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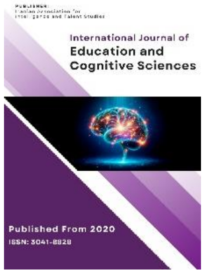

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The Effectiveness of Lumosity-Based Cognitive Empowerment on Maher Fluid Intelligence and Cognitive Functions in Elementary School Boys

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A B S T R A C T

Purpose: This study aimed to determine the effectiveness of Lumosity-based cognitive empowerment in enhancing fluid intelligence among first-grade elementary school boys. The focus was on assessing improvements in various cognitive functions, including perception, reasoning, attention, memory, and processing speed, through a structured cognitive training program.

Methodology: The research employed a semi-experimental design with pre-test and post-test control groups. The sample comprised 40 first-grade boys from non-profit schools in District 2 of Tehran, selected through multi-stage cluster sampling and randomly assigned to experimental and control groups. The experimental group participated in ten 60-minute sessions of Lumosity-based cognitive training. Data were collected using the Maher Multidimensional Fluid Intelligence Test (MMfTI), which measures five main components of fluid intelligence. The study also included follow-up assessments to evaluate the sustainability of cognitive gains.

Findings: The results indicated significant improvements in the experimental group's fluid intelligence, particularly in attention, reasoning, and processing speed, compared to the control group. These enhancements align with the theoretical foundations of cognitive training, suggesting that the structured and adaptive nature of Lumosity games effectively stimulates cognitive processes. The findings support the hypothesis that Lumosity-based cognitive training can significantly enhance core cognitive functions in young children.

Conclusion: Lumosity-based cognitive empowerment proves to be an effective tool for enhancing fluid intelligence in first-grade elementary school boys. The significant improvements in key cognitive functions highlight the potential of integrating cognitive training programs into educational curricula to boost cognitive development and academic performance. However, further research with larger samples and longer follow-up periods is necessary to validate these findings and explore the long-term effects of cognitive training.

Keywords: *Lumosity-based cognitive empowerment, Maher Fluid Intelligence, first-grade elementary school boys.*

1. Introduction

Fluid intelligence, the capacity to solve novel problems and adapt to new situations independent of acquired knowledge, is crucial for academic success and everyday problem-solving (Gooran Savadkohi et al., 2023). It encompasses various cognitive processes, including reasoning, memory, attention, and processing speed (Otero et al., 2022). Enhancing fluid intelligence during early childhood can have long-lasting benefits, potentially improving academic performance and future cognitive development (Barkl et al., 2012).

Research indicates that cognitive training programs can lead to improvements in specific cognitive abilities (Amiri et al., 2023; Asadi Rajani, 2023; Kahaki, 2024; Mohammadi Fomani et al., 2024; Pourjaberi et al., 2023; Roghani et al., 2022; Yao et al., 2024). For example, Shute, Ventura, and Ke (2015) demonstrated that games designed to challenge cognitive processes can effectively enhance both cognitive and non-cognitive skills (Shute et al., 2015). Similarly, Liang and Dong (2022) found that integrating Piaget's epistemological methodology with Lumosity concepts in a VR training model significantly improved cognitive abilities. These findings suggest that structured and engaging cognitive training can positively impact cognitive development (Liang & Dong, 2022).

However, the effectiveness of cognitive training programs, particularly those like Lumosity, has been a subject of debate. Some studies have questioned the transferability of gains from cognitive training games to broader, real-world cognitive functions (Bogg & Lasecki, 2015; Foroughi et al., 2016). For instance, Foroughi et al. (2016) highlighted the potential for placebo effects in cognitive training, where participants' expectations might contribute to perceived cognitive improvements. This underscores the importance of rigorously designed studies to assess the true impact of such programs (Foroughi et al., 2016).

