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Research Paper

Exploring the Efficacy of Mobile Game Implementation for Enhancing Memory, and Attention Span in Individuals with Down Syndrome: An Experimental Study

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ABSTRACT

Individuals with Down Syndrome (DS) commonly experience slower growth due to the presence of an extra chromosome, resulting in intellectual disability and developmental delays. Traditional pedagogical approaches, such as puzzles and paper-based card games, have been employed to teach essential knowledge to these children, as they benefit from experiential learning. However, digitalized versions of these activities focusing on retention and attention span are lacking. This research explores the effects of experiential learning on the cognitive development of Down Syndrome (DS) patients by integrating games. This research aims to bridge the gap between offline therapies and online gaming platforms by creating a low-cost distance learning platform that fosters cognitive development without impeding Down Syndrome (DS) patients' progress. The study highlights the benefits, positive outcomes, challenges, and potential enhancements associated with this practice, benefiting both Down Syndrome (DS) patients and caregivers. Additionally, the research examines the influence of games on the cognitive behaviour of Down Syndrome (DS) patients, particularly in memory abilities, attention span, and critical thinking capacity. Data was collected using the MindTri 21 app, featuring two games: Card Matching and Tangram. Multiple NGOs and schools working with Down Syndrome (DS) patients were engaged, and participants played both games twice, with intervals between sessions following the memory curve methodology. Serious games provide Down Syndrome (DS) patients with an additional avenue for enhancing their teaching-learning experiences, irrespective of cost or distance while promoting cognitive skill development.

Keywords: *Down Syndrome, Cognitive Development, Memory Skills, Critical Thinking Skills, Games, Cheap Distance Learning, Digitalization, Serious Games*

With the continuous advances in technologies posing great opportunities for today's society, the increasing generation of digital resources has led to the emergence of new ways of learning and thinking. Nowadays, digital tools such as smartphones and tablets have become ubiquitous. (Patricia García-Redondo et al., 2019). According to data, smartphone users are likely to cross 1 billion in India (Narayan R., 2022). Thus, the authors define the 21st century as the era of digital game-based learning. (Boot, W.R; Kramer, A.F. et al., 2008). The evolution period today brings changes in education

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alongside other fields. With the surge of COVID-19 in recent years, the need to digitize study materials has become crucial. Recently, there has been an increase in the number of mobile games that not only stimulate someone's interest in learning but also promote increased language development, critical thinking, and imagination, thus playing an essential role in a child's development. This is called Game-based learning (GBL), where gameplay enhances knowledge and skill acquisition by providing players with a sense of achievement after every problem.

Literature now provides the effectiveness and efficiency of training courses but says that they are no longer sufficient conditions in traditional learning environments (Billett, 2001; Boud & Middleton, 2003; Carini et al., 2006; Dabbagh & Kitsantas, 2012). Therefore, to improve user engagement, smart learning environments combine pedagogical approaches and smart technologies. Videogames offer exciting, innovative and highly effective methods for increasing knowledge, delivering persuasive messages, changing behaviours, and influencing health outcomes (Baranowski et al., 2015). As a widely recognized approach, several studies have investigated the reasons that make games such a powerful learning environment. They state that they are successful since they support multisensory, active, experimental, and problem-based learning (Papastergiou, 2009). Aside from these cognitive and intellectual benefits, games also provide self-assessment tools such as a scoreboard and different levels. Furthermore, besides the acquisition of knowledge, the game promotes logical-mathematical and critical thinking and the development of personal and social skills, language abilities, communication and collaboration skills, and creative, and problem-solving capabilities (McFarlane et al., 2002).

The serious games market was estimated to be worth $5.94 billion in 2020 and is anticipated to grow at a CAGR of 18.47% to $32.72 billion by 2030 (Vikas G. & Vineet K., 2022). Games are now regarded as a demanding and psychologically absorbing experience for mental functioning. Contrary to the traditional beliefs that playing games is mentally addicting, and harmful, in games like shooter games, the players show faster and more accurate attention allocation (C. S. Green & Bavelier, 2012).

