

# Development and Validation of a Gamified Videogame for Math Learning in Attention Deficit Hyperactivity Disorder Children (ADHD)

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## Abstract

The present research proposes a video game that combines learning and gamification in children with ADHD. Following the Waterfall Model, requirements were gathered in an interview with the Peruvian Association for Attention Deficit (APDA) for the video game that helps children learn in mathematics. “Casa de Spots” has been developed using Unity Engine and included topics like basic mathematics, even and odd numbers, fractions, and geometric figures. Gamification offers unlockable achievements while playing. A pilot test was carried out with 35 children (19 with ADHD and 16 without ADHD), where they received a satisfaction survey. Answers were analyzed and compared using the Mann-Whitney U test with a significance level of 0.05 to assess the proposed variables, concluding that each variable had the same distribution in both groups.

## Keywords

ADHD, Videogame, Gamification, U Mann-Whitney test, Waterfall model.

## 1. Introduction

### 1.1. Problem Statement

Attention Deficit Hyperactivity Disorder (ADHD) is labeled as a neurobiological disease that affects executive functions. There are millions of children who present this disorder worldwide, where 3% to 7% are school-aged children [1]. Some of these symptoms can be limited attention or behavior problems related to hyperactivity and impulsivity which can be an issue in the majority of schools. By taking these factors into account, children need to be motivated by interacting with some object. On the other hand, children can be more active while playing video games because these help children to focus on the tasks and to keep them concentrated but is recommended to have them keep healthy gaming habits to prevent addiction [2]. Usage of ICT as didactic tools can give different learning styles that may be applied to children with many special disorders, such as ADHD [3].

Attention Deficit Hyperactivity Disorder is defined as one of the most common “neurobiological behavior disorders” in childhood and is usually detected from that age and may last until adulthood. In a classroom consisting of 30 children, this disorder can be found at a rate of 1 or 2 children [1]. Some risks ADHD children may present are constant distractions, forgetting important things, constantly talking, and many behavior-related problems. These children may also present low academic performance in some learning areas like reading comprehension or mathematics while, on the other hand, risks of being expelled from school are present [4]. Some problems regarding mathematics that a child with ADHD can make, according to [5], are the difficulties to understand the statements of the problems. This can mean that they can’t mentally figure it out. Another problem is that children have difficulties performing calculations correctly apart from the fact that they can’t stop thinking about how to operate [5].

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CISETC 2021: International Congress on Educational and Technology in Sciences, November 16-18, 2021, Chiclayo, Peru

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CEUR Workshop Proceedings (CEUR-WS.org)

ADHD can also be compared to ludopathy [6]. In an Iowa State University, it was stated that longer use of video games can aggravate the ADHD symptoms, affecting their physical, social, and academic state [7]. UNESCO experts held a meeting in 2011 where they stated that ICT can be used as a tool for learning and attending children with special disorders including ADHD, as per the intrinsic capacity of videogames and motivation represent a good choice to handle attention [3].

## 1.2. Justification

The present research was made to propose a digital solution to teach mathematics to ADHD children so that it can be used as a complementary tool for their learning. EndeavorRX is one of the few titles that was clinically approved to be applied in ADHD children's treatment post-diagnosis [8], [9]. Regarding executive functions affected by ADHD, applying learning techniques like Gamification, Game-Based Learning (GBL), or Serious Games in a learning area indirectly supports the affected functions during training.

The main idea of this research was to combine some of these ideas to develop the game and support attention as well as learning. The game would grant children freedom and develop their interest to keep learning and be motivated. An important detail considered in this research is that children work out their attention as well as their concentration if the videogame includes rewards like unlockable achievements or characters that have progression levels so that the children can focus directly on the tasks to further advance into their progression [10].

Since March 2020, the COVID-19 pandemic has limited every person to take online classes. This way of learning can be troublesome for ADHD children because it can be an obstacle to their learning. Duda, cited in [11], mentioned that anxiety is a huge problem for ADHD children, summing up the fact their retention ability is limited.

## 2. State of Art

Gonzales et al. [12] spoke about how ADHD appears at first ages and how does it impact society as well as academic skills. The game was developed and tested in a classroom consisting of 13 children (7 boys and 6 girls) diagnosed with ADHD and six learning regulators, where the children had to play the game in which every level is labeled as a 'civilization'. By this research, only the first civilization was tested on the children following a CSUQ questionnaire to measure usability, quality of the information, quality of the interface, and overall satisfaction. The children then filled a PrEmo questionnaire after playing the game. Overall, the results were positive regarding the agreement of users to the game interface.