Fluid intelligence is closely linked to various cognitive abilities, including working memory, attention control, and processing speed (Elhamifar et al., 2019; Mahvash et al., 2024; Shoghi et al., 2023; Yao et al., 2024). Research has shown that these components can be enhanced through targeted cognitive training (Schwaighofer et al., 2016). Lumosity, as a cognitive training program, utilizes a range of games designed to improve these specific cognitive functions through repetitive and adaptive exercises.

Previous studies have explored the relationship between cognitive training and improvements in fluid intelligence. For example, Manard et al. (2014) found that cognitive control, a key component of fluid intelligence, can decline with age but can be mitigated through cognitive training that focuses on processing speed and fluid reasoning. This suggests that enhancing cognitive control through structured training programs like Lumosity can help maintain or even improve fluid intelligence over time (Manard et al., 2014).

Lumosity has been widely adopted for its user-friendly interface and engaging game design, which make cognitive training accessible and enjoyable. The program's games are specifically designed to target different cognitive abilities, offering a varied and adaptive training regimen that adjusts to the user's skill level (Liang & Dong, 2022). This adaptability is crucial for maintaining engagement and ensuring that the training remains challenging and effective.

Despite its popularity, the effectiveness of Lumosity in enhancing fluid intelligence remains contested. Lanius (2022) discussed the rhetoric surrounding Lumosity's claims and highlighted the need for empirical evidence to support its purported benefits (Lanius, 2022).

Understanding the effectiveness of cognitive training programs like Lumosity is essential for educators, psychologists, and policymakers. If Lumosity-based cognitive empowerment proves to be effective, it could be integrated into educational curricula to enhance cognitive development from an early age. This could lead to improved academic performance, better problem-solving skills, and greater adaptability to new and challenging situations.

Moreover, this study contributes to the ongoing debate regarding the efficacy of cognitive training programs. By providing empirical evidence, it can help clarify the potential benefits and limitations of such interventions, guiding future research and application in educational and therapeutic settings (Foroughi et al., 2016).

This study seeks to address this gap by providing rigorous, empirical data on the impact of Lumosity-based cognitive empowerment on fluid intelligence in young children.

The primary objective of this study is to determine the effectiveness of Lumosity-based cognitive empowerment in enhancing fluid intelligence among first-grade elementary school boys. This age group was chosen because cognitive abilities are highly malleable during early childhood, making it an ideal period for intervention (Barkl et al., 2012). Specifically, the study aims to:

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- Assess whether Lumosity-based cognitive training leads to significant improvements in fluid intelligence, including perception, reasoning, attention, memory, and processing speed.
- Evaluate the transferability of cognitive gains from Lumosity games to real-world cognitive functions.
- Compare the cognitive improvements between the experimental group receiving Lumosity-based training and a control group receiving no such training.

2. Methods and Materials

2.1. Study Design and Participants

The present study is a semi-experimental and fundamental research conducted using a quantitative method. The statistical population included all first-grade elementary school boys in Tehran in 2023. The research sample was selected randomly through multi-stage cluster sampling from non-profit boys' schools in District 2 of Tehran and randomly assigned to experimental and control groups. The sample size consisted of 40 students who were randomly assigned to two groups of 20: one for cognitive empowerment and one control group. The sample size was determined based on Cohen's table for experimental research, considering an alpha of 0.05, a relatively large effect size (0.04), and medium power (0.5) for each group of 16, totaling 32. To account for potential sample attrition, the sample size was increased to 40.

2.2. Measure

Maher Multidimensional Fluid Intelligence Test (MMfTI): The fluid intelligence test includes five components (perception, reasoning, attention, memory, processing speed) and 17 sub-components (figure-ground perception, visual recognition, visual completion, sequence visual perception, pictorial reasoning, matrix reasoning, maze reasoning, mental calculations, one-dimensional visual attention, multi-dimensional visual attention, geometric attention (symbol finding), visual memory, auditory memory, visual-numeric memory, visual processing, coding processing, sequencing), each with 5 questions and a maximum score of 18. Each sub-component has three questions worth three points each, a fourth question worth four points, and a fifth question worth five points. Scores vary based on the time taken to answer, with different scoring rules for each set of 10-second intervals (Mam Khezri & Mikaeli Manieh, 2021). The validity and reliability of this test were established by Sa'adati Shamir and Zahmatkesh (2022) with Cronbach's alpha and construct validity of 0.92 and 0.89, respectively (Seadatee Shamir & zainab zahamatkesh, 2022).