A meta-analysis of training studies concluded how these training benefits last over an extended period, and crucially transfer to other tasks outside the gaming context (Uttal et al., 2013). In the case of puzzle games, the robust effects on cognitive performances are not noticed (C. S. Green & Bavelier 2012). Unfortunately, there are not many digital platforms to provide game-based learning opportunities to children with Down Syndrome. Enrica Pesare et al., 2016;

With technology becoming an essential part of our lives right now, we witness it being used by people from all walks of life, including people with special needs. Besides this, there are indications that serious games could be very powerful learning tools (Girard et al., 2013). However, there is still a need for empirical studies of their effectiveness in supporting learning, especially in the case of people with intellectual disability (ID) or cognitive disability (CD).

Children with disorders have their unique talents, personalities, and mental states as the other children, with which comes a fair share of challenges that these children face with their learning abilities (Wishart J., 2001). Immerse technologies hold great potential in delivering these experiences, and exposure to these technologies can help reduce stress and improve

mood (Ramdoss et al., 2011). However, game development has generally focused on the non-disabled population (Grammenos et al., 2009) rather than taking a design-for-all approach (Connell et al., 2007), which is often refuted by the fact that serious games for people with disabilities must be tailored to the individual needs of certain disabilities, the multiple meanings, thus, can be more effective in awakening the creativity of the players (Lanyi & Brown, 2010).

Down Syndrome is a chromosomal disorder that occurs because of an extra chromosome, which causes growth deficiency and intellectual disability. These people at a young age develop different skills at a slower rate. Despite the interest of people with Down Syndrome in digital games, these games are complex to make because of the varied growth and development differences in each person's skills (Centre for Disease Control and Prevention, 2021).

Seeing the scope that video games may potentially reduce some neurological deficits that inhibit learning in people with Down Syndrome (Morrison, 2006) because they can improve brain plasticity in normal people (Kühn, Gleich, Lorenz, Lindenberger, & Gallinat, 2013) then there is a chance it is possible with people affected with Down Syndrome as it affects the brain plasticity that makes it difficult to process new information n (Chakrabarti et al., 2010).

With the growing use of virtual reality (VR) based therapy to facilitate the development and learning process of the group with Down Syndrome, Video games have been shown to increase dopamine release and improve plasticity (Koepp et al., 1998). Also, during the past decade, evidence has been provided to support the idea that video games have greater potential to improve cognitive abilities (Green & Bavelier, 2012).

It has been observed that in the case of children with disabilities, the use of playful tools increases interest in the game and motivation to play and to perform rehabilitation activities through games (REID, 2002), and providing virtual environments, in this case, can help evaluation of this process of these individuals (Standen; Brown, 2005; Dias et al., 2017).

Numerous games used to achieve the same have evidence to be able to influence the life of people with Down Syndrome in different aspects like educationally, socially, etc. Concurrently, the development of gaming has increasingly developed toward serious purposes It was first found out in 1987 that famous games like Pac-Man can have a positive impact on cognitive skills (Clark et al., 1987), but there remains a gap between the kinds of games that can stimulate cognitive development and show specific results. These games give a sense of freedom to not only the educators by giving them the choice of teaching whenever and wherever they want to, but also giving the people affected with Down Syndrome a chance to not become dependent on others for education, thus increasing their enthusiasm for learning.

Considering how games can keep people in different conditions attached to a task for a long period, it helps in increasing concentration levels. The game is a captivating area for the players, which helps them learn everything better, and gain a deeper knowledge about the field of study. All of the challenges faced by the people affected with Down Syndrome constitute a significant problem, and considering them was a tool for developing something that could provide results aimed at specific target cognitive skills rather than a broad

overview. This is critical because if there is a possible scope of education going digital, there must be a force that improves the motivation and engagement of individuals with Down Syndrome in using technologies to acquire the education they require, without the need to carry physical games everywhere.

People with Down Syndrome are already digital natives who like engaging with computers and mobile devices (Feng et al., 2010). Even though such tools exist (Saz et al., 2009), they are currently not being used effectively by people with Down Syndrome because of various reasons like the complexity of the game, the difficulty of dealing with the equipment provided to play the game, and these even pose a lesser chance in the educational area because there are not many available games which provide educational support to children affected with Down Syndrome, one such example is Nintendo Wii.

Utilizing methods that don't use complex software may be more effective in the learning settings for people affected with Down Syndrome. In the realm of research focused on gaming experiences for individuals with disabilities, a noteworthy constraint in prior investigations has emerged. Specifically, the imperative for tailored gaming solutions that align with the distinct needs of people with disabilities has been underscored, particularly emphasizing the importance of avoiding undue complexity.

