# *Cognitive Augmentation Through Game Dynamics: The IMLS Variant of Mathesso and Its Implications for Mathematical Intuition Enhancement*

Leonard Bernau, Science 21 Foundation, Czech Republic
Filip Paulů, Science 21 Foundation, Czech Republic
Tomáš Benka, Science 21 Foundation, Czech Republic
Kamila Podoubská, Science 21 Foundation, Czech Republic
Kevin Jágr, Science 21 Foundation, Czech Republic

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**Abstract**
In this article, an interdisciplinary approach is undertaken to analyze the IMLS (Inverse Mathesso with Lowest Sum) variant of the Mathesso board game, fusing principles from mathematics and cognitive psychology. Retaining the token system of the original, the IMLS introduces distinct cognitive and psychological benefits. Enhanced activation of reverse synaesthesia, underpinned by cognitive psychology research, contributes to the systematic augmentation of memory retention capabilities. Additionally, the IMLS stimulates anticipatory abilities across multi-faceted logical layers, including contradictory ones. The game's 'inverse complexity', observed as players advance, emphasizes the strategic objective of achieving the lowest token sum, diverging from the original Mathesso's approach. This shift fosters unconventional extensions in logical reasoning. The IMLS not only amplifies mathematical intuition but, supported by psychological studies, showcases implications for real-world logical applications and cognitive processing patterns. A key feature of the IMLS setup is the initial exposure of the tokens' colored sides, setting a primary probability distribution for token pairs at 50/50, dynamically adjusting as gameplay evolves.

Keywords: Mathesso, Inverse Mathesso With Lowest Sum, Imls, Mathematical Intuition, Cognitive Augmentation, Model of Cognitive Process, Reverse Synaesthesia, Logical Reasoning, Strategic Gameplay

## Introduction

Mathematics is foundational to understanding and functioning in the modern world. It is essential for problem-solving, logical reasoning, and technological adeptness. Early math skills are critical for later success in school and beyond. A study found that preschoolers' math skills are predictive of their future academic performance, not just in math but also in reading and science, across all grades up to eighth grade (Claessens & Engel, 2013).

As young children develop the ability to perceive and operate with numbers, the process gets concerningly often disturbed by misunderstanding (Whyte & Bull, 2008). Such difficulties combined with the pressure to perform cause lack of self-confidence and often lead to aversion, that only deepens due to way-too-early transition from arithmetic to mathematics without providing opportunity to master the basics (Kaskens et al., 2020).

The Science 21 Foundation is working on a mathematical model of the cognitive process. Based on this model, a large number of applications (Bernau et al., 2020) are being designed to augment various cognitive processes. One of the applications is a universal mathematical game in which players do not need to count or even know numbers. A game that entertains children and adults alike and that not only teaches them how to count but most importantly opens them up to the basics of mathematics. Because counting and mathematics are not the same thing. This is the first of many misunderstandings that playing Mathesso will set straight (Janeček et al., 2022).

Mathesso aims to activate the cognitive processes responsible for the origin and development of mathematical intuition (Dehaene, 2009). It uses reverse synaesthesia as the most important learning mechanism (Watson et al., 2014). It is a phenomenon where people associate certain sensory perceptions with others, for example tones in music with colors (Zamm et al., 2013), in Mathesso we associate colors with numbers. When playing Mathesso, preschool children can quickly evolve what is known as a backbone algorithmic system, a concept described in Odic (2017). Children do not need to be able to recognise a single number, they can start learning the principle of multiplication, prime numbers and powers simply with the guidance of colors. Among other things, they will gain intuitive knowledge of the multiplication table (Janeček et al., 2022) that more advanced players then combine with addition and subtraction in the IMLS (Inverse Mathesso with Lowest Sum) version of the game.

