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Adaptive Game-Based Cognitive Training System For Enhancing Attention In Children With ADHD

Karnam Akhil[1], R. Vijaya Saraswathi[2], Vasavi Ravuri[3], M. Srikanth[4], Kollipara Praveen Kumar[5], Uppala Reshmitha[6]
[1]Assistant Professor, Department of CSE, VNR Vignana Jyothi Institute of Engineering and Technology akhilresearch18@gmail.com
[2]Assistant Professor, Department of CSE, VNR Vignana Jyothi Institute of Engineering and Technology vijayasaraswathi_r@vnrvjiet.in
[3]Assistant Professor, Department of CSE, VNR Vignana Jyothi Institute of Engineering and Technology vasavi_r@vnrvjiet.in
[4]Assistant Professor, Department of CSE, VNR Vignana Jyothi Institute of Engineering and Technology srikanth_m@vnrvjiet.in
[5]Computer Science and Engineering, VNR Vignana Jyothi Institute of Engineering and Technology 19071a0581@vnrvjiet.in
[6]Computer Science and Business Systems, VNR Vignana Jyothi Institute of Engineering and Technology 20071a3254@vnrvjiet.in
Correspondence Author: Vasavi Ravuri*

Abstract
Attention Deficit Hyperactivity Disorder (ADHD) is a neurobiological disorder characterized by complexity in maintaining attention, impulsive behaviours, and hyperactivity, which severely can impact children's academic performance and day to day activities. Traditional approaches, including medication and Cognitive Behavioural Therapy (CBT), have shown effectiveness but often lack engagement, limiting their impact. This research presents a novel game-based therapeutic intervention designed to enhance cognitive function in children with ADHD. The proposed system combines cognitive science principles, interactive game mechanics, and data-driven personalization to create an adaptive, engaging, and effective learning environment. Developed using Unity and C#, the game integrates cognitive training through a reward-based framework where players earn points by completing tasks and answering questions, promoting sustained attention and memory recall. To further personalize the experience, data mining techniques, including Exploratory Data Analysis (EDA) and Association Rule Mining (ARM), are employed to analyse student performance and dynamically adjust gameplay. The system is validated through pilot testing, demonstrating significant improvements in attention and cognitive engagement among children. This study bridges the gap between interactive technology and cognitive therapy, providing a scalable, accessible, and enjoyable alternative to conventional ADHD treatments.

Keywords: *Attention Deficit Hyperactivity Disorder (ADHD), Cognitive Behavioral Therapy (CBT), Association Rule Mining (ARM), Exploratory Data Analysis (EDA), cognitive science*

1.INTRODUCTION

Attention Deficit is a neurobiological disorder that affects one's ability to pay attention, control impulses, and sustain hyperactivity. The disorder, often referred to as attention deficit hyperactivity disorder (ADHD), significantly affects school work in children in school and daily activities of life. While medications and traditional therapies are available, the need for interactive, non-invasive therapies augmenting cognitive function is on the rise. This research tries to provide a new solution by bringing together cognitive science and interactive gaming in assisting children with attention deficits [1].

Cognitive science is an inter-and trans-disciplinary approach that seeks to uncover how people think, learn, and process information. Through the application of the findings of psychology, neuroscience, and statistics, scientists are able to develop new methods of improving attention and memory [2]. From this research, we find out about the potential of game-based interventions for children with attention disorders to make cognitive therapy more enjoyable and accessible [3].

Cognitive-behavioral therapy (CBT) and other traditional approaches have proven useful for attention disorders, but spontaneity that holds the child's attention is impossible with such treatments. A novel concept: utilizing game principles to therapy, creating an interactive drill to hold the child's attention and at the same time to develop their mental potential [4]. Through custom exercises and learning

accommodation elements, the game dynamically adjusts to the player's development, giving a maximized and optimizing therapeutic experience [5].

A second, paramount emphasis of this study is knowledge of the effects of visual stimulation, such as color therapy and interactive exercise, on attention. Research has proven that certain colors and patterns cause neural responses to increase concentration and memory recall [6]. The inclusion of these factors within the game allows us to establish an environment which naturally fosters sustained attention and intellectual development.

In the end, this study seeks to fill the gap between interactive technology and children's healthcare. Using cognitive science and therapy games, we will design an interactive device that not only helps children with attention deficit but also paves the way for more innovations in digital cognitive treatment [7]. This research brings to the forefront the capabilities of game-based solutions in acting to increase awareness and promote mental development through the use of a positive alternative to standard treatment programs.

