

					7	0.86	2.68	1.72	0.51
					8	2.93	0.80	0.88	0.80
					9	3.03	89.0	0.31	0.89
					10	2.65	1.44	0.20	0.72
Visual processing speed					Symbol processing speed				
1	2.89	93.1	0.67	0.81	1	2.18	92.1	0.23	0.88
2	2.90	1.60	0.80	0.92	2	2.13	1.36	0.65	0.78
3	2.01	1.76	0.69	0.90	3	2.49	1.16	0.43	0.70
4	2.09	1.90	0.64	0.56	4	2.55	1.78	0.71	0.80
5	2.45	76.1	0.78	0.60	5	2.79	80.1	0.42	0.93
Letter sequence									
1	2.70	1.16	0.29	0.84					
2	2.60	1.80	0.43	0.81					
3	2.56	1.35	0.70	0.69					
4	2.33	1.14	0.83	0.77					
5	2.43	1.09	0.57	0.89					
One-dimensional vision					Multidimensional vision				
1	1.92	23.1	0.60	0.85	1	2.98	90.1	0.22	0.91
2	1.90	1.60	0.57	0.96	2	2.78	1.50	0.48	0.89
3	1.80	08.1	0.66	0.78	3	2.69	1.45	0.39	0.89
4	1.86	1.86	0.68	0.89	4	2.70	0.83	0.61	0.80
5	2.37	70.1	0.54	0.80	5	3.19	02.1	0.50	0.83
Geometric (symbolically)									
1	1.84	1.14	0.17	0.80					
2	1.88	0.86	0.29	0.81					
3	1.70	87.0	0.70	0.85					
4	2.92	1.42	0.29	0.78					
5	2.75	1.85	0.23	0.89					
Visual memory					Numerical memory				
1	1.98	90.1	0.40	0.86	1	2.22	91.1	0.33	0.87
2	2.30	1.68	0.34	0.92	2	2.11	1.16	0.56	0.88
3	2.41	90 .0	0.56	0.97	3	2.65	1.32	.071	0.74
4	2.61	1.46	0.68	0.95	4	2.86	1.46	0.41	0.92
5	2.79	88.1	0.59	0.96	5	2.34	81.1	0.39	0.90
Auditory memory									
1	2.74	1.19	0.19	0.81					
2	2.88	.890	0.55	0.80					
3	2.90	89.0	0.72	0.90					
4	2.33	95.0	0.28	0.81					
5	2.43	1.05	0.27	0.81					

Figure 1

Factor analysis indicators related to the multifaceted test model of skilled fluid intelligence (MMFTI)



As can be seen in Figure 1, among the 90 questions related to the sub-variables of fluid intelligence, which have 5 sub-variables (1-perception, 2-reasoning, 3-attention, 4-memory, 5-processing speed), all the questions have loads. The factor and T value were significant, and the sub-variables related to 5 variables were also significant, which shows that the sub-variables related to each of these variables were good metrics for measuring their own variables .Based on this, the highest path coefficient was found on the factor of skilled fluid intelligence in the order of reasoning with factor load value (β=66.0. T=37.0), attention (β=58.0. T=34.0), memory (β=55.0. T= 33.0), processing speed (β=36.0. T=24.0) and perception (β=32.0. T=19.0). Also, the factor load of each of the sub-variables on the variables is shown in Figure 1. The results of the reliability index and Cronbach's alpha, which were used to measure the reliability of the questions, showed that the above factors are reliable.

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Table 6

Fit indices of final models for 5 factors of fluid intelligence

6-factor structure	Absolute indices						Comparative indices			Other indices		
	K^2	P	DF	K^2. DF	GFI	AGFI	NFI	TLI	CFI	RMSEA	RMR	SRMR
Perception	1.345	00.0	123	0.432	95.0	89.0	81.0	82.0	79.0	060.0	15.0	063.0
Reasoning	2.205	00.0	93	½	94.0	91.0	83.0	91.0	90.0	058.0	18.0	064.0
Attention	0.335	00.0	114	0.133	85.0	84.0	87.0	79.0	87.0	079.0	17.0	071.0
Memory	44.31	00.0	249	0.443	94.0	83.0	76.0	74.0	84.0	080.0	19.0	069.0
Processing speed	472	00.0	239	0.743	81.0	89.0	85.0	82.0	88.0	089.0	19.0	090.0

The results in Table 6 show that although the chi-square index is significant for all 5 final factors, due to the sensitivity of this index to the number of samples and the large sample size of this research, the non-significance of the chi-square index is not far from the mind. It can be a good indicator for determining the fit of the models. However, all the other 5 indicators for these structures are optimal (according to the range of indicators mentioned above).

Discussion and Conclusion

The results of this study highlight the efficacy of the Maher Multifaceted Fluid Test of Intelligence (MMFTI) in assessing the fluid intelligence of fourth to sixth-grade students. The study confirmed that the MMFTI, standardized on students aged 10 to 12, is a reliable and valid tool for measuring fluid intelligence across five components: reasoning, attention, memory, processing speed, and perception. These findings align with and expand upon existing research in the field of educational psychology and intelligence assessment.

The structural model of the research confirmed that all five components significantly contribute to the overall test structure, with Cronbach's alpha values consistently above 0.80, indicating high reliability.

