University of the Philippines Manila
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Augmented Reality Based Inhibition/Impulse Control Assessment Tool for Attention Deficiency Hyperactivity Disorder (ADHD) Children

A special problem in partial fulfillment
of the requirements for the degree of
Bachelor of Science in Computer Science

Submitted by:

Glenn Angelo E. Anicoche

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ACCEPTANCE SHEET

The Special Problem entitled " Augmented Reality Based Inhibition/Impulse Control Assessment Tool for Attention Deficiency Hyperactivity Disorder (ADHD) Children " prepared and submitted by Glenn Angelo E. Anicoche in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science has been examined and is recommended for acceptance.

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Abstract

Attention Deficit Hyperactivity Disorder is a behavioral disorder that can be observed during a child's growth progress. ADHD is the most frequent neurodevelopmental disorder with a worldwide prevalence ranging between 4% to 8%. While there are existing therapeutical methods to treat/address ADHD, using gamified methods can increaes their willingness and focus. Existing assessment tools regarding the behavioral developments of ADHD children heavily rely on the subjective observations of the medical professional handling the patient. An objective assessment tool can collect data/metrics that can act as evidence to be used by the medical professional to prove or disprove the observations they made. By using technology such as augmented reality, the focus of the patient when using the assessment tool can be improved which can lead to producing better data. The application developed in this study is able to collect metrics such as score, errors, success/error rates, and average response times, and sends it to a database where the medical professional can export the data and import it to Microsoft Excel to generate visualization tools.

Keywords: augmented reality, gamification, assessment tool, ADHD, Brown's model of ADHD, impulse control, inhibition

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I. Introduction

A. Background of the Study

Attention Deficit Hyperactivity Disorder is a behavioral disorder that can be observed during a child's growth progress. ADHD is the most frequent neurodevelopmental disorder with a worldwide prevalence ranging between 4% to 8% [1]. ADHD can be a hindrance causing a child's lack/absence of self-confidence, separation from the social environment such as academic spheres or even just relationships with friends. ADHD can be observed through three dimensions: impulsivity, hyperactivity and inattention that leads to unsettling and continuous diagnostic of restricted learning and adaptation. If ADHD goes untreated, people that have it have a higher probability of being involved in accidents, dropping out of school, being subject to addiction, or even mortality [2]. The most commonly applied form of therapy and considered the most effective treatment for ADHD is Cognitive Behavioral Therapy (CBT) [3]. CBT challenges its patients in repetitive motion to overcome unhelpful cognitive distortions observed rooting from attention dysfunctions, such as ADHD. Though it has its cons which include that psychotherapies are not usually implemented in public health systems. Condescendingly, lack of motivation and engagement are core characteristics of ADHD [4], and these can be hindrances to patients participating in CBT. Therefore, ADHD therapies should focus or at least include fun as a factor to pique the interest of the patient in participating and improve engagement. Enter the use of new technologies such as AR/VR and/or gamified media. Video games which contain nongame objectives, or "serious video games" have been implemented in different activities such as training and education [1]. Some examples of these applications are The Secret Trail of Moon [5], a serious video game aimed at treating ADHD, AugThat, an AR application which allows students to explore planets and create a cosmic universe, and ARBio which is an AR application that allows students to scan a marker and augments the 3d model of the animal that is on the marker. These are just a few

examples of the new technologies that are incorporated/implemented as complementary materials to everyday life such as education and training. It gives a feel that video game-based tools can be useful and effective in different applications/implementations, and can therefore be adapted to try and develop a tool that can be used for treatment of ADHD. It addresses the low intrinsic motivation of patients with ADHD that causes faster boredom, and relying on more engaging tasks to retain attention to the activity.

B. Statement of the Problem

Given the statements from the background of the study, the problem at hand is to develop a game/application that caters to patients with ADHD that can help as a complementary tool to other therapeutic methods. The idea is not to make the data collected as the only measurement of improvement of the child with ADHD, but to provide additional data that can be used by the medical professional to assess the developments of the child resulting from the therapy program as improvements/developments can only be seen through observation by the medical professional and/or the family; the data can provide a quantitative basis which can be interpreted by the medical professional. By utilizing the fun factor that video games bring, it can help the patient/user develop better focus or retain its attention on the/application, therefore acting as a therapy itself that practices better focus. Though these technologies (AR/VR/Gamified Media) bring promising advantages that can be useful for therapy and other medical applications, it is still not widely developed, implemented, and available for use. Through the application that will be developed after this study, the goal is to create a useful application that can be adapted as a basis for future applications/tools that can complement traditional therapy methods being used for ADHD.

C. Objectives of the Study

The objective of this study is to develop a videogame-based objective assessment tool for ADHD in children that aims to assess the improvements brought about by therapy to their impulsiveness. The application contains adapted mechanics from other games that are supposed to cater to ADHD namely the Go/No-Go test. The application is a mobile application to be used with a monitoring medical professional and is to be played by the patient during clinical sessions with the medical professional. The application also collects metrics that should provide the medical professional with quantitative data that can help to assess the performance of the patient and its improvements from the therapy program of the medical professional.

The mobile application have the following functionalities:

1. Allows the ADHD patient to
    (a) Scan the image target
    (b) Enter his/her name
    (c) Start the game by pressing the start button
2. Allows the medical professional to
    (a) Have access to the database
    (b) Export JSON file of metrics collected by the game
        i. Score
        ii. Error
        iii. Success Rate
        iv. Error Rate
        v. Average Response Time
        vi. Average Error Response Time
        vii. Average Success Response Time

The JSON file of the metrics collected can be imported to a 3rd party spreadsheet application that can generate visualization tools such as graphs to easily observe the developments of the patient.

D. Significance of the Problem

According to Interactive Software Federation Europe (ISFE), there are more than 24 million video game players in the 6-15 years old age group. This is an ideal age group to develop and utilize a serious video game because 1) it is better to treat ADHD at an earlier age and 2) these are the ages that are more playful and more likely to be involved and interested in games, therefore that interest can be utilized by developing serious video games with therapy & treatment as the main priority. With the availability and accessibility of smart devices that are capable of utilizing AR/VR or gamified media, adapting these new technologies to develop new treatments or therapies can introduce new interest and excitement to the stakeholders. Video games offer beneficial cognitive effects on attention and visuospatial abilities, it can improve attention, effort. As mentioned previously, "serious video games" have the factor of being motivationally challenging while still offering the user a fun learning experience. The narratives/story line and other aspects within the game can increase the level of engagement of the user to achieve a specific goal in-game. The level of engagement from the user is linked to its positive emotions produced by effort and achieving the goals, which are necessary to turn a video game into a tool that can be used for ADHD.