2. Related Work

Chronic diseases and neurobiological disorders are the most sought-after domains to treat children suffering from the adverse effects of these diseases. Few attempts were made to treat children suffering from such diseases, and one was successful. Empower Stars, a video game prototypic solution for children suffering from cancer and various other chronic pediatric diseases, aims to improve the physical and psychological aspects of the children. The video game prototype Empower Stars! is a joint initiative involving academic faculty, video game developers, and healthcare providers [3]. This solution prototype integrates superheroes, space exploration, and star rewards to cultivate uplifting experiences and empowerment in overcoming illness, removing the notion of players "dying." The video game also incorporates a multi-level feedback system that enhances the recommendation system used to provide possible suggestions to the patients regarding the disease.

The game leads to a new advancement in the industry. Children who played video games had shown improvement in their health, and this provided cancer-related knowledge to the patients to better themselves and to be more aware of the severity and adverse effects of the disease along with the precautions that could prevent the increase in the severity [8]. Studies of neurological research highlight that specific video games have positive effects on cognitive and motor functions in students. The research has demonstrated that playing video games can be safe and lead to improved cognitive function in students suffering from attention deficit [9].

3. Proposed Work

The proposed system is a structured method with game development as shown in figure 1, data analysis, and cognitive neuroscience principles integrated into it. Most importantly, creating a highly interactive and engaging video game that would help in the development of the cognitive skills of ADHD students is the most important aspect. The process involved herein is multidimensional, from stages of software requirement analysis, system design, and data collection to ensure the final product matches both learning and therapy goals. The working premise of this project draws on prior research illustrating the cognitive benefits of video games. By combining elements of Cognitive Behavioral Therapy (CBT) with the game world, the system aims to provide an effective and individualized intervention for students who have attention problems. Software development involves the application of appropriate tools and technology to ensure the game not only runs, but is playable as well. The game engine Unity is employed to design the interactive space so that it can support animation, activities, and reward feedback systems without a hitch. The programming language employed is C#, which can process the game logic as well as the real-time input of the user efficiently. The game layout also consists of a user-friendly interface that gives motivational feedback, monitoring of progress, and real-time score updates to encourage the students.

In addition, non-functional requirements such as security, compatibility, and maintainability are also considered to deliver a smooth and consistent gaming experience on different devices. Key feature of the strategy is data-driven personalization. The work is survey-based data collection from 10–12-year students to quantify their attention level of cognition. Data is collected through the use of data mining practices such as association rule mining and exploratory data analysis (EDA). The system designs personalized game scenarios and difficulties based on opinions from students. The addition of machine learning

algorithms facilitates adaptive game play that dynamically adapts game play in real time to user performance in order to provide a personalized experience that allows cognitive development.