The prominence of reasoning in the MMFTI aligns with Sternberg's (2020) Triarchic Theory of Intelligence, which underscores the importance of analytical skills in problem-solving and understanding complex information. Reasoning facilitates a more profound comprehension of societal policies and educational systems, which is essential for navigating modern academic and social environments. This finding is consistent with the results of similar studies, which have highlighted reasoning as a crucial component of cognitive performance (Hasanpour et al., 2020; Kamkar et al., 2021; Karimi et al., 2023). Attention, the second most significant factor, plays a critical role in cognitive processing by facilitating the transfer of information to the brain and memory systems. Adequate attention ensures that information is thoroughly analyzed and processed, which is vital for deep learning and cognitive development. This result supports previous research by Gooran Savadkohi et al. (2023), who found that training in metacognitive skills, which enhance attention, significantly improved students' academic performance and fluid intelligence. Memory, identified as the third critical factor, is indispensable in the retention and retrieval of information. High verbal and perceptual intelligence and deep reasoning are contingent on robust memory capabilities (Gooran Savadkohi et al., 2023).

This finding resonates with the work of Yazdani et al. (2023), who demonstrated that metacognitive strategies aimed at improving memory could enhance academic self-efficacy and reduce test anxiety among students. Processing speed, though ranked fourth, is essential for cognitive efficiency, impacting the rapid retrieval and application of knowledge (Yazdani et al., 2023). Faster processing speeds can enhance memory capacity and the utilization of cognitive resources. This is consistent with the findings of Khorshidi et al. (2024), who reported that teaching metacognitive strategies improved processing speed and organizational planning in students with mathematical disorders. Perception, the final component, is crucial for understanding and interpreting visual information, which is particularly important for technical tasks (Khorshidi et al., 2024). This ability is foundational for developing crystallized intelligence, as it involves integrating new information with existing knowledge structures. The role of perception in cognitive tasks aligns with Gardner's (2011) Theory of Multiple Intelligences, which includes spatial intelligence as a critical dimension of cognitive functioning (Alborzi & Khosh Lahjeh Sedgh, 2023;

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Tahmasebiboldaji, 2022; Urban & Urban, 2018; Varshney & Barbey, 2021).

The results of the MMFTI study are supported by numerous aligning studies that emphasize the importance of a multifaceted approach to intelligence assessment. For instance, Kokabi Rahman et al. (2023) found that cognitive and metacognitive strategies significantly enhance academic motivation and engagement, reinforcing the value of integrating these strategies into intelligence assessments (Kokabi Rahman et al., 2023). Similarly, Karimi et al. (2023) highlighted the effectiveness of teaching metacognitive skills based on quantum thinking, which aligns with the comprehensive approach of the MMFTI (Karimi et al., 2023). Further supporting the findings, Nematollahi et al. (2023) demonstrated that metacognitive therapy effectively reduces rumination, anxiety, and worry, highlighting the broader implications of metacognitive strategies for cognitive and emotional regulation (Nematollahi et al., 2023). These results underscore the potential of metacognitive training to enhance both cognitive performance and mental health, supporting the inclusion of metacognitive dimensions in the MMFTI. The consistency of these findings with existing research underscores the validity of the MMFTI as a comprehensive tool for assessing fluid intelligence. The integration of reasoning, attention, memory, processing speed, and perception provides a nuanced understanding of students' cognitive abilities, aligning with contemporary theories of intelligence that advocate for a holistic approach (Enayati Shabkolai et al., 2023; Pourjaberi et al., 2023).

Although the study had promising results, some limitations need to be recognized. The sample was only from Tehran, so the findings may not apply to other regions. Increasing the sample size to 800 students helps strengthen the findings, but future studies should include a more diverse sample for better generalizability. The study's cross-sectional design limits the ability to determine causality. Longitudinal studies are necessary to understand MMFTI score stability and fluid intelligence development in various educational stages. Relying on self-reported measures for cognitive and metacognitive strategies may introduce bias. Students' self-perceptions may not always accurately reflect their mental processes. While the MMFTI is thorough, it may not cover all aspects of intelligence. Adding emotional intelligence and social skills could give a more complete evaluation of students' intellectual abilities. Researchers should include these aspects in future studies to improve the test's accuracy.

Several suggestions are given for future research to address limitations and build on the study's findings. It is recommended to replicate the study with a more diverse sample to understand the MMFTI's applicability across different settings. Longitudinal studies could offer insights into the developmental trajectories of fluid intelligence and the effectiveness of cognitive strategies. Including emotional and social intelligence dimensions in the MMFTI could provide a more comprehensive assessment of students' intellectual capacities. Investigating the interactions between cognitive, metacognitive, and emotional factors could enhance understanding of intelligence development. Studying how educational interventions impact components of MMFTI can help educators. Research on teaching methods can offer recommendations for cognitive development. Metacognitive strategies can boost student performance. Assessment tools like MMFTI can identify strengths and weaknesses for personalized support. Emotional intelligence should be developed alongside cognitive skills. Policymakers should invest in teacher training and comprehensive assessment tools for better academic outcomes.

The MMFTI assesses the fluid intelligence of fourth to sixth-grade students. It emphasizes a multifaceted approach to intelligence assessment, combining reasoning, attention, memory, processing speed, and perception. This approach provides a detailed understanding of students' cognitive abilities. The study's results are backed by research, confirming the reliability of the MMFTI. Future research should address limitations and consider adding more dimensions to improve the test. By improving our understanding of intelligence, educators can better support students' development and academic success. The present research had some limitations. First, due to the diverse cultures in Iran, it would have been better to understand the normative scores of the test. The test was conducted throughout Iran to obtain a general norm score based on the average score of the entire country. All the provinces of Iran should be sampled and in the following research different provinces should be compared in terms of IQ. The test attempted to ensure that the age groups of the

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subjects are similar, which is considered a strength compared to other tests like the Wechsler and Binet tests. However, combining three educational levels in one age group in the early years of educational growth is still seen as a limitation. It is suggested that an independent test be developed for each educational level and age group, taking into account the specific characteristics and capabilities of each age group.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. In order to comply with the ethical principles of the research, school administrators were assured that none of the research forms contain personal information, and students can withdraw from the research process if they do not wish to participate.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed to this study.

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