E. Scope and Limitations

The scope of this study includes researching traditional ADHD treatments and the cognitive skills that are targeted, adapting these concepts and developing/implementing it to game aspects/mechanics. By researching the cognitive skills that traditional ADHD treatments target, game mechanics can be developed to tackle/target similar cognitive skills therefore complimenting the traditional ADHD

treatment. The final output is a functioning game with the derived game mechanic/s that can be demonstrated for the panel and one that can be therefore used for future research and developments and/or be tested on ADHD patients to really measure the effectiveness of the application developed based on actual data collected from live participants. For the limitations of the study, other studies and researches that are of this nature spanned anywhere from 1-2 whole years with a team of professionals on different domains working with one another to create a tool in the same space, and also due to the need for approval from the ethics board/committee in regards to conducting tests on human subjects, actual clinical trials on participants are not within the scope of this study and can be conducted as a continuation/evaluation of the tool that is to be developed by this study.

1. This project is not able to proceed with actual clinical trials due to the time needed for development and the application of approval from the ethics board especially as the participants of the study are supposed to be younger children.

2. Regarding the limitations of the device:

   (a) Mobile device must be running on Android OS.

   (b) Android version is 8.0 or later to utilize the tracking functionalities of Vuforia/ARCore that enables the Augmented Reality features of the application.

   (c) At least 300MB storage space on the device where the application is to be installed.

F. Assumptions

1. The child is undergoing therapy for ADHD.

2. The child is approved by the medical professional to be fit to carry a mobile device to play use the tool.

3. The game is to be played during the clinical session with the medical professional.

II. Review of Related Literature

PANDAS[6]

PANDAS: Pediatric Attention-Deficit/Hyperactivity Disorder Application Software is a product of a study with the aim of developing a novel method that provides rapid screening for the hyperactive subtype of ADHD. Since ADHD is defined by DSM for mental health, only specialists such as psychiatrists can give diagnosis. Therefore, the tool developed wasn't aimed to be a diagnosis tool, rather a screening tool for school children to be identified as potential ADHD patients. The game layer of the app was the input to the data-processing layer which collected metrics. It is a jungle/tropical themed game that considered the age group of the participants in the research. The gameplay required the player to get a raft from one end of the river to the other while avoiding obstacles and collecting as many gems as possible. The player controlled the raft by using the buttons found on the bottom corners of the screen.

Figure 1: Screenshot of PANDAS

As mentioned, the game layer served as an input to the data-processing layer, data collected included personal user data such as age, gender, race, game enjoyment, and if diagnosed with ADHD or not. Gameplay variables and accelerometer data were also collected to be translated to applicable DSM-V criteria into measurable parameters. These parameters were mistakes made, task completion time, task termination, distractibility, forgetfulness, and sustained attention. And all this

data was stored in a Firebase database. The test was conducted on 30 subjects between the age of 5-16 years old and the participation was voluntary with parental consent. The main criteria for the inclusion in the test was the age since ADHD is more prevalent in minors/younger ages. Another criteria is that the child should not have any history of severe mental illness. The advantage of using a game as a method of screening for ADHD is that it can be used to provide screening without going to a specialist as this tool can be used by parents and teachers.

The Secret Tail of the Moon[7, 5]

The Secret Tail of the Moon(TSTM) is a therapeutic adventure-puzzle VR-based video game that utilizes cognitive training for patients with ADHD. It is a VR game that follows a story of a kid that appears in a cave that travels with a fox and a racoon, through their adventures in the woods, they discover a war between two animal factions. With a goal to unite the animals again, they set out on a quest that will put an end to the war of the two factions which also poses a threat to the forest itself. In contrast to the previous game reviewed, its target population are children already diagnosed with ADHD with ages over 12 years old. The behavior change procedures utilized in the study/game are by feedback and monitoring, the achievement of goals and planning, the shaping of knowledge, repetition, natural consequences, rewards, and regulation and identity techniques. TSTM follows the theoretical psychological models of Thomas Brown's model of executive functions, and Barkley's behavioral inhibition model. The first minigame that is inside TSTM is called Smasher, the player must break a rock blocking their way by pressing the X button when the appropriate set of chess pieces appear on screen, it targets sustained attention and inhibitory control. The next one is called Enigma and the player must remember a shown sequence and place it in the correct order as quickly as possible, Enigma targets the working memory of the player. The next one is called Kuburi which targets the Visuospatial ability(part of the working memory) and cognitive flexibility of the player, the mechanics of

the game is to follow the shown drawing using 3D cubes with 6 different faces. The 4th game in TSTM is called Teka Teki which targets the planning skill of the player in a game where the player must guide the fox through a maze with blocks blocking the way to get the lock. The next game is called Kitsune which targets the impulse control of the player by requiring them to avoid objects that are in the way by following the indicators shown on screen. And the last game is simply a Chess game that targets the reasoning, planning, and math calculations of the player where they learn the basics rules of chess through different lessons which increase in difficulty. Tested with 36 users, comments and feedback resulting from playing the game suggested that TSTM, was fun, understandable, easy to play, intuitive, had good graphics, and was of adequate duration for most participants. Though there are games that presented difficulty for the participants such as Teka Teki (planning game), 100% of the participants reported feeling good after testing the game. Player motivation was also a good aspect of TSTM meaning that the players had internal motivation to play and follow the game. The side effects that were mentioned that occurred after playing TSTM was perceived dizziness or motion sickness, which are expected potential side effects of using VR for an extended amount of time based on their literature.

Augmented Reality in Frustration Learning of ADHD patients[8]

A study conducted in the Philippines which utilized Augmented Reality to improve the frustration tolerance of ADHD learners. Frustration is defined as the feeling of not achieving a desired goal that omits a rewarding event or an item. Poor frustration tolerance is a symptom of ADHD. It is a symptom that can be observed in an adult which resembles the signs of childhood ADHD, though it may have decreased overtime. The main objective of the study is to discover whether AR-based technology can improve the learning ability of an ADHD learner. There participants of the study were ADHD learners in selected Special Education Centers. After performing purposive sampling and through the guidance of the ad-