Bul et al. [13], exposed the idea of applying game technologies in clinical and educational environments due to their potential of enhancing patient compromise with behavioral treatment programs. Beyond the design of a serious game, its intervention must be aligned to the behavioral attitudes of the person who uses it. The main objective of this research was to evaluate the feasibility of the videogame before applying it in randomized tests. "Plan-It Commander" is a serious game developed for ADHD children. The game is an online platform in which a space adventurer must accomplish sub-missions to help the player in their problem-solving skills. Each level presents a progressive complexity curve and allows the player to customize their spaceship with items in their inventory. Furthermore, every level focuses on time management, planification, and organization. As part of a pilot test, participants (n = 42) had to answer usability and acceptance questionnaires regarding aspects of the game. Parents along with their children completed the questionnaires on a 10-point Likert scale, one for the enhancement expectations and the other one for overall satisfaction. Both questionnaires showed positive results in every aspect, but the development of the complete game is due to finish.

Bayarri Garcia [14], focused on the creation of a mobile platform where ADHD children aged 3-6 can enhance their attention and concentration, and a web platform where parents and teachers can manage the children's results and performance. This game, named "Imjoying" included the characteristic of gamification elements to further promote children's motivation and interest. The methodology used in this research was based on the traditional software life cycle methodology, while

in the design phase UX techniques like heuristic evaluation were used for the game interfaces. In the implementation phase, the software architecture included a MySQL database, which was connected to a WAMP server to retrieve data and display it through both applications. Only two minigames were implemented: “Matching Game” and “Color Game”.

Supangan et al. [15], developed an Android mobile application to aid in the learning of subjects like math, language, and hygiene skills in ADHD students. Each subject includes different activities based on the main topic. Math, for example, includes activities like basic operations, odd and even numbers, primary colors, and figures; while language includes greetings and asking things, and finally. The authors performed some interviews in a public school to know about learning plans and teaching methodologies for ADHD children including treatment and recording positive and negative things they do. The videogame offers a login and registration menu along with an interface to monitor the children’s progress. During the testing process, usability, compatibility, interface, and performance tests were performed on the Unity Engine for Android Smartphone devices. After implementation, UAT tests were conducted with special education instructors, and concluded they were satisfied with the application.

Martínez Feu [16], had performed field research using a virtual reality tool known as “AULA Nespora”, a device used for attention assessment and supervising the student in visual and audio tasks simulated in a classroom having distractors. The test was performed by two groups with 10 students each, one with ADHD students and the other group with non-ADHD children. Twenty school counselors also participated during the test and were given a questionnaire. Different variables for attention assessment like distractor and omission values were evaluated for every task as well for distractor and visual aspects. The questionnaire for counselors evaluated certain aspects of the tool like utility, innovation, student motivation, time, and information quality. For analysis of both the questionnaire and test results, the T-test and U Mann-Whitney test was conducted, concluding that there was a high validation degree in most variables based on deviations and task omissions; while in the questionnaire, installation and management were underrated for the male group and the variable ‘non-replaceable for the female group. The T-test concluded that there was a significant difference in both groups in utility, motivation, time, information quality. Overall, the AULA Nesplora assessment tool was concluded to be a valid tool for ADHD assessment.

Finally, Kanellos et al. [17], implemented a user experience assessment for the REEFOCUS system was performed. This system provides an intervention program based on games for management and support of ADHD systems with two game modes: Virtual World Management (VWM) and Multisensory Mixed Reality (MMR). Both game modes work together with a single encephalogram electrode to impulse neurofeedback mechanism for ADHD sustained attention and registration of brain waves as well as providing a monitoring system for the children’s progress. The final prototype was tested in a pilot study at the Sant Joan de Déu Barcelona Children’s Hospital, where 75 ADHD children aged 8-14 participated, divided into five groups. Sixty-four children tested the prototype in 8 weeks and completed a survey regarding user satisfaction and usability issues using a 5-point Likert scale. During data collection, two groups were formed, the first having 40 participants between children and teens with ADHD and the second having 39 parents. The results of the pilot test showed that most kids understood the objectives and instructions of both game modes and had higher satisfaction scores regarding the storyline, graphics, and music. Similarly, the results for the assessment for the cognitive exercises completed solely by the ADHD group showed that satisfaction scores were lower for the Sustained Attention test, but higher for the rest of the variables. Only 69% of parents approved the usage of this program, indicating that children could play it up to twice per week. This research concluded that the experiments of the pilot study indicated that REEFOCUS functionality shows high satisfaction by children, parents, and doctors specialized in game-based intervention.