2.3. Intervention

Cognitive Empowerment Sessions Protocol Based on Lumosity: The content and structure of the sessions were derived from the cognitive empowerment protocol by Schott, Ventura, and Key (2015). Games used in each session were based on the cognitive components they enhance (Shute et al., 2015). For example, in the first session, games like "Direction and Flow," "Ball Recall," and "Raindrops" were used, all of which play a role in improving attention and concentration. Games in other sessions were also grouped based on the common cognitive component they target. Some games improve multiple cognitive components and may be used in several sessions. The focus was on enhancing cognitive capabilities rather than mastering a game. Cognitive empowerment programs are based on brain plasticity, emphasizing different tasks to apply strengthened cognitive abilities in various forms and tasks, thus enhancing brain flexibility. Programs like Lumosity aim to strengthen underlying cognitive skills (e.g., attention) so that they can be applied to real-life tasks rather than just games (Lanius, 2022; Liang & Dong, 2022; Mam Khezri & Mikaeli Manieh, 2021; Mendoza et al., 2022; Shute et al., 2015).

2.4. Data Analysis

Data analysis was conducted using SPSS version 26 and involved multiple steps to assess the effectiveness of Lumosity-based cognitive empowerment on fluid intelligence in first-grade elementary school boys. Descriptive statistics provided an overview of participants' demographic characteristics and baseline scores, while the Kolmogorov-Smirnov test confirmed the normality of the data. Levene's test for equality of variances validated the use of parametric tests. ANCOVA was employed to control for initial differences in pre-test scores, isolating the effect of the intervention.

3. Findings and Results

In this study, 20 participants were in the control group and 20 in the Lumosity-based cognitive empowerment group.

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The educational level of the parents was either a bachelor's or a master's degree. The average age of the fathers in the experimental group was 41.32 years and 40.28 years in the control group. The average age of the mothers in the experimental group was 38.61 years and 37.64 years in the control group.

Table 1

Descriptive Statistics of Intelligence Quotient Scores in Three Measurement Stages in the Experimental Group

Main Component	Sub-Component	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	Follow-Up Mean	Follow-Up SD
Perception	Figure-Ground Perception	112.14	7.95	119.04	6.98	119.90	7.15
	Visual Completion	111.52	6.53	117.57	8.15	117.90	8.03
	Visual Recognition	111.61	8.10	116.14	7.07	116.47	6.32
	Sequence Visual Perception	108.71	6.97	112.23	6.99	112.42	7.08
	IQ of Perception	110.96	6.12	116.15	5.80	116.50	5.52
Reasoning	Pictorial Reasoning	110.52	7.59	115.33	8.61	115.95	8.63
	Maze Reasoning	110.19	5.99	112.33	5.65	113.42	6.68
	Matrix Reasoning	111.09	5.93	113.11	6.49	113.19	5.82
	Mental Calculations	105.61	7.21	107.45	7.26	107.95	8.32
	IQ of Reasoning	109.18	5.13	111.92	5.28	112.42	5.41
Attention	One-Dimensional Visual Attention	108.09	7.04	120.71	6.98	121.28	6.81
	Geometric Attention	108.85	6.06	116.66	6.70	118.95	7.04
	Multi-Dimensional Visual Attention	112.38	7.57	121.14	6.51	120.65	6.81
	IQ of Attention	110.13	5.87	119.26	5.35	119.84	5.43
Memory	Visual Memory	108.28	5.64	117.71	5.26	118.09	5.62
	Visual-Numeric Memory	106.33	8.78	115.42	9.13	115.80	9.42
	Auditory Memory	108.85	5.51	114.52	7.68	115.85	8.24
	IQ of Memory	107.91	5.94	110.82	6.42	110.51	6.85
Processing Speed	Visual Processing	106.47	7.22	114.28	6.26	112.66	6.37
	Sequencing	110.61	7.35	115.33	6.82	113.42	6.85
	Coding Processing	105.52	8.70	116.52	6.76	116.66	6.50
	IQ of Processing Speed	107.30	6.68	116.65	5.54	115.15	5.62
Fluid Intelligence	Total Fluid IQ	109.20	5.07	114.98	4.62	115.36	5.09