## Application

The game Mathesso is an adaptation of a well-known children's game, which is widely known in the world under various names such as Concentration, Somewhere Memory, Matching, Pairs, Match, Match Up, Pelmanism, Pexeso or Pairs (Wilson et al., 2011). This game is popular for its simplicity and intuitive rules that allow even very young children from the age of three to participate (Rakoczy et al., 2009). This allows children to learn the concepts and rules of the game in a funny way without having to know how to read or write (Fuson et al., 2015).

The basic rules of Mathesso are simple and easy to understand. Two jettons are turned over in turn, if they are the same the player takes them, if not he turns them back. The next player continues to do the same. Play continues until all jettons are collected from the board. For the little ones, the one with the higher stack of jettons wins. For more advanced players, the chips

have different point values, which adds a strategic dimension. The winner is the player with the highest number of points.

Mathesso is proving to be an effective tool for developing mathematical intuition in children. The game naturally promotes the development of the ability to recognize and apply mathematical concepts such as number relationships, basic multiplication and division operations, and even understanding the concept of prime numbers, all without formal training in mathematics. Children learn to identify patterns and think strategically about the next moves, which contributes to the development of their analytical and problem-solving skills (Tarım, 2015).

Mathesso offers more than just fun for little ones. Its ability to foster the development of mathematical thinking and intuition in children makes it a valuable pedagogical tool that can be an integral part of early education. Through an interactive and fun format, the game helps children develop key cognitive and mathematical skills that are the foundation for future educational success (Alsubaie et al., 2018).

After its initial launch in 2021, Mathesso has quickly spread and gained the attention of the public and educational institutions. The "Mathesso in Schools" project aimed to integrate the game into school curricula. By the beginning of 2024, significant interest in the game was recorded, with more than 1,000 schools and other educational institutions in the Czech Republic expressing interest in incorporation of it in the educational process. Detailed statistics are presented in Table 1.

| **Institutions** | **Count** | **% in the Czech Republic** |
|---|---|---|
| Kindergartens | 17 | 0.3% |
| Elementary Schools | 962 | 20% |
| High Schools | 47 | 4% |
| Retirement homes | 5 | 4% |

Table 1: Number of institutions owned by Mathesso at the beginning of 2024.

We are working closely with several of these institutions on studies regarding in-depth research on the impact of Mathesso on educational processes and its impact on students. These studies focus on the integration of the game into the school curriculum and evaluate its effectiveness in improving students' mathematical skills and cognitive abilities. Initial results suggest a positive impact on mathematical intuition and logical thinking.

In 2024, a new tradition of international Mathesso tournaments was launched, attracting participants from different countries, including twenty chess grandmasters. This competition brought further international recognition to the game and positive feedback from participants who appreciated the strategic depth and educational potential of the game.

Mathesso is not limited to the Czech Republic. There are ambitions to expand its use as a teaching tool to other countries, including the African continent, Peru, and Portugal. These initiatives are driven by a desire to provide equal educational opportunities through innovative and accessible learning tools.

Mathesso is fast becoming an established educational tool with the potential for global impact. Its ability to promote cognitive development and mathematical skills has been used in a variety of educational contexts, contributing to the wider acceptance of play as an effective pedagogical tool.

For example, independently of us, a study was published at Charles University about the possibilities of the usage of Mathesso as a diagnostic tool in psychological assessment. They compared the results of cognitive tests and the game performance of adults and came up with a significant correlation between the error rate in the gameplay and performance on an intelligence test. So the game itself has the potential to reflect the intelligence performance of the player (Šimková, 2023).

**Inverse Mathesso With Lowest Sum (Imls)**

In an ongoing effort to improve and deepen the pedagogical benefits of Mathesso, a new variant called "Inverse Mathesso with Lowest Sum" (IMLS) has been developed. This innovation is based on the original game concept but introduces a new dimension of strategic thinking and mathematical reasoning.

IMLS uses the same set of chips as traditional Mathesso, allowing for easy adaptation for those already familiar with the game or who already own it. The main change in the rules is that at the start of the game, the chips are placed with the colored side facing up, as opposed to the original layout. This arrangement of the chips encourages players to think about the strategies of the game from a different perspective.