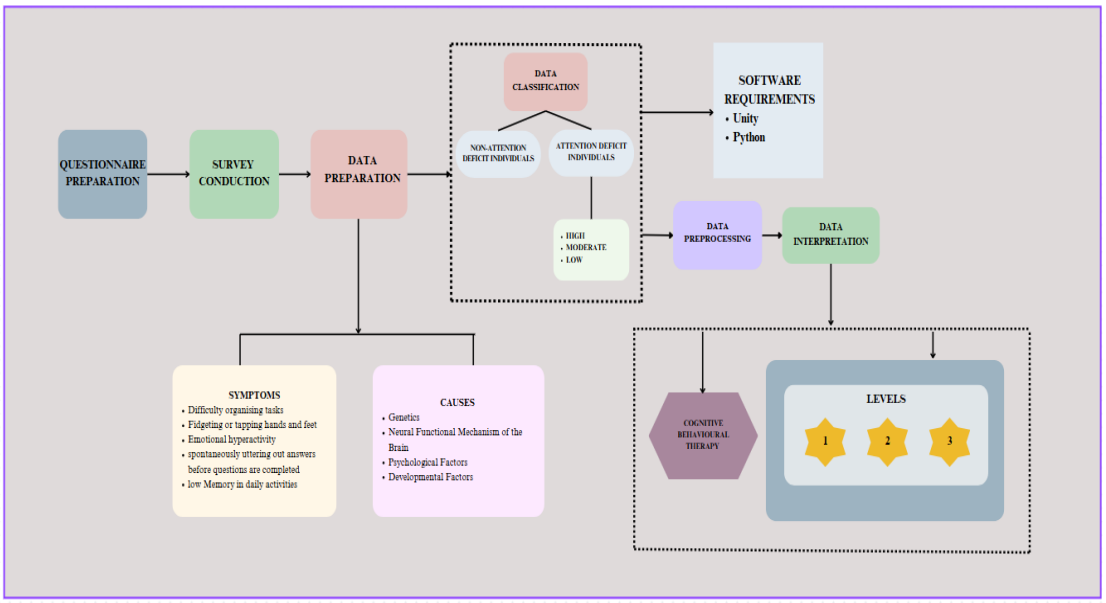

Figure - 1: prototype of video game for children with attention defecit to improve their cognitive attention [10]

3.1 Algorithmic Framework

.(i) Initialise Player
(ii)Coin_count=0, Question_count=0, Score=0
(iii)answer = “”, Questions[n], Answers[n]
2. While game is not over
if(Player.collision(Coin)) then
//collision -A game object(Player) colliding with another game object(Coin)
Coin_count++; //player is collecting the coins
Score++; // Each collected coin adds 1 point to the score
if(Coin-count%5 == 0 && Coin_count > 0) then
display_question(); //A question will be displayed after collecting 5 coins
Question_count++;
if(Player.collision(cracker)) then
Exit; //if the player hits the cracker the will end.
End while
3. display_question() {
print(Question[Question_count]);
ans = scan(input);
if(ans == Answer[Question_count]) then
Score++; //for every right answer player will score 1 extra point (implies for all questions)
if(!Question_count%5 == 0 && Question_count > 0) then
// Every 5th question is a bonus question
Score--;
// For every wrong answer 1 point will be deducted from score but not for bonus question
4.if(Score >= 75) then
next_level();
else
start_again();

Note : The player will be allowed to go to next level only if the score is equal or greater than the minimum required score else, the player has to play the same level to reach the required score.

Time Complexity :

Time Complexity of the game algorithm is O(m×n) where m represents no.of player playing the same level in different devices and n represents no.of comparisons that are required to check the player collisions to increase score or to end the game.

4. RESULTS AND DISCUSSION

The prototype game successfully integrates cognitive training by way of an interactive, reward-based environment that responds to the level of attention given by the player. The game's design, based on Unity and C#, utilizes students in a guided yet rewarding learning process that challenges cognitive faculties by way of increasingly demanding activities.The data mining techniques employed for processing students' responses provided useful insights into attention deficiency patterns. Exploratory Data Analysis (EDA) revealed relationships between cognitive abilities, response accuracy, and game performance. Association Rule Mining also revealed strong behavioral patterns, allowing for personalized gameplay modifications. The results indicate that the integration of data-driven insights with game-based interventions can successfully enhance focus and cognitive engagement in students.

The future directions of the project are integrating the game on higher levels in association with the algorithm, integrating background parameters for personalized cognitive training. IoT and AR/VR-based training can further be used to improve the experience and effectiveness for children with attention deficiency[7]. Integrating Cognitive Behavioral Therapy (CBT) recommendations can provide an integrated solution for attention disorder management[4]. As a result of the iterative process involved in game development, frequent surveys of administration and professional feedback will be instrumental in continuing to develop and test the efficacy of this intervention.

4.1. Exploratory Data Analysis

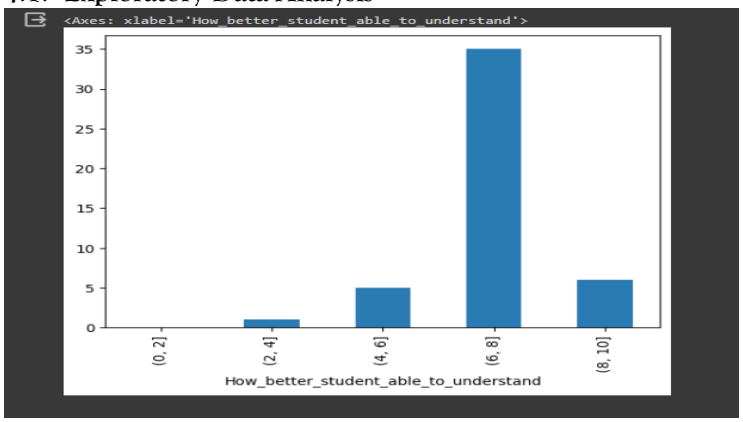

Figure - 2 EDA on IQ and EQ

Figure-2 shows Exploratory Data Analysis (EDA) on IQ and EQ of the student which is crucial for enhancing our understanding of the dataset through various graphical representations and visualizations.