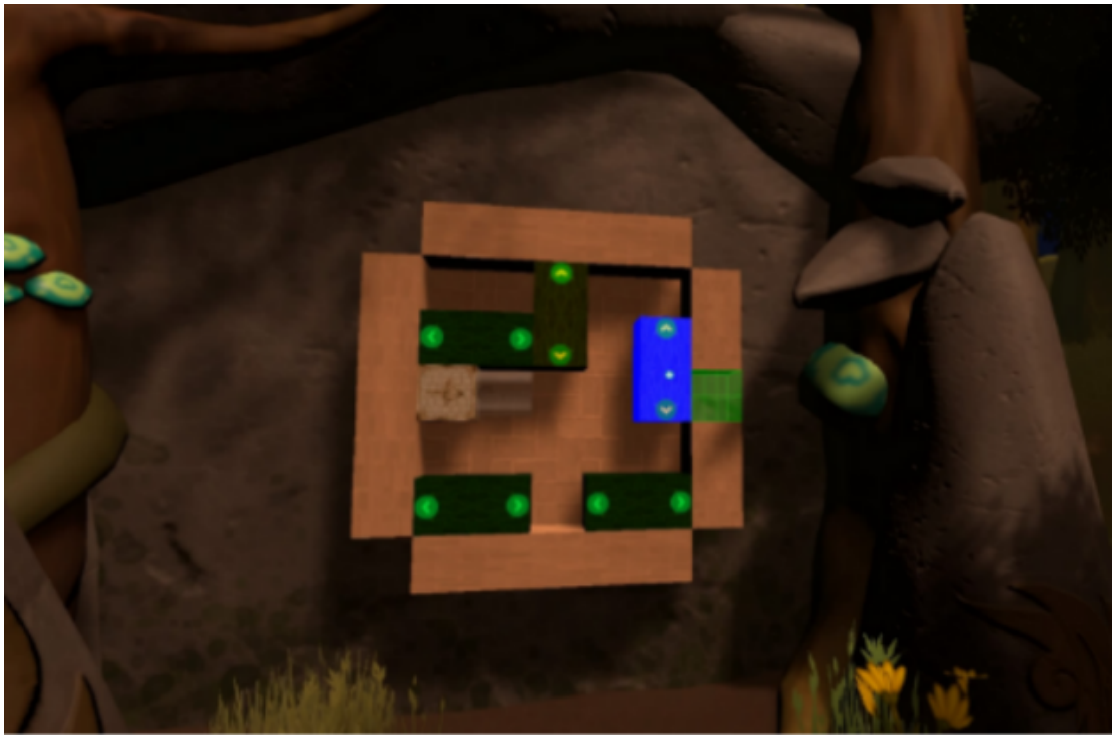

Figure 2: Screenshot of the game Teka Teki

ministrators of the SPED Centers, 11 ADHD learners participated in the study, 9 of which were male and 58.33% of which were diagnosed with the Hyperactive type of ADHD. A criteria for being a participant to the study is that the learner had to be formally assessed by a registered psychologist to have ADHD. To tackle the main goal of the study, a psychological distress tolerance tool, specifically the Mirror Tracing Persistence Task is used to determine the frustration tolerance of the participant. There were 2 activities in the study, the first one is the MTPT phase where the participant must trace a mirror-reflected pattern which is being covered to stimulate frustration. Time start, time end and duration in activity were recorded and later interpreted and a follow up interview was conducted to assess the student's experience regarding the task. The next phase included the use of an AR-based mobile application. The gameplay of the AR application is interactive find-the-object type that aims to teach the ADHD learner about mathematics. The AR application has markers pre-developed by the creators of the application. Same as the previous phase, the participant was asked some questions regarding their experience when using the application. Based on the time spent

Participant	MTPT (in minutes)	AR (in minutes)
Participant 1	5.5833 – Quit	13.0333 - Quit
Participant 2	2.1667 – Quit	15.0500 – Not Quit
Participant 3	4.0000 – Quit	5.7167 - Quit
Participant 4	2.0000 – Quit	13.7500 – Not Quit
Participant 5	6.0000 – Quit	22.0000 – Not Quit
Participant 6	3.0000 – Quit	11.0000 – Quit
Participant 7	5.1333 – Quit	18.3333 – Not Quit
Participant 8	2.0000 – Quit	16.0000 – Not Quit
Participant 9	1.7833 – Quit	5.0000 – Quit
Participant 10	.6667 – Quit	2.3500 – Quit
Participant 11	4.1000 – Quit	21.0833 – Not Quit

Figure 3: Time spent by participants in each activity

on the 2 phases by the participants shown in table 1, it can be seen that the frustration tolerance of the ADHD learners were low. This only proved that ADHD learners show behaviors relating to a lower level of tolerance as being conveyed in several ADHD studies. On the Augmented Reality activity however, there is a noticeable increase in time spent of the participants compared to their MTPT results. The average time spent in the MTPT activity was 3.31 minutes and 13.03 minutes for the Augmented Reality activity. Another noticeable result from the table is that there in the MTPT activity, all participants quitted the activity while in the AR activity, 6 out of 11 participants were able to complete the required levels of the task. During the interviews after the activities, most participants enjoyed the AR activity more compared to the MTPT activity as it was more exciting and entertaining even though they had difficulties navigating through the application especially when the predetermined markers were not being recognized by the application.

ACTIVATE[9]

A study in 2018 titled "Effects of E-Games on the Development of Saudi Children with Attention Deficit Hyperactivity Disorder Cognitively, Behaviourally and Socially: An Experimental Study" by Alghamdi et al. investigated the effects of educational video games on the cognitive, behavioral and social development of