Gamification to be proven as an effective learning experience, it is important to see how it can be combined with different dimensions - cognitive, emotional, and social (Illeris et al., 2002; Lee & Hammer, 2011) - involved in the learning process. In the cognitive area, it can provide challenges that are perfectly tailored to one's illness and as the difficulty increases, the skills of the player also increase. In the emotional area, except for providing motivation, it involves a range of user emotions: curiosity, joy, and frustration.

While the positive emotions encourage them to solve problems, the negative emotions encourage the players to use failures to their advantage. For example, the MindTri 21 app, unlike traditional learning methods, ensures that a player does not proceed to the next level unless they have passed the previous one. This ensures that repeated failures should not be seen as a way to escape but as an opportunity for continuous improvement. Thus, defeat becomes a necessary part of the learning process for students to view failure as a window to enhancement and avoid succumbing to the feelings of overwhelm, anxiety, helplessness or fear. Further, it can be inferred that the use of playful elements in learning contexts does not aim to replace textbooks but to promote a powerful learning experience through which one can develop skills in a highly activity-involving learning environment (Enrica Pesare et al., 2016).

A salient concern within the previous studies has been the utilization of games designed primarily for individuals without disabilities, potentially subjecting those with disabilities to a sense of unease or incongruity. This calls for a renewed examination of game design paradigms to ensure inclusivity and address the unique requirements of individuals with disabilities, cultivating an environment of comfort and engagement for all players involved.

The investigation of two widely recognized serious games has highlighted a noteworthy issue: individuals with Down's Syndrome often encounter difficulties in comprehending and retaining both primary and secondary objectives within the game (Torrente et al., 2012). Consequently, this study maintains a keen awareness of this limitation within the

development of "MindTri 21," ensuring the exclusion of intricate motives or challenges that might exacerbate or reintroduce this issue. These observations not only contribute valuable insights into game design but also underscore their significance in the cultivation of targeted serious games tailored to specific disabilities.

METHODOLOGY

Aim of the Study

The aim of this study is to explore the efficacy of mobile game implementation for enhancing cognitive skills, specifically memory, attention span and critical thinking, in Down Syndrome patients.

Research Design

This study is an experimental analysis of the efficacy of serious games in the cognitive skill development of Down Syndrome patients. The research comprised individuals aged between 10 and 19 years, all diagnosed with Down Syndrome. These serious games mirror online adaptations of the conventional therapeutic interventions dispensed within educational and rehabilitative institutions tailored for individuals with Down Syndrome. The two specific cognitive skills focused in this paper are memory retention and attention span.

Consent and Ethical Issues

In the pursuit of comprehensive data acquisition, meticulous adherence to ethical considerations was a cornerstone of the present study. Safeguarding the privacy and confidentiality of respondents remained a paramount concern throughout the research endeavour. A steadfast commitment was upheld to ensure that no divulgence of information to any third party occurred. Notably, no personally identifiable particulars, encompassing names and photographs, were unveiled or procured for either the study or subsequent publication.

Tools Used

To facilitate the meticulous collection of data, the research employed the "MindTri 21: Puzzle Games" application. This application, a fusion of Flutter and Unity technologies, with Firebase to collect the backend data, featured two distinct games—namely, Tangram and the Memory Card Game—devised as instruments for data acquisition within this investigation. Each game consists of 4 levels.

Data Collection Procedure

The data collection regimen encompassed two iterations per participant, demarcated by a 3-4-day interval. This temporal spacing aligned with the principles of the forgetting curve, thereby enabling an evaluation of the effectiveness of the serious games in nurturing participants' cognitive development.

RESULTS AND DISCUSSION

MindTri 21: This virtual realm provided a secure space for them to explore behaviours, a particularly valuable aspect given their challenges with attention spans. The foundation of these games was rooted in a concept wherein the intention was to capture the interest of Down Syndrome patients (Griffiths, 2002). To achieve this, the game design featured specific elements, including distinct levels, opportunities for player choice to foster continuous engagement, and a balance between challenges that were manageable yet still encouraged skill improvement. (Chakraborty et al.,2021). The game aimed to provide a

motivating and intriguing learning experience for Down Syndrome (DS) patients, fostering their interest in skill enhancement and personal growth.