4.2. Association Rule Mining(ARM)

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(correct multiplication , ) --> (1, ) With support as 0.5172413793103449 and confidence as 0.9375000000000001
(1, ) --> (correct multiplication , ) With support as 0.5172413793103449 and confidence as 0.5882352941176471
(completed figure pattern, ) --> (1, No Rough , ) With support as 0.5 and confidence as 0.7435897435897436
(1, No Rough , ) --> (completed figure pattern, ) With support as 0.5 and confidence as 0.7073170731707318
(1, ) --> (completed figure pattern, ) With support as 0.6206896551724138 and confidence as 0.7058823529411765
(completed figure pattern, ) --> (1, ) With support as 0.6206896551724138 and confidence as 0.9230769230769231
(1, ) --> (mirror word not identified, ) With support as 0.5862068965517241 and confidence as 0.6666666666666666
(mirror word not identified, ) --> (1, ) With support as 0.5862068965517241 and confidence as 0.9189189189189187
(completed figure pattern, No Rough , ) --> (1, ) With support as 0.5 and confidence as 0.90625
(1, ) --> (completed figure pattern, No Rough , ) With support as 0.5 and confidence as 0.5686274509803921
(No Rough , ) --> (Picture Element, ) With support as 0.5172413793103449 and confidence as 0.6382978723404256
(Picture Element, ) --> (No Rough , ) With support as 0.5172413793103449 and confidence as 0.8333333333333334
(No Rough , ) --> (completed figure pattern, ) With support as 0.5517241379310345 and confidence as 0.6808510638297872
(completed figure pattern, ) --> (No Rough , ) With support as 0.5517241379310345 and confidence as 0.8205128205128205
(1, completed figure pattern, ) --> (No Rough , ) With support as 0.5 and confidence as 0.8055555555555556
(No Rough , ) --> (1, completed figure pattern, ) With support as 0.5 and confidence as 0.6170212765957447
(No Rough , ) --> (1, ) With support as 0.7068965517241379 and confidence as 0.8723404255319149
(1, ) --> (No Rough , ) With support as 0.7068965517241379 and confidence as 0.803921568627451
(mirror word not identified, ) --> (No Rough , ) With support as 0.5 and confidence as 0.7837837837837838
(No Rough , ) --> (mirror word not identified, ) With support as 0.5 and confidence as 0.6170212765957447
(Picture Element, ) --> (1, ) With support as 0.5172413793103449 and confidence as 0.8333333333333334
(1, ) --> (Picture Element, ) With support as 0.5172413793103449 and confidence as 0.5882352941176471
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Figure - 3 Association rule mining

Figure -3 shows the rules generated from data that satisfies the minimum support and confidence levels

4.2.1. Sample Survey Question

3) Anna is having a birthday party. She is six-years-old today. Anna told her mother she would like a very special cake for her sixth birthday. She said she wanted a birthday cake with three layers: a large layer on the bottom with pink color, a medium-sized layer of blue in the middle and a small layer of pink on top with two cherries. Her mother went into the kitchen and baked the cake. She is very happy because her mother baked her cake exactly like she wanted. Anna's party was so much fun. Ten of her classmates came today out of which 3 were boys. Everyone loved the birthday cake. They also gave her wonderful gifts. The one she loved the best was a big beach ball that her friend Alex gave to her. She loved the color of the ball, as pink is her favorite color. She plans to take it on vacation when she goes to the beach. Anna's grandparents also came. They gave her a new pair of roller skates. Anna's grandparents loved her birthday cake and took a picture of it.

1. Who gave Anna her favourite gift?
2. When was Anna's birthday party?
3. What was special about Anna's cake?
4. How old was Anna last year?
5. What is Anna's favourite color?