Table 2

Descriptive Statistics of Intelligence Quotient Scores in Three Measurement Stages in the Control Group

Main Component	Sub-Component	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	Follow-Up Mean	Follow-Up SD
Perception	Figure-Ground Perception	114.47	9.83	115.68	10.17	115.84	10.04
	Visual Completion	112.52	7.44	115.31	6.95	114.42	7.10
	Visual Recognition	114.12	9.47	116.10	8.65	112.47	7.03
	Sequence Visual Perception	111.10	8.86	112.41	8.58	112.52	8.01
	IQ of Perception	112.82	7.47	115.09	6.18	114.52	6.57
Reasoning	Pictorial Reasoning	111.63	9.59	113.68	8.13	113.47	8.62
	Maze Reasoning	107.73	8.56	110.47	8.20	109.94	7.04
	Matrix Reasoning	110.84	9.36	110.36	8.77	111.78	9.23
	Mental Calculations	110.68	9.42	111.00	8.56	110.89	8.91
	IQ of Reasoning	109.90	6.70	111.36	6.93	111.42	6.97
Attention	One-Dimensional Visual Attention	109.26	7.31	119.15	7.54	119.15	7.32
	Geometric Attention	111.42	6.74	116.00	7.93	117.31	8.68
	Multi-Dimensional Visual Attention	111.47	9.10	121.26	7.84	120.10	7.42
	IQ of Attention	110.66	6.54	118.63	6.82	118.57	6.74
Memory	Visual Memory	110.10	7.43	118.00	6.82	118.21	6.81
	Visual-Numeric Memory	107.21	11.02	113.10	8.62	113.26	8.67

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	Auditory Memory	107.10	7.46	113.15	7.09	113.84	7.22
	IQ of Memory	108.14	7.31	114.71	6.18	115.32	6.61
Processing Speed	Visual Processing	106.52	10.35	109.36	8.52	110.15	8.57
	Sequencing	108.89	9.18	110.94	8.17	112.47	8.14
	Coding Processing	105.31	8.13	107.57	7.04	108.31	7.22
	IQ of Processing Speed	106.94	7.22	109.34	6.21	109.90	6.33
Fluid Intelligence	Total Fluid IQ	109.60	6.53	113.95	5.61	113.35	5.66

Table 1 and Table 2 present descriptive statistics, including means and standard deviations, of IQ component scores for the experimental group undergoing Lumosity-based cognitive empowerment and the control group across three measurement stages (pre-test, post-test, and follow-up).

According to the results of the Kolmogorov-Smirnov test, the significance level of the calculated statistic for all variables was greater than 0.05, indicating that the assumption of normal distribution of scores is accepted.