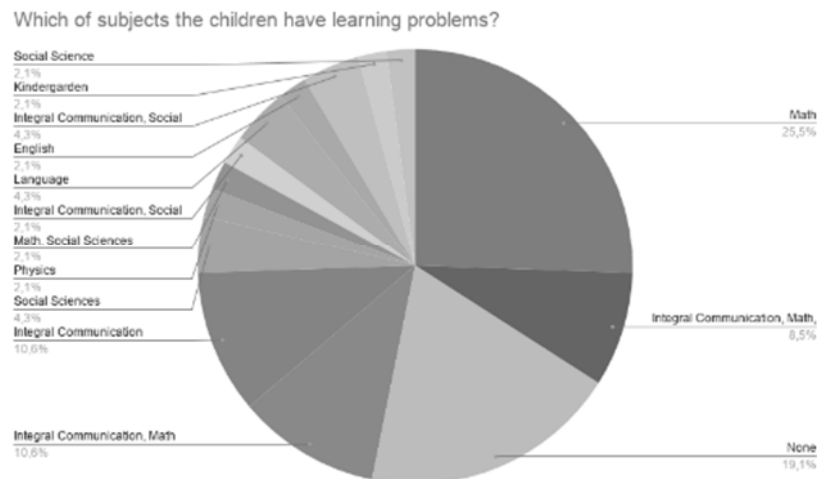
### **3. Methodology**

The following research focuses on the development of a videogame to support math learning for ADHD children combining Game-Based Learning and Gamification. The Waterfall Model, as proposed by [18], was used to develop the videogame as it is very common for educational videogames [19]. User Experience (UX) [20], [21] was applied at some development points. As suggested by Gimeno

[22], the game must have an easy-to-use interface and a storyline that attracts players to an enjoyable experience.

### 1. Analysis Phase

In the first phase, Analysis, the diffusion of a probe for people with ADHD was performed to know the difficulties regarding concentration, attention, and videogame preferences such as hours played daily preferred videogame console, and preferred genre.



**Figure 1:** Difficulties at School Subjects from ADHD Children

After reviewing the results of the probe, an interview to meet the requirements was made to the president of APDA, who stated that there is a strong difficulty in math learning as shown in “Fig. 1” and that the content to be implemented in the videogame must be children-friendly. In Table 1, the requirements gathered by the president for the development of the game are shown.

**Table 1**

Functional Requirements

Functional Requirement #	Description
1	Menus and elements containing texts must have bright colors.
2	The videogame must contain a menu that allows the learning of the subjects.
3	The videogame needs to have music that keeps the child happy.
4	The videogame must not contain noises that frustrate children.
5	The videogame must contain a motivating theme.
6	The videogame must have a score and reward system.
7	The videogame must include questions containing an image.
8	The videogame must store the username so they can be congregated when winning.
9	The videogame must contain basic math subjects.
10	The videogame must include problems involving a context.
11	The videogame must offer retry options.
12	The videogame must have easy winning conditions to complete a level.
13	The penalty of losing points must be lower than the number of points earned when failing a question.

### 2. Design Phase

The second phase, Design, included the adaptation of the requirements into several deliverables such as use cases, class diagrams, architecture, and Heuristic Evaluation for the interface sketches. The main objective of the videogame was to help through the construction of a dog house for a dalmatian dog named 'Spots', who encourages the player to learn all subjects to be offered to progress in the construction. For the math exercises, four subjects were defined: basic math, fractions, figures, and odd/even numbers, a level per subject. The definition of the subjects was suggested by a math teacher specialized in learning for ADHD children. The last three levels had exercises linked to a figure or graph so that the children playing the game are set upon a real context and focus their attention. The elements of gamification based on [23] were defined according to the requirements and the topics that are defined for this game. Each level lasts fifty seconds and three lives which are deducted one by one for every wrong answer, and a scoring system that sums or reduces for every correct or wrong answer.

### 3. Implementation Phase

In this Phase, all sketches were adapted and used the Unity Editor software as well as including the gamified elements and questions needed for the videogame. Before testing with real users, all of the Unity scenes were internally tested to correct possible identified flaws and export the videogame to computer and smartphone devices. At one point during development, the name of the videogame was changed from "Casa de Casino" to "Casa de Spots" to avoid confusion with card games and ludopathy. As a matter of feedback, the president stated that the videogame should be useful to motivate and use it to learn differently.