The most significant change is the way of evaluation: the player who has the lowest sum of points at the end of the game wins. This change trains the player's mathematical intuition for multiplication and division as well as addition and subtraction, for several situations at once. Thus, the player subconsciously gains intuition for solving systems of equations (Fleck & Kounios, 2009).

The full game Mathesso contains chips up to 121 which equals 11 times 11. However, it is recommended to use only a smaller number of chips depending on which part of mathematics you want to practice. In this article, for practical purposes, we will use the jettons up to the number 6 shown in Figure 1, otherwise known as the Mathesso Travel variant.

Figure 1: The start of the IMLS game with jettons up to 6 (Mathesso Travel).

***Rules***

1. Flip the jetton with the highest number.
2. Flip any other jetton or declare that there is no matching jetton.
    a. You may challenge the previous player if you believe they made a mistake and give him your jetton.
    b. Keep the jetton(s) with either the white side with the same number or the colored side facing you for a different number.
3. The next player continues from point 1.

After all chips are collected from the board, the player with the lowest point total wins.

***Cognitive Augmentation***

Playing any game exercises certain cognitive functions of the player (Unsworth et al., 2015). In our game, thanks to the cognitive process model, the rules were designed to not only improve mathematical intuition more than the original version but also to train players in the aspects that are most beneficial in everyday life. These aspects include memory, strategy, logic, attention, randomness, mathematical intuition, predictability, and empathy. Some of the phenomena of the game are described here.

From a strategic point of view, this game is at a high level. In the first game, players usually concentrate on finding even the pairs with the smallest sum. After a while, the player starts to

concentrate on making sure that the opponents do not get the opportunity to get chips with a smaller numerical sum than himself. In this way, the player subconsciously acquires that intuition for solving systems of equations (Fleck & Kounios, 2009).

As a presentation of the complexity of possible strategies, the first move advantage is discussed here in terms of the number of players. In this case, the key question is which jetton is advantageous to flip first: the jetton with the green-pink six or the orange-red six. The probabilities of what average score a player ends up with after the first turn only relative to his opponents have been calculated. The results, shown in Figure 2, show that in this small version of the game, it is always more advantageous to flip the green-pink jetton because it always has a smaller average. The results also suggest that the benefits change non-linearly and although it is disadvantageous to start this way in game with two players, it already looks the opposite with four players. This shows that the mere factor of the number of players significantly changes the strategy of the game. There are many such factors in the game, and their significant non-linear change with each change in play or just move, shows the large number of strategies that can be chosen, keeping the game interesting even for advanced players (Bonanno, 2015).