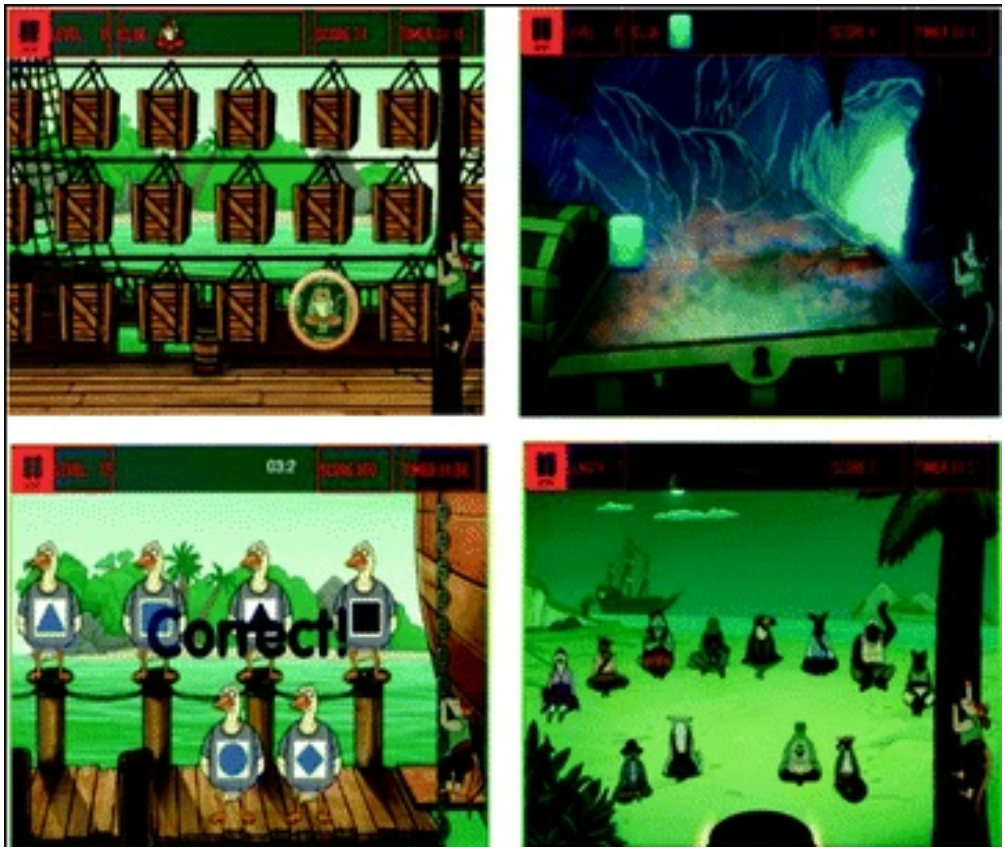

Figure 4: Screenshot of games in ACTIVATE

Saudi children with ADHD. The participants of the study consisted of 17 female children with ADHD aged between 6 to 12 years old and were given 30 minutes, three times a week, for four months to play the games. The data gathered by the study came from 5 sources, Conner's rating scale – used as a preliminary screening for ADHD, teachers and parents interviews, observations and notes during the experiment, short interviews with the participants after every session and after the experiment, and gathered data by the system. The data collected by the system are error rates, duration, scores, levels reached, correct and wrong clicks among other things. The system, called ACTIVATE, is a web-based application that provides certain brain-training exercises to enhance and develop their learning skills in classroom settings. 8 core cognitive capacities were targeted to be strengthened by the system by stimulating them, these are – Sustained Attention, Working Memory, Speed of Information Processing, Response Inhibition, Cognitive Flexibility, Category Formation, Pattern Formation, and Multiple Simultaneous Attention.

Core cognitive capacities							
Participants	Sustained attention	Response inhibition	Speed of processing	Cognitive flexibility	Working memory	Formation and use	Pattern recognition
Std 1H	7%	30%	33%	0	0	0	31%
Std 2LB	12%	26%	54%	30%	10%	0	0
Std 3K	18%	0	7%	19%	37%	0	33%
Std 4LW	12%	14%	54%	19%	60%	0	0
Std 5T	25%	80%	16%	0	7%	0	0
Std 6M	25%	40%	31%	60%	10%	0	0
Std 7JN	32%	7%	28%	83%	0	0	39%
Std 8LN	35%	64%	80%	42%	0	0	66%
Std 9LS	22%	39%	85%	42%	0	0	66%
Std 10JR	60%	0	70%	42%	7%	50%	66%
Std11RG	70%	47%	39%	29%	7%	0	0
Std 12I	34%	4%	24%	42%	0	0	0
Std 13RL	15%	0	55%	42%	0	64%	20%
Std 14T	9%	29%	68%	22%	0	98%	80%
Std 15D	25%	23%	71%	15%	0	0	88%
Std 16RF	15%	29%	55%	42%	0	0	51%
Std 17LH	25%	0	55%	42%	7%	23%	0

Figure 5: Improvement averages in cognitive capacities of participants

The system is composed of three portals, the teacher, where he/she can monitor the scores and progress, error rate, and response speed, and where the system can generate reports for each student that gives details about their strengths and weaknesses and how much they improved since they began using the application. The student portal contains 6 games that target the 8 aforementioned cognitive skills. These games train the student's ability to move between different tasks, remember sequences, classify items, and reinforce thinking strategies. Audio instructions are given to help students understand the tasks which range from feeding the crew, categorizing items, helping animals and more. Each student is allowed to play each game within 5 minutes only. The test portal is where students undertake two tests, pre- and post-intervention which are recommended by the National Institute of Health (NIH). The tests contain Flanker Task Test, Working Memory Test, and Go/No-Go Test which can help the teachers measure the amount of cognitive growth through real-time data, analysis of the amount of success that affects the academic performance of students. From the results generated by the system, the average computed by the researchers found that the sustained attention of the children has improved by 23%, response inhibition by 28%, speed of processing by 49%, and cognitive flexibility by 38%. These improvements are predicted to continue as long as the students continue to follow the program of playing the

games. The NIH tests which were taken pre- and post- experiment focused on Accuracy and Reaction Time as the main parameters in the tests. In the Flanker test, comparing the pre- and post- experiment performance, from the 72% average accuracy of more than half of the participants, nearly 98% had a 100% accuracy and faster reaction time during the post- test. For the Go/No-Go Test, the No Go results were focused due to the difficulty to hold back when no action must be done. The pre- test generated an average score of 52% "no goes" while the post-test average was 74%. Though there is a case were a student had a better performance on the pre- test compared to the post- test; however, the student showed significant progress in response inhibition and processing speed in the games as measured by the system, which is what Go/No-Go test measures. The disparity between the scores of the two tests by that student can be attributed to the lack of focus during the post-test. The study concludes that results show significant improvement in behavior and skills quantitatively and qualitatively; the academic performance of the students have also been enhanced; and strong encourages children with ADHD to play with such games that are developed to enhance their skills and abilities attributing to probable benefit that can positively affect their lives.

III. Theoretical Framework

According to [10] in creating a therapeutic game that is aimed not only at ADHD, there are 3 issues that need to be tackled in order for it to be successful, the first one is that there needs to be a focus on the therapeutic objectives, next is to use game design principles, and the last one is the collaboration with the patient/s by incorporating their own interests and their opinions to the game in order to pique their attention more. There are studies that continue on to clinical trials which state that the combined knowledge of medical practitioners and game developers in their own domains of behavior and UI/UX/player experience respectively, produces a better product/therapeutic game with a balance in the therapeutic and technical components. However, to achieve this, there must be a common language easily understandable by both parties so that there won't be any misunderstandings and complications during the development and the trials itself. However, for this study, as it stated that clinical trials are beyond the scope.