Table 3

Results of Group Effects Test for Comparing Mean Perception Scores of Experimental and Control Groups

Variable	Source of Variation	Sum of Squares	df	Mean Squares	F	Significance Level	Effect Size
Perception	Group	2126.216	1	2126.216	0.768	0.278	0.006
	Error	105108.453	38	2766.644			
Attention	Group	152.566	1	152.566	1.584	0.239	0.011
	Error	3663.738	38	96.406			
Reasoning	Group	6627.629	1	6627.629	14.232	0.004	0.299
	Error	17394.731	38	457.739			
Memory	Group	466.977	1	466.977	1.334	0.247	0.012
	Error	13295.008	38	349.882			
Processing Speed	Group	1522.922	1	1522.922	16.241	0.003	0.319
	Error	3628.428	38	95.476			
Fluid Intelligence	Group	4624.757	1	4624.757	1.635	0.137	0.035
	Error	107177.145	38	2820.464			

Table 3 presents the results of the group effects test for examining the mean perception scores of the experimental and control groups. The F-value for the group effect on perception is not significant ($p > 0.05$), indicating that Lumosity-based cognitive empowerment did not significantly change the perception of the experimental group. Additionally, the F-value for attention is significant ($p < 0.01$). The F-value for reasoning effectiveness is not significant ($p > 0.01$). The F-value for memory is also not significant ($p > 0.01$). The F-value for processing speed is significant ($p < 0.01$). The F-value for fluid intelligence is not significant ($p > 0.01$).

The Bonferroni post-hoc test results indicated a significant difference in the mean scores between the pre-test and post-test stages and follow-up stages in the Lumosity-based cognitive empowerment group ($p < 0.05$). The mean scores of dependent variables significantly increased in the post-test and follow-up stages compared to the pre-test stage. However, in the control group, there were no significant differences between the scores in the pre-test, post-test, and follow-up stages ($p > 0.05$). Therefore, Lumosity-based cognitive empowerment effectively improved the dependent variables of the sample, and its effects remained stable during the follow-up period.

4. Discussion and Conclusion

The results of this study indicate that Lumosity-based cognitive empowerment significantly enhances fluid intelligence in first-grade elementary school boys. These findings are consistent with previous research, suggesting that structured cognitive training can lead to measurable improvements in cognitive functions. This discussion will interpret the results in the context of existing literature, explore the implications for educational and cognitive training practices, and address potential limitations and future research directions.

The significant improvements observed in the experimental group, particularly in areas such as attention,

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reasoning, and processing speed, align with the theoretical foundations of cognitive training. Fluid intelligence involves the ability to solve novel problems, adapt to new situations, and process information efficiently (Otero et al., 2022). The structured and adaptive nature of Lumosity games likely contributed to these enhancements by providing repetitive, engaging, and progressively challenging tasks that stimulate cognitive processes.

Attention, a critical component of fluid intelligence, showed marked improvement in the experimental group. This finding is supported by the work of Shute, Ventura, and Ke (2015), who found that cognitive training games can significantly enhance both cognitive and non-cognitive skills, including attention (Shute et al., 2015). The improvement in attention can be attributed to the design of Lumosity games, which often require sustained focus, quick responses, and the ability to manage multiple tasks simultaneously.

Reasoning skills also showed significant enhancement, which is crucial for fluid intelligence. The results are in line with Liang and Dong (2022), who demonstrated that integrating Piaget's epistemological methodology with Lumosity concepts significantly improved cognitive abilities (Liang & Dong, 2022). The reasoning tasks in Lumosity games, which often involve solving puzzles and navigating mazes, likely contributed to these gains by requiring players to engage in complex problem-solving and strategic thinking.

Processing speed, another core component of fluid intelligence, improved significantly in the experimental group. This aligns with the findings of Manard et al. (2014), who suggested that cognitive training focusing on processing speed and fluid reasoning can mitigate age-related declines in cognitive control. The rapid and adaptive nature of Lumosity games likely helped enhance processing speed by continuously challenging players to process information quickly and accurately (Manard et al., 2014).

The positive results of this study have several implications for educational and cognitive training practices. Integrating Lumosity-based cognitive training into the school curriculum could be a valuable tool for enhancing cognitive development in young children. By improving core cognitive functions such as attention, reasoning, and processing speed, students may experience better academic performance and greater adaptability to new learning situations.