The games were also designed by adhering to the accessibility principles outlined by Jaramillo-Alcázar et al. (2021). The inclusion of captions, a reasonable font size and writing style, and orchestrating a gradual game progression from simple to increased complexity and simplified language aids in making the game content more comprehensible, ensuring that players can engage with the material irrespective of their challenges. This was done to ensure an optimal environment for effective and immersive Game-based Learning (GBL) (Marfisi-Schottman et al., 2010). Delving into the transformative impact of the designed serious games on the distinct cognitive skills of Down Syndrome (DS) patients, particularly their memory, critical thinking, and attention span abilities, players were made to play the game twice and the following analysis was drawn:

Table 1: Summary of Dependent T-test Analysis between the time taken in two attempts at the tangram game and memory game done with an equal gap on variable Time Taken (N= 5)

Attempt	Time taken in the First		Time taken in the Second		t	p
	M	SD	M	SD		
Tangram	15.6	8.2	13.6	1.0	1.65	.08
Memory	33.0	115.4	29.9	62.6	2.24	.04

Tangram Game: T-test for dependent samples between the two attempts of participants with Down's Syndrome at the tangram game on variable **time taken** (t= 1.65, p= 0.086, t-test for dependent samples, Table 1). This means that the tangram game significantly impacted the amount of **time taken** to attempt the game, which was almost halved on the second attempt.

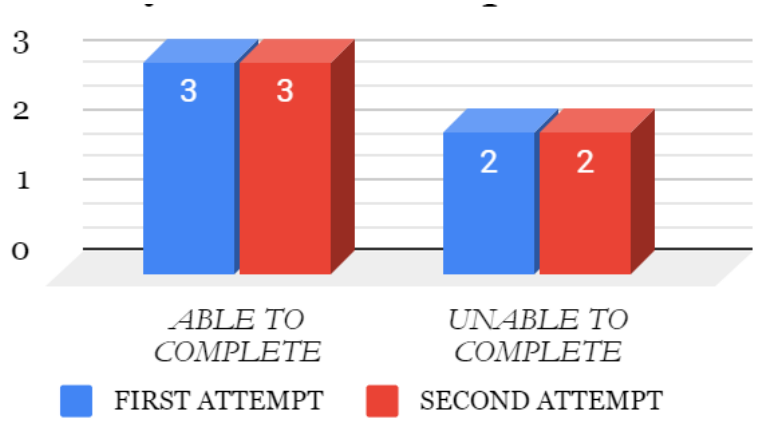

Figure 1: Graphical Representation of completion of the two levels of the tangram puzzle game (N=5)

In Figure 1, One can see the difference in the two attempts that happened with a gap of 4 days. It can be observed that about **80% (4)** of the participants were able to complete it and **20% (1)** of the participants were unable to complete the memory card game on the first attempt. On the contrary, about **100% (5)** of participants were able to complete the game and **0% (0)** were unable to complete the game on the second attempt. Hence, most of the participants could complete all four levels of the game on their second attempt.

Memory Game: T-test for independent samples between the two attempts of participants with Down's Syndrome at the tangram game on variable **time taken** ($t = 2.24$, $p<0.05$, t-test for dependent samples, Table 1). This means that the memory card game significantly impacted the amount of **time taken** to attempt the game, which was almost halved on the second attempt.

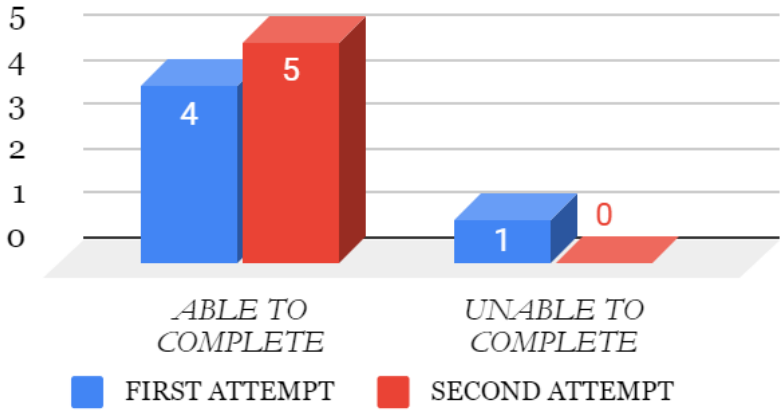

Figure 2: Graphical Representation of completion of the two levels of the memory card game (N= 5)