A. ADHD

ADHD is a psychiatric disorder diagnosed during the early stages of childhood, it is considered to be among the most prevalent psychiatric childhood disorders which affects 8% to 10% of children and persists into adolescence in approximately 80% of cases [11, 9]. ADHD can be observed through three dimensions: impulsivity, hyperactivity, and inattention. ADHD diagnosis before the age of 7 years old is important because of the resulting effects of untreated ADHD on the patient, their immediate family, and the people around them. These effects may include underachieving in school which may lead to further implications such as difficulty in job seeking, difficulty in building relationships with the family, peers, teachers and employers because of their condition [12], and involvement to risk-taking behaviors such as dangerous driving, risky sexual activities, substance abuse, other criminal activities or even mortality, which can indefinitely affect their life, among

other things [13].

According to several studies, there are three types of ADHD:

1. predominantly inattentive (ADD) which is the intersection of the learning and attention domains of ADHD characterized by difficulties in maintaining focus on task at hand and getting bored easily as some of its main characteristics,

2. predominantly hyperactive-impulsive (Classic ADHD) is the intersection of behavior and attention disorder characterized by fidgeting, non-stop talking, difficulties in staying still, etc., and

3. combined hyperactive-impulsive and inattentive.

Locally here in the Philippines, ADHD is one of the most common mental disorders observed in Filipino children with a prevalence rate of 3-5% of the country's population of the age range 0 to 14 years old according to the ADHD Society of the Philippines. Some of the symptoms that ADHD Society of the Philippines say to watch out for are difficulty in sustaining attention, struggling to follow instructions, difficulty in listening, fidgeting, difficulty in staying still, zoomies, and often interrupts or intrudes others among other things. Statistics also show that 35% of children here in the Philippines who are diagnosed with ADHD do not finish their high school education [8].

B. Brown's ADHD model

According to Thomas E. Brown who is a clinical psychologist who's done research on ADHD, he has developed a model detailing ADHD symptoms as a result of impairment of six executive functions, which allow a person to manage their thinking and behavior, planning and prioritization skills, in other words, executive functions are how the brain manages itself [14]. This ADHD model has been developed through clinical interviews with children, adolescents, and adults with the condition. These executive functions are the following: 1. Organizing, prioritizing, and

activating to work, which involves challenges in things like organizing materials, setting priorities on a project and/or even getting started on it; 2. Focusing and shifting attention to tasks, which might translate to problems in maintaining focus and attention on a given task, and/or having the urge to shift to a new one; 3. Regulating alertness, sustaining effort, and processing speed, which involves challenges when monitoring and maintaining attention and trying to sustain a level of effort over time; 4. Managing frustration and modulating emotions, which may translate into emotion-led behavior, emotion-focused thoughts, and difficulty putting feelings in perspective; 5. Utilizing working memory and accessing recall, which may involve having difficulty with short-term memory and recalling information, and an inability to remember a particular piece of information on demand; and, 6. Monitoring action and regulating behavior which could lead to impulsivity and difficulty altering changing behaviors according to context as well as setting the speed of action.

Having these functions identified separately on Brown's ADHD model, the brain could actually use multiple executive functions at a certain time which helps a person navigate through different situations that he/she might face everyday. Given these identified executive functions, the game to be developed can have a specific function in mind to target to improve.

C. Existing Treatments for ADHD

Treatment for ADHD is considered multimodal as it can include the use of medication, utilization of psychoeducation, and psychological intervention, with each treatment having their own side-effects or shortcomings such as the lack of motivation to engage with treatment from the patients themselves because of their overall lack of motivation, psychotherapies can also be expensive and unsustainable for most families evidence by the high rates of treatment discontinuation [5] The most effective treatment approaches for ADHD have been derived from multiple clinical researches. A review of evidence-based psychosocial treatments for

children and adolescents with ADHD indicated that there is adequate evidence for behavioral parent training and behavioral school interventions that has resulted in such treatments being classified as empirically validated interventions.

Attention Bias Modification (ABM) is an emerging technique derived from neurocognitive models of anxiety as it is observed to have a significant potential to enhance both pharmacological and psychological interventions for anxiety, as well as effective standalone interventions [15].

However, there is a gap between the demand and the supply of mental health services, and it has led to the developments of different platforms and methods of administering clinical interventions for mental health illnesses e.g. anxiety such as eHealth, which is the use of electronic communication (calls, video conferences, etc.) to deliver health care practices, mHealth, which is a derivative of eHealth that utilizes mobile devices. These models aim to mitigate the impact of both practical and social barriers to treatment by utilizing such mediums to widen out the reach of these clinical practices.

D. Cognitive behavioral therapy

onsidered to be the most common and the most effective therapy for ADHD, Cognitive behavioral therapy (CBT) is a type of psychological treatment that has been demonstrated to be effective for a range of disorders such as depression, anxiety, substance abuse, marital problems, eating disorders and mental illnesses, including ADHD. The core principles that CBT is based upon are the following: 1) Psychological problems are based, in part, on faulty or unhelpful ways of thinking. 2) Psychological problems are based, in part, on learned patterns of unhelpful behavior. 3) People suffering from psychological problems can learn better ways of coping with them, thereby relieving their symptoms and becoming more effective in their lives. CBT challenges its patients in repetitive motion that can help in overcoming unnecessary cognitive distortions coming from attention disorders such as ADHD. As previously mentioned, all forms of therapies or treatments

has its own set of side-effects, as for CBT, the side-effects or cons include that psychotherapies are not usually implemented in public health systems, and that it is reliant on the motivation and engagement of the patient to undergo the therapy which can be difficult as lack of motivation is one of the core characteristics of ADHD. Researchers from Massachusetts General Hospital and Harvard Medical School wrote that "The conceptual and empirical basis for CBT approaches in adult ADHD is growing and suggests that targeted, skills-based interventions have a role in effectively treating this disorder. At this stage of development, however, subsequent studies must progress in terms of methodological rigor. Additional randomized controlled trials with active control groups are needed and intervention packages must be tested across multiple trials by more than one research group." [16] As for the results of CBT, benefits often show up after 12-15 one-hour sessions, which is considered quick, however, most patients that undergo this treatment tend to continue for much longer and consider it as a long-term maintenance of coping skills and improvements. A stretched out schedule of sessions is also considered to be better rather than a shorter period with more sessions compressed as CBT aims to help individuals make sustained changes in their daily lives, therefore a longer period of with the same amount of sessions can allow more time for practice of the very activities or strategies that CBT trains such as daily tasks and endeavors in real time.