Figure - 4 : Sample survey question

Figure – 4 shows a sample question from the questionnaire prepared to test test the students attention and abilitites

4.2.2. Game Output

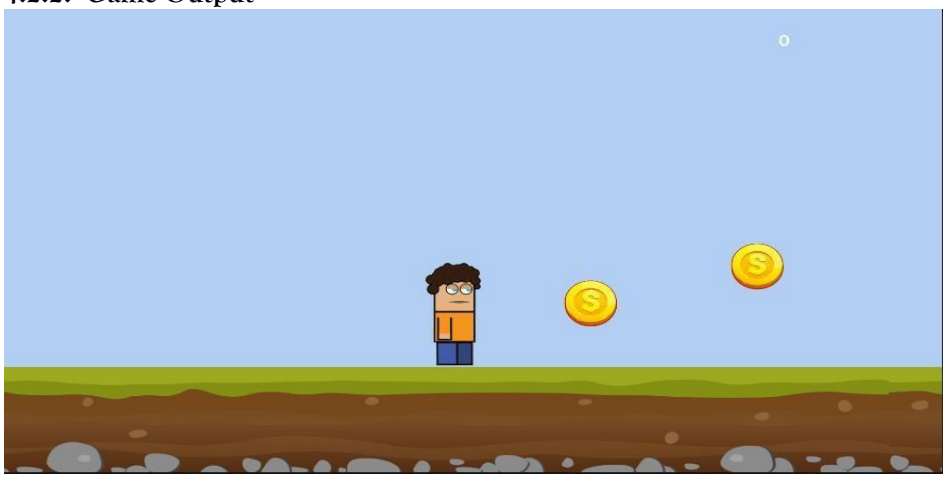

Figure - 5 Initial Position of the player

Figure 5 illustrates the positioning of the layer at the initial level.

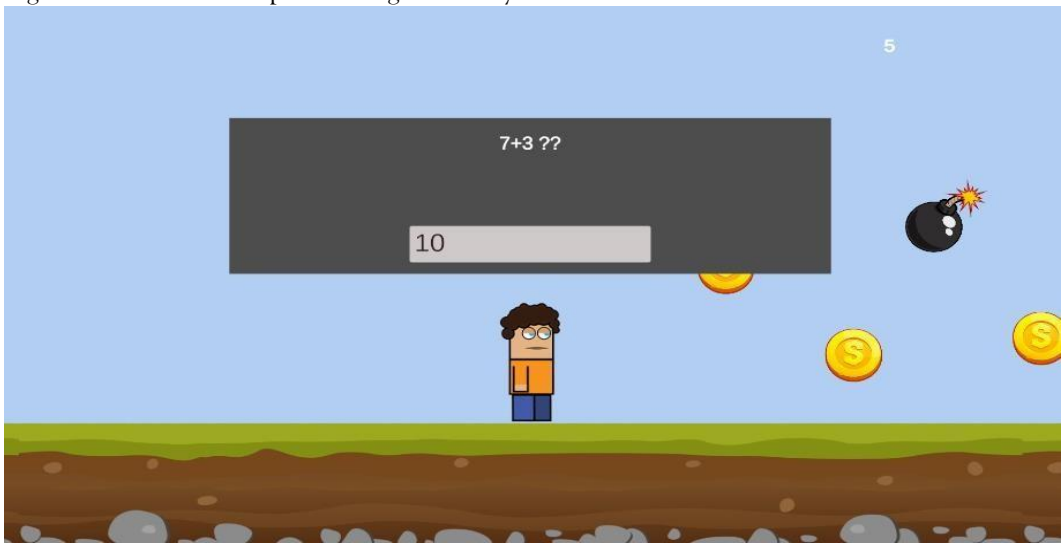

Figure - 6 :Display of Question

As shown in figure 6, Question displaying after collection of every 5 coins and player will answer the question, score will increase by one point if the answer is right