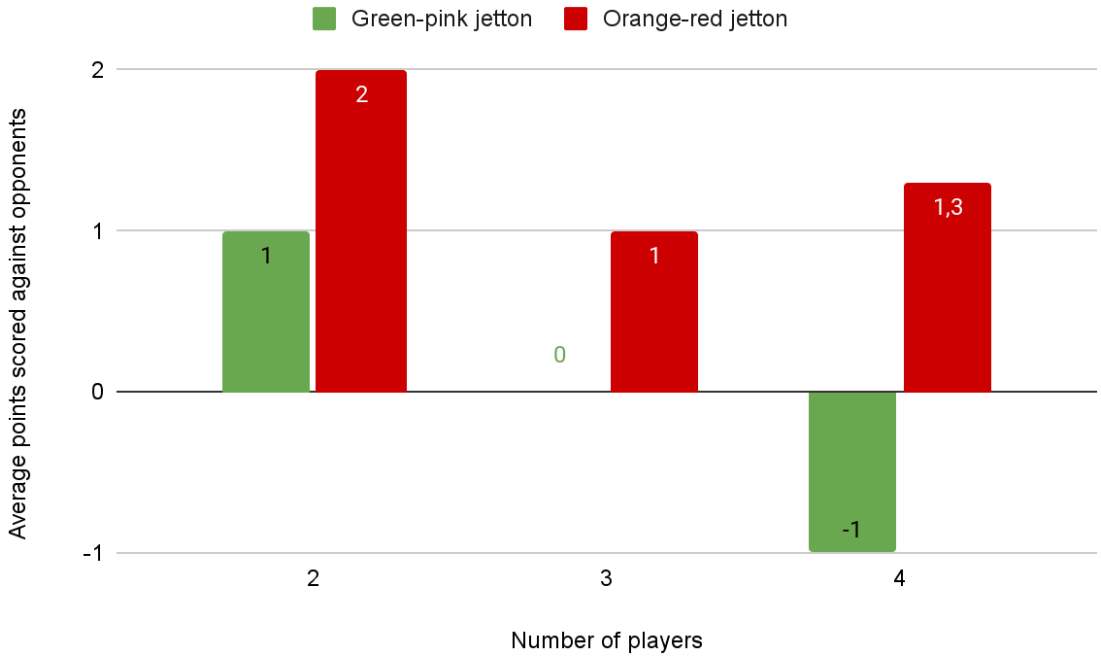


Figure 2: Evaluation of the first move strategy in the IMLS variant with Travel Mathesso.

Another phenomenon of this game is randomness. Mathesso is one of the few games that include an element of randomness, which is unlike games such as chess or go. We perceive randomness as a key educational element, which is particularly important for the realization that not everything can be influenced by pure logical reasoning, and yet this element can have significant benefits (Al-Hammadi & Abdelazim, 2015). This feature allows players to learn how to cope with uncertainty and unpredictability, skills that are also very valuable in real life.

The last phenomenon we discuss in this game is bluffing, which is designed to reflect real-life situations as much as possible. Bluffing (W. Wang et al., 2020) is one of the most interesting features of this game. One such situation can take place when a player flips over a

yellow prime number jetton and declares that it is the last five on the white side of the jettons in play. Several things can happen:

1. Another player believes him and does not intervene.
2. The next player notices his "mistake" because there is a white five under the pink-green five, and tries to refute his claim.
3. The next player realizes he is bluffing and tries to prove it.
4. The next player discovers that he is bluffing, but accepts it because proving it would be too risky, so he lets it go.
5. The next player also bluffs.
6. The next player discovers that he is bluffing, and hopes that the next player will also bluff, which is called double bluffing.
7. Etc...

The possibilities are many, and it often turns out that people try to read the other player rather than calculate the correct answer. This makes the game all the more interesting and fun, and strengthens skills like predictability and empathy (The Oxford Handbook of Lying, 2018).

**Conclusion**

The original Mathesso game succeeded as a tool for developing children's mathematical intuition. Due to its ability to intuitively introduce basic mathematical concepts without the need for formal education, Mathesso is gaining widespread use in schools and other educational institutions. This paper introduces the Mathesso game and its newly developed variant, Inverse Mathesso with Lowest Sum (IMLS), which integrates the principles of addition and subtraction into the original game format.

With the development of IMLS, educational impact takes on a new dimension compared to the original variant. The game motivates players to think more strategically, where the combination of multiplication and division with addition and subtraction in several possible variations simultaneously leads to intuitive solutions of systems of equations throughout the game. This approach not only strengthens mathematical skills but also improves players' cognitive flexibility and analytical skills.

Research is now moving towards further extending the mathematical methods incorporated in the game to enhance its pedagogical potential. Plans are underway to integrate additional mathematical operations and concepts that could further deepen players' understanding and application of mathematical principles. The goal is to make IMLS a standard educational tool widely available for schools and other educational institutions to promote wider acceptance and effectiveness in mathematics learning.

The development of IMLS is an example of how innovative pedagogical tools can enhance traditional educational methods and offer students a stimulating and interactive way to learn and develop key skills for their future academic and personal success without the assistance of a teacher.

**References**


Al-Hammadi, M., & Abdelazim, A. (2015). Randomness impact in digital game-based learning. *2015 IEEE Global Engineering Education Conference (EDUCON)*.