E. Benefits of Video Games (and mobile applications)

Video games, specifically computer games can be considered as a wide reaching platform as it is played by millions of people around the world. In 2015, 40% of the population of the United States played computer games for more than 3+ hours every week. There are different types of these video games that differ in the goals of the game, the interaction, and involved techniques, there are games that are fast mini-games such as arcade/mobile games as simple as connecting three or more items in a row (e.g. candy crush), more complex genres such as adventure

story games that puts the player into the shoes of a character that they can play following a story or RTS or real time strategy games that require real time decision making and execution of strategies to achieve the goal or simply win, and finally, there are Augmented Reality/Virtual Reality that mixes the real world with a virtual reality. Well-developed games have been shown to increase concentration, improve retention of information, and develop changes in the behavior of the player [10]. Some studies state that video games can have beneficial cognitive effects on attention and visuospatial abilities i.e. improved attention, effort and motivation, better attentional control, processing speed, and task switching, there are also studies that state the benefits of video games on the emotional and social skills.

Given these, there has been growing interest and development in utilizing these games in the fields of education, health, and other domains, calling these as "serious video games", video games with nongame objectives. These serious video games contain activities that are motivationally challenging while still offering a fun learning experience for the user. The technical resources can increase the level of engagement to accomplish a task which generally improves the attention of the player, which is an essential aspect to turn a video game into a tool especially for ADHD as attention retention is a dimension of it. Even though these are serious video games, users might still find themselves experiencing the usual "feelings" that relate to enjoyment such as wanting to win the game, or reaching the end to see how the game pans out.

Another angle to look at the benefit of video games is its accessibility. Most people, even younger children given that they have access to it, find downloading applications on their handheld smart devices very easy through the App Store (iOS) or Play Store (Android). There are even specific classifications in these downloading applications that correspond to educational and health applications, both separate and combined. These apps can be easily integrated into the daily lives of stakeholders e.g. educational applications which are carefully studied and considered by researchers and curriculum makers, are integrated into school

programs with aims to aid students in overcoming difficulties, and/or presenting them with new and interesting ways of learning. Moreso, there are also non-game applications that aid/can aid people with ADHD such as alarm applications and to-do lists that can remind and notify them of what they need to do [9].

F. Types of games aimed to aid Mental Health Disorders (e.g. ADHD)

[10] tableted the types of games that are aimed for mental health. These are the following types identified by the study:

- Exergames, games which include sport or movements,
- AR/VR games, which offer immersive interaction in a virtual or augmented reality environment that incorporates visual, audio, and sensory (vibrations, haptics) stimuli to offer deeper immersive experience in hopes to increase engagement and positive therapeutic outcomes,
- CBT-based serious games, which follows the principles of the previously mentioned most common type of therapy for mental illnesses by completing only one level per week or any limitation of progress at a given time frame/period,
- Entertainment games, games that targets to influence the mood of the player by emotional regulation, stress release, or social support pathways, this type also includes puzzle games that engage in visuospatial cognitive activities,
- Biofeedback-Based games, rehearse relaxation skills while receiving visual feedback through the use of physiological indicators measured by sensors, and
- Cognitive training games, training games aimed at reducing cognitive impairment of the user

Previous studies in this domain of research take advantage of single and multiple categories of these games. For example, a study first published online in 2018, after tests and revisions on their found serious games, they selected ACTIVATE containing multiple brain-training exercises that target specific executive functions divided into eight core cognitive capacity namely: Sustained Attention, Working Memory, Speed of Information Processing, Response Inhibition, Cognitive Flexibility, Category Formation, Pattern Formation, and Multiple Simultaneous Attention. The ACTIVATE application contains six games that target those eight cognitive skills, as well as training the student's ability of multitasking, information retention, and thinking strategies. The study can be observed to have utilized multiple types of serious games namely being an entertainment game because of the puzzle games, cognitive training games by targeting multiple core cognitive skills, and CBT-based serious games as there is a limitation to the gameplay or progress of the user, only allowing it to play each game within five minutes only and having 4-6 game-sessions depending on the timing.

EndeavorRX, the first FDA-cleared video game that can help improve attention in children with ADHD with its gameplay. It is targeted at children aged 8 - 12 years old with the ADD or combined ADHD type. The gameplay of EndeavorRx is similar to mobile games such as Subway Surfer where the child must guide its character along the course and avoid obstacles along the way. Aside from the main mechanic, there are also visual and auditory stimuli present while playing that acts as distraction while playing, therefore requiring the child to focus on several things simultaneously [17].

G. Mechanics of serious-games aimed towards ADHD

There are 3 major characteristics that serious-games towards ADHD target to enhance according to the meta-analysis in [18], these are the attention, memory, and the behavioral characteristics of the patient. There are different ways to enhance these characteristics. The Go/No-go test is a particularly common mechanic that

is used to enhance and measure sustained attention and response control; this test is utilized in the first FDA approved therapeutic game EndeavorRX. What it is is it requires the participant to respond to a "Go" stimulus which is a predetermined component/entity that is introduced in the instructions or the tutorial, and inhibit a response to a "No-Go" stimuli. Games that enhance the behavior characteristic trains the player to scenario type mechanics in which they must select the most socially appropriate option for the social context that is in the game, however, there is still lack of evidence to validate that these games enhance the behavior of the patient.

H. Platforms which can accommodate serious-games

In the recent years, there have been significant improvements in the different platforms and devices that are used on a daily basis. More capable devices have also been made accessible and affordable by different manufacturers therefore giving a larger array of platforms/devices in which these games can be played on. The first one that can be utilized are mobile devices. Smartphones/tablets have been made much more powerful, even comparable to laptops/desktops in recent years. This opens the possibility and the opportunity to utilize these devices to cater these games, even if it is the common 2D/3D game or even Augmented Reality (AR) and/or Virtual Reality (VR). An example of this is the study of [8] where Augmented Reality is utilized by developing an AR-based mobile application that uses printed markers to an interactive "find-the-object" type of gameplay. That study shows that mobile devices are capable of being utilized as platforms in which therapeutic games that use innovative technologies can be played in. Aside from mobile devices, desktops/laptops are also utilized to cater these serious-games. [9] developed a web-based application called "ACTIVATE" that provides brain-training exercises for children with ADHD to help enhance their learning skills and targets 8 identified core cognitive capacities: Sustained Attention, Working Memory, Speed of Information Processing, Response Inhibition, Cognitive Flexibility,

Category Formation, Pattern Formation, and Multiple Simultaneous Attention.