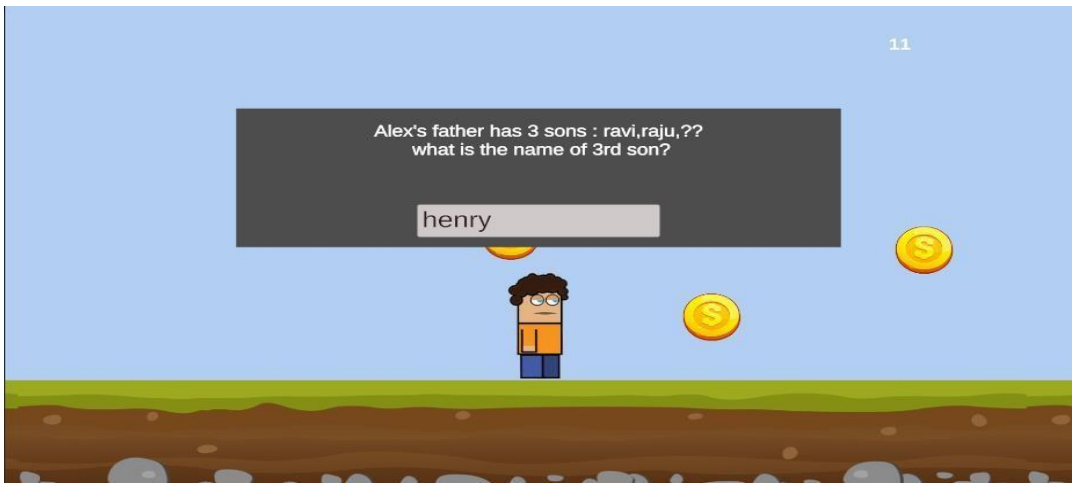

Figure - 7 score will decrease by one point if the answer is wrong

Figure 7 visualizes the score based on the user attemption to the corresponding question as accepted/yes/Correct or Wrong

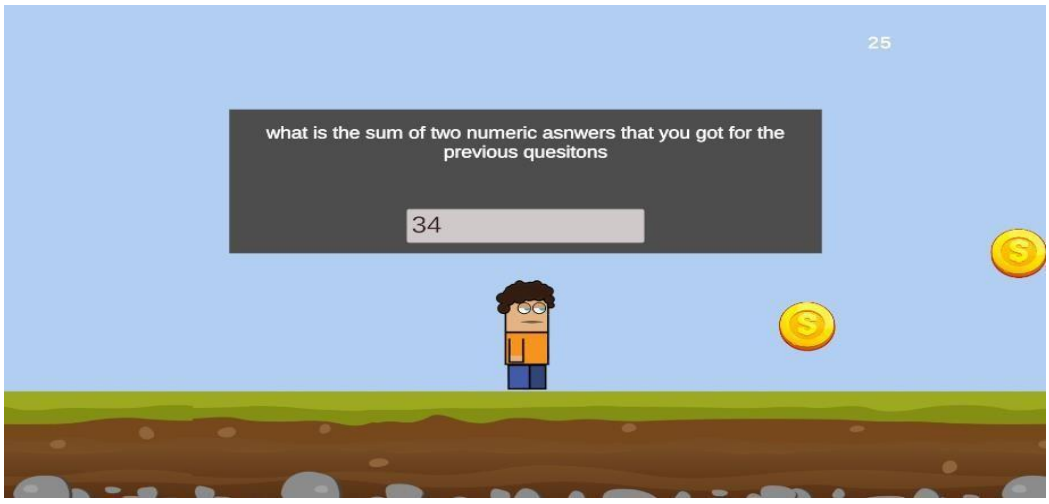

Figure 8: Sample illustration of Bonus point

Figure - 8 views Bonus question will be displayed after 5 normal questions - bonus question's answer will be depended of previous answers.

Figure 9: Conclusion of the game

Figure - 9 If player hits the 'Cracker' object in the game - the game ends abruptly and the player has to play again form beginning

The above figures - 5 to 9 show the game flow created to help children improve their attention. The player starts the game by collecting the coins, after collecting 5 coins a question will be displayed on the screen. If the player answers the question right, the score increases by one point and if the player answers the question wrong, the score decreases by one point. After 4 such questions, the 5th question will be the memory-based question, for which the answer depends on the previous 4 answers. There are no negative marks for the bonus question. The game continues this way and if the player hits the 'cracker' the game will end abruptly.

5. CONCLUSION AND FUTURE SCOPE

Attention deficit is a neurobiological condition involving impairments of cognition and motor abilities, with associated problems of focusing, organizing, and learning. Current research supports the enhancing effect of video games on cognition. Our work introduces a novel game that focuses on improving attention and memory for kids with attention deficit. Based on exploratory data analysis and association rule mining, we gleaned information from questionnaires. With expert guidance, this prototype connects child healthcare and therapeutic games, presenting a promising treatment for neurodevelopmental disorders.

In Future, authors would like to extend the game and test on real-time data on the approval of medical associations.

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