In Figure 2, One can see the difference in the two attempts that happened with a gap of 4 days. It can be observed that about **60% (3)** of the participants were able to complete it and **40% (2)** of the participants were unable to complete the memory card game on the first attempt. On the contrary, about **60% (3)** of the participants were able to complete the game and **2% (2)** were unable to complete the game on the second attempt. Hence, most of the participants could complete all four levels of the game on their second attempt.

The present study aimed to analyze the efficacy of serious games on the cognitive skill development of Down Syndrome patients by taking into account the time taken to complete the levels at each attempt. To that end, for the analysis of data obtained from individuals with Down Syndrome in New Delhi, dependent data was collected which revealed a positive link between enhanced attention span and advancements in the completion time of cognitive tasks, specifically the games of tangram and memory card.

In alignment with existing research and context, the games under study were derived from pre-existing game concepts, bolstered by the integration of factors geared towards goal-directed learning. Drawing upon insights from a literature review focused on crafting serious games to address specific disabilities, the design incorporated techniques to create an environment where individuals with Down Syndrome (DS) could engage without feeling undue pressure from the real world.

The results are consistent with the previous studies which showed a positive correlation between serious games and the cognitive skills of patients with disabilities (Hersh M. & Leporini B., 2018), and revealed a compelling trend wherein participants displayed a notable reduction in the time required to complete the maximum attainable levels within each game, signifying their progressive engagement, improved attention span and improving memory retention. This result was consistent with a previous study that skills practised in games

transfer to other situations (Enrica Pesare et al., 2016; Standen PJ et al., 2009; Green & Bavelier, 2003).

Notably, the tangram game showcased an intriguing pattern: Participants who initially struggled to complete the game's challenges in their initial attempts exhibited a heightened likelihood of successfully conquering all four levels upon the second attempt. This observation underscores the tangible benefits of game-based learning in facilitating skill acquisition over successive attempts, particularly in the context of Down Syndrome (DS) patients.

The tangram game's unique approach, characterized by its jigsaw-style puzzle framework, strategically departed from conventional tangram game structures. This deviation aimed to establish an environment that was conducive to learning, devoid of undue stress or pressure for Down Syndrome (DS) patients. Furthermore, the tangram game's implementation has demonstrated the potential to bolster sensorimotor coordination, visualization skills, and social interaction abilities among Down Syndrome (DS) patients (Dhiman et al., 2023). This structure was introduced in the app keeping in mind that there would be instances where the participants could forget the main aim of the game.

On the other hand, the memory card game, strategically designed to enhance a spectrum of cognitive faculties encompassing attention, concentration, and memory, operates as a short-term memory challenge wherein participants are necessitated to strategize their actions in real time.

Iterative engagement with this game is anticipated to engender progressive cognitive refinement (Dr. R. Sivakumar, 2022). This approach is also known to promote recovery of prior knowledge because players must use previously learned information to improve their score in the game.

One of the key reasons that individuals with Down Syndrome found it challenging to engage in the memory card game in comparison to the tangram game could be due to their weak memory retention skills. This observation is in line with the research which showed that they have difficulty retaining and processing information (Chapman & Hesketh, 2001; Jarrold & Baddeley, 2001) which can alleviate their problems. This observation combined with the tangram game’s observation could point towards an inclination towards becoming dependent on spaced instructions or hints. This premise underpins the observed phenomenon of the consistent performance level exhibited during the second attempt, despite the substantial reduction in average completion time by half.

Memory game requires visual speed, concentration, and memory retention skills, which are commonly trained, explicitly or implicitly, by playing video games. Further, this result shows that even though people with intellectual disabilities have difficulty making choices showed a decrease in real-time decision-making choices in the memory game which is consistent with the findings of a previous study which showed a decrease in choice reaction time for people who played a game (Standen PJ et al., 2009).

Furthermore, there was no use of rankings or leaderboards involved, except for the timer option, which will be discontinued after the research concludes, to avoid stressing the users. This was in line with a measure that was successful where in a study researcher wanted the

user to make as many attempts at a level as they wished (César González-Ferreras et al., 2017).