I. Augmented Reality/Virtual Reality

Augmented Reality(AR) and Virtual Reality(VR) are emerging technologies that utilize a digital immersion and overlays on the real world that allows users to interact with the overlay[19]. AR overlays digital content into the real world, an example is the famous mobile game Pokémon GO, it overlays the Pokémon on to the real world using the camera of the mobile device to make it appear that the Pokemon is right in front of the user. VR on the other hand is 100% digital and utilizes goggles-like devices to fully immerse the user into the virtual environment. AR/VR have been made more accessible to developers and users alike because of softwares/applications that make it easier to utilize and enjoy these technologies. For developers, Unity provides and caters AR/VR application development and even contains courses to be familiar and to be able to create a game from scratch. For users, smartphones are now capable of utilizing AR/VR. As mentioned before, games such as Pokémon GO use the camera of the device to overlay the Pokémon into the real world. Smartphones can also accommodate VR, one such application that allows users to experience VR is YouTube, it has a VR mode feature which works well with a VR headset that uses the display and the gyro feature of the smartphone and distorts it to create a VR experience.

IV. Design and Implementation

In this chapter, (supposed) participants/who the program/game that will be developed is for, methods and the development stages that will be done in order to create a game that is aimed to be an assessment tool for ADHD are discussed.

A. Game Development Process

In regards to the game development itself and the stages that will go on from the start of the brainstorming until the final game state, a framework is adapted from [5] that is made for the development of the game "The Secret Trail of Moon" that is made to aid ADHD. The adapted framework shown in 6 contains several stages that correspond to the different development processes that are necessary when creating a therapeutic game. As with any game development project, it all starts off with identifying the niche or in this case, as a therapeutic game, the condition that is to be addressed. The goal of the study is to create a gamified form of an assessment tool for ADHD that can run on different devices provided they meet the minimum requirements. With that in mind, compressing techniques and other techniques must be utilized in the development stage of the game to be able to achieve that goal. The sizes of the assets that are inside contribute in a way to the playability of the game especially in lower performing devices as these components(e.g. Environment, entities) are needed to be loaded by the device for the player to be able to play and interact with the game. The exploration stage of the framework evaluates the status of the game and if it is still inline with the initial goals, here, changes can be made if the game is not deemed to be inline with the therapeutic goals, or can be refined and finished to the final design if it meets the criteria. Having discussed Dr.Brown's model of ADHD, the game to be developed can be streamlined to one or more of the executive functions that have been identified in order to have a better experience, and supposedly have a more significant improvement to the specific executive function/s. The executive function that will

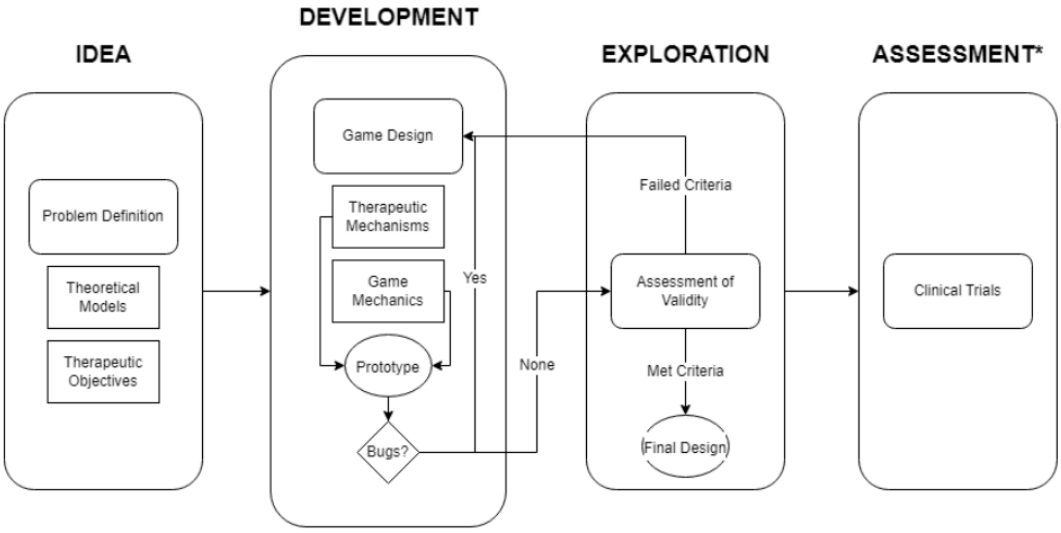

Figure 6: Adapted Framework used as a guide in creating the application

be targeted in the game to be developed is the inhibition/impulse control which includes the difficulty in controlling impulses and stopping oneself from acting on rash/rushed decisions[14]. In the previously mentioned game, TSTM, a specific mini-game called Kitsune was made that also targeted the impulse control function of the player. Its gameplay is to avoid the objects that are in the way by following the indicators that are flashed on screen. The gameplay of the game that is to be developed in this study is a mobile-based AR game that will use a predetermined image target such as a card or a paper that will act as a trigger to start the game. Upon starting the game, an entity will emerge from the image target, coinciding with that, multiple different elements will appear on screen. The player will then be instructed to feed the entity a specific item and feed it that item only. Feeding it the correct item will give the player points for each item fed, however, feeding it other items will give the player an error count. With regards to measuring the improvement that the player has gained with playing the game, several data will be collected every time the game is played such as the number of successes (a food item is fed, or a nonfood item is ignored), number of errors (a food item is ignored, or a nonfood item is fed), error rate (total instances where incorrect response were done divided by the total number of items spawned), success rate (total instances

Features	Focus
Target Population	Patients diagnosed with ADHD and undergoing therapy/treatment.
Short description of the objective	A mobile-based AR assessment tool aimed at targeting the inhibition/impulse control of the player by looking at the improvement of the success-error ratio, and averages in response times to provide an objective basis for the medical professional to interpret if the patient is improving.
Type of game	Arcade type of game that utilizes a Go/No-Go Task
Objective of the video game	Feed the entity with the instructed item/s that flash on screen to gain points within the given time.
Rules/Restrictions of the video game	A hungry entity will emerge from the image target and the player must feed the instructed item to the entity to gain points and avoid feeding it other items.

Figure 7: Description of the game to be developed

where correct response were done divided by the total number of items spawned), average speed that an item is fed, average speed that a correct item is fed.