Alsubaie, A., Alaithan, M., Boubaid, M., & Jhanjhi, N. Z. (2018). Making learning fun: Educational concepts & logics through game. *2018 20th International Conference on Advanced Communication Technology (ICACT)*.

Bernau, L., Paulů, F., & Voves, J. (2020). Electronic Equivalent of Consciousness with Elementary Mental Process Model. In *Proceedings of the international neural networks society* (pp. 487–496).

Bonanno, G. (2015). Reasoning about strategies and rational play in dynamic games. In *Lecture notes in computer science* (pp. 34–62).

Claessens, A., & Engel, M. (2013). How Important is Where you Start? Early Mathematics Knowledge and Later School Success. *Teachers College Record*, *115*(6), 1–29.

Dehaene, S. (2009). Origins of mathematical intuitions. *Annals of the New York Academy of Sciences*, *1156*(1), 232–259.

Fleck, J. I., & Kounios, J. (2009). Intuition, creativity, and unconscious aspects of problem solving. In *Elsevier eBooks* (pp. 431–446).

Fuson, K. C., Clements, D. H., & Sarama, J. (2015). Making early math education work for all children. *Phi Delta Kappan*, *97*(3), 63–68.

Janeček, K., Bernau, L., Benka, T., & Paulů, F. (2022). Mathematical algorithm for understanding numbers and their operations integrated into the cornerstone of learning in a pelmanism game: Mathesso. *European Conference on Education Official Conference Proceedings*.

Kaskens, J., Segers, E., Goei, S. L., Van Luit, J. E. H., & Verhoeven, L. (2020). Impact of Children's math self-concept, math self-efficacy, math anxiety, and teacher competencies on math development. *Teaching and Teacher Education*, *94*, 103096.

Odic, D. (2017). Children's intuitive sense of number develops independently of their perception of area, density, length, and time. *Developmental Science*, *21*(2).

The Oxford Handbook of Lying. (2018). In *Oxford University Press eBooks*.

Rakoczy, H., Brosche, N., Warneken, F., & Tomasello, M. (2009). Young children's understanding of the context-relativity of normative rules in conventional games. *British Journal of Developmental Psychology*, *27*(2), 445–456.

Šimková, Z. (2023). Mathesso: Board game as a diagnostic tool. Bachelor thesis, supervisor Děchtěrenko, F. *Prague: Charles University, Faculty of Arts, Department of Psychology.*

Tarım, K. (2015). Effects of cooperative group work activities on pre-school children's pattern recognition skills. *Kuram Ve Uygulamada Egitim Bilimleri*.

Unsworth, N., Redick, T. S., McMillan, B. D., Hambrick, D. Z., Kane, M. J., & Engle, R. W. (2015). Is playing video games related to cognitive abilities? *Psychological Science*, *26*(6), 759–774.

Wang, W., Wang, Y., Zhou, X., & Yu, R. (2020). Interpersonal brain synchronization under bluffing in strategic games. *Social Cognitive and Affective Neuroscience*, *15*(12), 1315–1324.

Watson, M. R., Akins, K., Spiker, C., Crawford, L., & Enns, J. T. (2014). Synesthesia and learning: a critical review and novel theory. *Frontiers in Human Neuroscience*, *8*.

Whyte, J. C., & Bull, R. (2008). Number games, magnitude representation, and basic number skills in preschoolers. *Developmental Psychology*, *44*(2), 588–596.

Wilson, S., Darling, S., & Sykes, J. F. (2011). Adaptive memory: fitness relevant stimuli show a memory advantage in a game of pelmanism. *Psychonomic Bulletin & Review*, *18*(4), 781–786.

Zamm, A., Schlaug, G., Eagleman, D. M., & Loui, P. (2013). Pathways to seeing music: Enhanced structural connectivity in colored-music synesthesia. *NeuroImage*, *74*, 359–366.

**Contact email:** leonard.bernau@science21.cz