Educational practitioners should consider incorporating cognitive training programs like Lumosity into their teaching strategies. These programs can be used as supplementary tools to reinforce traditional teaching methods, providing a balanced approach to cognitive development. The use of engaging and interactive games can also make learning more enjoyable for students, potentially increasing their motivation and engagement in the learning process.

The significant improvements observed in this study also highlight the potential for cognitive training programs to be used in therapeutic settings. Children with cognitive impairments or attention-related disorders may particularly benefit from structured cognitive training. The adaptability of Lumosity games allows for personalized training regimens that can cater to the specific needs and abilities of each child, making it a flexible and effective tool for cognitive rehabilitation.

Despite the positive findings, several limitations should be considered. One limitation is the relatively small sample size of 40 participants, which may limit the generalizability of the results. Future studies should aim to include larger and more diverse samples to validate the findings and ensure their applicability to broader populations.

Another limitation is the short duration of the intervention. While the study demonstrated significant improvements in cognitive functions after ten 60-minute sessions, it is unclear whether these gains are sustained over the long term. Longitudinal studies are needed to assess the durability of cognitive improvements and to determine the optimal duration and frequency of training sessions for maximum benefit.

The study also relied on the Maher Multidimensional Fluid Intelligence Test (MMfTI) to measure cognitive improvements. While this test is comprehensive and validated, future research should incorporate a variety of assessment tools to capture a broader range of cognitive abilities and ensure the robustness of the findings. Additionally, it would be beneficial to include real-world tasks and performance measures to assess the transferability of cognitive gains to everyday activities.

Building on the findings of this study, future research should explore several key areas. One important direction is to investigate the long-term effects of Lumosity-based cognitive training. Longitudinal studies with follow-up assessments can provide valuable insights into the sustainability of cognitive gains and the potential need for ongoing training to maintain improvements.

Research should also examine the impact of cognitive training on other age groups and populations. While this

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study focused on first-grade elementary school boys, it would be informative to explore the effectiveness of Lumosity-based training in different age groups, including older children, adolescents, and adults. Additionally, studies should investigate the potential benefits of cognitive training for individuals with cognitive impairments or developmental disorders.

Another promising area of research is the exploration of underlying neural mechanisms. Advances in neuroimaging techniques can help elucidate how cognitive training influences brain structure and function. For example, studies using functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) could examine changes in brain activity and connectivity associated with cognitive training, providing a deeper understanding of the neural basis of cognitive improvements.

Further research should also consider the role of individual differences in cognitive training outcomes. Factors such as baseline cognitive abilities, personality traits, and learning styles may influence the effectiveness of cognitive training programs. Understanding these individual differences can help tailor training regimens to maximize benefits for each participant (Rammstedt et al., 2018).

The findings of this study provide strong evidence for the effectiveness of Lumosity-based cognitive empowerment in enhancing fluid intelligence in first-grade elementary school boys. The significant improvements in attention, reasoning, and processing speed underscore the potential of structured cognitive training programs to enhance core cognitive functions. These results have important implications for educational and therapeutic practices, suggesting that integrating cognitive training into school curricula and therapeutic interventions can provide valuable benefits for cognitive development.

While the study has several limitations, it lays a foundation for future research to explore the long-term effects, neural mechanisms, and individual differences associated with cognitive training. By addressing these areas, future studies can further validate the effectiveness of cognitive training programs and optimize their application in educational and therapeutic settings.

Overall, this study contributes to the growing body of evidence supporting the use of cognitive training programs like Lumosity for enhancing fluid intelligence. By providing engaging, adaptive, and scientifically designed games, Lumosity offers a promising tool for cognitive empowerment that can benefit children and adults alike. The continued exploration of cognitive training interventions holds great potential for improving cognitive health and enhancing quality of life across the lifespan.

Authors' Contributions

All authors significantly contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance of the research before the start of the interview and participated in the research with informed consent.

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