Despite this spectrum being untapped for Down Syndrome patients, the findings of this study illuminate the significant positive impact of these serious games on the cognitive prowess of Down Syndrome (DS) patients, thereby offering a novel avenue for enhancing their overall cognitive development and quality of life. Even the most problematic students were able to carry out the activities until the end. This can be attributed to the high level of engagement offered by the app's large font size, simple language, attractive graphics, and sound simulations. This approach stands in stark contrast to traditional methods, offering a less costly yet highly effective means of achieving transformative outcomes (Ricciardi & Paolis, 2014).

In addition to this, even though a significant decrease in time was observed through this study, it is not recommended that Down Syndrome patients use these games in autonomous mode or without the assistance of a guardian, a teacher, or a parent. This is because of their relatively shorter attention span, there is a possibility that their amazement by the graphic adventure could distract them without putting the required effort into doing the activities. This point is made in line with the fact that Down Syndrome patients are attracted towards interacting with computers and mobile devices, just like any other people (Feng et al., 2010).

CONCLUSION

While game-based learning has been extensively explored among diverse populations, its application in the context of Down Syndrome (DS) patients remains relatively uncharted. This research underscores the pressing need for a more comprehensive investigation into the potential impact of serious game-assisted learning on the cognitive skill development of individuals with Down Syndrome (DS). Unlike conventional entertainment-focused games, these educational tools wield the power to influence learners' emotions and moods (N. Nazry et al., 2017).

Positioned as engaging instruments of education, these games foster the acquisition of knowledge and the honing of skills through the resolution of challenges, marked by incremental progress as players ascend through various levels (A. A. Juan et al., 2017). Additionally, existing research points towards the potential for video games to contribute to the cultivation and reinforcement of vital skills, such as the improvement of spatial visualization ability (Subrahmanyam K. & Greenfield P., 1994).

Given the paucity of dedicated investigations within this particular realm, the imperative to delve deeper into the possibilities and benefits that serious game-based learning can offer to Down Syndrome (DS) patients becomes all the more apparent. Following the comprehensive analysis and examination of the graphical representations, it becomes evident that serious games exert a discernible influence on the attention span and memory aptitude of individuals diagnosed with Down Syndrome (DS). The study's outcomes notably indicate a heightened engagement level among Down Syndrome (DS) patients, as substantiated by their notably expedited completion times for various game levels. However, this study, just like most case testing in the case of Down Syndrome (DS) patients, involves only a small number of participants and short periods, indicating a need for large-scale trials.

It is worth emphasizing that the development of these games was guided by the intention to furnish a gratifying and anxiety-free milieu for learning—an approach consistently correlated with favourable outcomes, as corroborated by previous investigations. An illustrative instance of this is a study involving a game termed "Flash," which effectively assessed the game's efficacy. The study underscored heightened interest engendered by the game's adept contextualization of textual content. Regrettably, such a narrative incorporation proved impractical within the present game, given the potential time augmentation attributed to narrative intricacies. This decision was substantially influenced by the temporal limitations faced by participants in their contributions to this study.

Consequently, it is prudent to deliberate on the prospective dimensions of this study. One avenue deserving further exploration pertains to the potential integration of storyline elements within the games which are used as a conventional approach within offline therapeutic settings. This could conceivably illuminate disparities in attention span and memory retention outcomes. Accordingly, this can provide a more nuanced understanding of the potential cognitive enhancements for individuals with Down Syndrome (DS), potentially opening new avenues for tailored interventions and improved educational strategies. Further, the involvement of user-end feedback regularly during long-term study can help find a concrete result related to this area. Additionally, the role of a guardian is shown to be very relevant throughout the game. However, giving real-time feedback is often seen as risky because it can turn out to be incorrect (César González-Ferreras et al., 2017). Therefore, providing feedback, alongside giving another attempt (followed in the app used in the study) can motivate them, both when the user performs the activity correctly or incorrectly can be proven beneficial.

Extending the investigation into an avenue of large-scale research and comparing the number of attempts to complete each level could also point in prospectus positives inclined towards improved memory retention. This way, the research community could glean valuable and even more promising insights into the interplay between narrative engagement and cognitive skill development in the context of Down Syndrome (DS) patients.

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Conflict of Interest

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