Figure 2: Main Menu

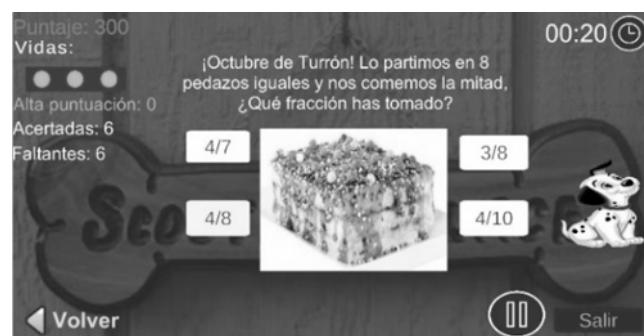


Figure 3: Current Level

### 4. Testing Phase

On the other hand, a satisfaction questionnaire was created, one for each group of children (ADHD and non-ADHD). In coordination with the math teacher and a teacher specialized in ADHD learning, a meeting was held to evaluate and discuss the possible questions that can be asked in the satisfaction questionnaire. Based on the teachers' feedback, the recommended questions that can help assess the children's game experience are listed in Table 2.

**Table 2**  
Variables Assessed

Question	Variable
How much did you like the game?	ADHD symptom expectations
How easy you see the video game?	Ease-Of-Use
How much you were attracted to the images and colors?	Visual and graphic aspects
Did the offered levels were interesting to you?	Content
How attractive did you see the gamified elements?	Gamified Elements
How do you rate your experience playing this game?	Game Experience

To gather the participants for the testing phase, an announcement promoting the videogame was released for children to play the game, starting a pilot testing. 35 children (19 with ADHD, 16 without ADHD) had access to the game and extract (for computer) or installed (for smartphones) on their devices. The children had to play the game to later fill a satisfaction questionnaire divided by condition, regarding certain points based on their experience. Furthermore, they also may give their feedback and opinion about their experience playing. To further analyze and compare the results, the U Mann-Whitney test was applied to both types of questionnaires.

#### 5. Maintenance Phase

The game “Casa de Spots” is currently in this phase in the Waterfall Model. Based on the results gathered on the questionnaires, children’s comments may work as the base for future improvements.

### 4. Post-Test Analysis

After completing the testing phase with an undefined sample number of children, analyzing the questionnaire results was the next step.

#### 4.1. Analysis

As mentioned before, to measure and compare the different satisfaction points in both groups, a U Mann-Whitney test was used to evaluate this version of the game before a randomized control trial. The present research measured six different variables, each one linked to a 3-point Likert scale in the questionnaire for both groups of children. These questions are defined as in Table 3.

**Table 3**  
Satisfaction Variables Evaluated

Corresponding Question	Associated Variable
How much did you like the game?	ADHD symptom expectations
How easy you see the video game?	Ease-Of-Use
How much you were attracted to the images and colors?	Visual and graphic aspects
Did the offered levels were interesting to you?	Content
How attractive did you see the gamified elements?	Gamified Elements
How do you rate your experience playing this game?	Game Experience

To get a better overview of the evaluated aspects, a U Mann-Whitney was performed with the answers from the six variables as input. As two groups of children independent from each other participated in the testing phase, their answers contributed to the analysis of both tests. Table 2 displays the results of the test with a significance level  $\alpha$  of 0.05. The obtained results were important as it tells that the game positively attracted the attention of both groups as a matter of comparison. The following hypothesis was formed for this step:

$H_0$ : There is no significant difference regarding the dependent variable between the two groups.

$H_1$ : There is a significant difference regarding the dependent variable distribution between the two groups

**Table 4**  
U Mann-Whitney Results

Associated Variable	Significance Level	Decision
ADHD symptom expectations	0.909	Accept $H_0$
Ease-of-Use	0.286	Accept $H_0$
Visual and graphic aspects	0.545	Accept $H_0$

## 5. Results and Conclusion

The proposed videogame ‘Casa de Spots’ was defined as a learning videogame using gamification for ADHD children. However, it is still in a maintenance phase as the main objective of this paper was to know if this idea can contribute to ADHD children. The following paper considered a lack of literature regarding accepted videogames to aid ADHD children in any aspect.

On another aspect, the COVID-19 pandemic has limited this paper’s scope so that it only validates the application of the game rather than a controlled test. It should be noted that there will be more improvements to the videogame, as mentioned earlier, so it may be applied in a context where there are no limitations and the possibility of direct observation is present.

Children also had the opportunity to give their opinions in the questionnaire about which features they wish to be implemented in the future. Among the most positive comments, children commented that they wish for more levels, feedback options (i.e., a happy face wherever a question is well answered), complex and selective difficulties, etc. Overall, these comments were essential to know about their thoughts and opinions. Even though the pandemic limitations mentioned above were present, children’s feedback was not affected to be excluded from the test.

As future work, the game needs to be further improved and applied in controlled tests to evaluate different aspects and how the game affects their improvement in aspects like math issues or ADHD-related problems. Techniques like a monitoring system connected to an SQL database, Artificial Intelligence for self-aid, and Augmented Reality support are among the plausible alternatives to make “Casa de Spots” a viable option to be used for ADHD support.

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