B. Use Cases

According to 10][[11] ADHD is a psychiatric disorder diagnosed during the early stages of childhood, it ought to be treated as early as then because of the consequences that can come from ADHD being left untreated such as difficulties in maintaining relationships, lack of self-confidence, among other consequences that will have significant effects on the future of the patient. As with the recent pandemic also, children have been more proficient with operating gadgets, it is assumed that there won't be difficulties in introducing them to the platform/game that will be on devices that they have used before. Therefore, the game that will be developed is targeted at younger children within the range of 6-8 years old as the theme of the game might be too childish or won't pique the interests of older children already. Aside from the patient being a user, the medical professional is also a user of the system as they will have access to the database where the met-

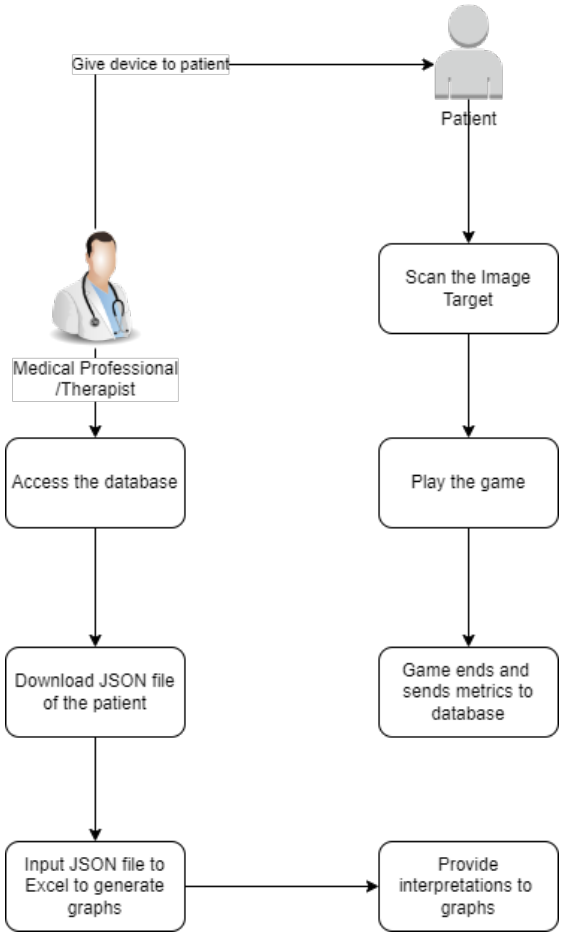

Figure 8: Activity Diagram

rics are stored; the medical professional can then export the data of the patient as JSON file and input that file into Excel which will then ease the visualization of the data by putting it into a graph; the activity diagram for the system is shown below.

C. System Architecture

1. Unity Game Engine: The game development is done using the Unity game engine, which provides a wide range of tools, features, and cross-platform support for building AR games.

2. Vuforia AR SDK: Vuforia is used as the AR software development kit (SDK) for Unity. It enables marker-based AR tracking, image recognition, and markerless tracking for placing virtual objects in the real world.

3. Game Objects and Scenes: The game is built using Unity's game objects, which represent various entities in the game, such as the player, items, UI elements, and more. Scenes are used to organize different levels or sections of the game.

4. Graphics and Assets: Unity supports importing 3D models, textures, and other assets to create visually appealing game elements. The assets used in the game are downloaded from the internet via various websites that provide free assets.

5. Item Spawning and Placement: The GameController script handles the spawning and placement of items in the game. It uses Vuforia to track the image target and determines valid positions to spawn items around the image target. The script ensures that a maximum of six items are active at any given time.

6. Item Interactions: The ItemController script is attached to each spawned item. It handles the click detection on the items using the 'OnMouseDown' event. When an item is clicked, the script determines the item's tag ("food" or "nonfood") and performs the necessary actions, such as calculating response times, updating success/error rates, and destroying the item.

7. Metrics Tracking: The GameController script tracks various metrics, including response times, success rate, error rate, and total score. It maintains counters and lists to store the necessary data for calculations. The collected metrics are sent to the database hosted by Firebase for later extraction and interpretation.

8. Deployment: Unity provides build settings to configure platform-specific settings and generate the necessary app packages or APK files for distribution. Since the application is meant to be used on an Android device, Unity is set to build the application for Android and will generate an APK that can be used to install the application on the device.

9. Firebase Database: A service provided by Google, Firebase can be used in Unity Games by importing the SDK. Firebase Realtime Database service provides a real-time database for the app where data is stored in JSON format and is synchronized across all clients in real time. This data can be exported in JSON format and can be used in various 3rd-Party programs such as Microsoft Excel, which will be used to generate graphs for interpreting the data.

D. Technical Architecture

To have access to the tracking capabilities that enables the game to start, the following minimum requirements must be met by the Android device that will run the application:

1. Android Version: 8.0 (as stated by Vuforia)
2. Must have a camera
3. Touchscreen display
4. Internet Access (to be able to send metrics to the Database)

V. Results

A. Application

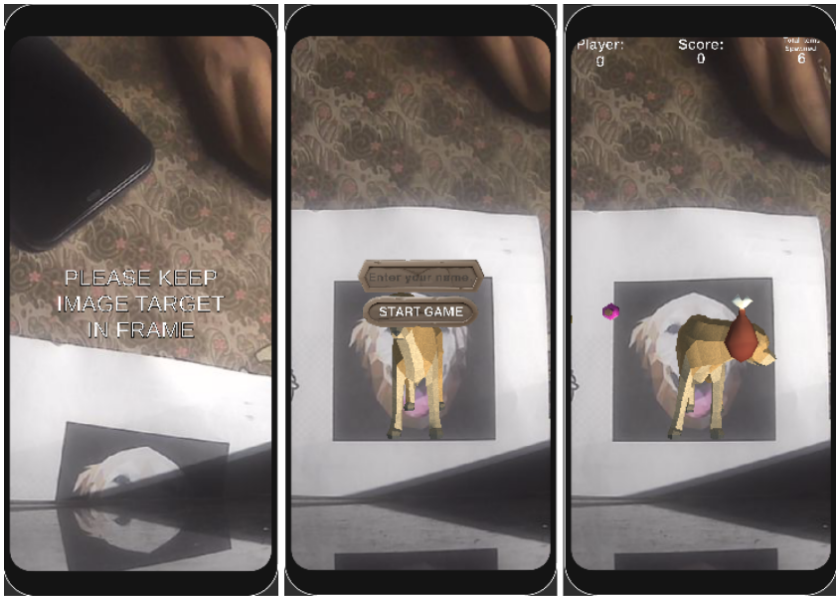

Figure 9: Screenshot of the game from the Unity Simulator

The game is developed to run on an Android device with an Android version of at least 8.0 (Android 'Oreo') to be able to utilize the ARCore and its functionalities. After installation and opening the application, it greets the user with a prompt to look for the image target and keep it in frame. The image target for this game is a dog since the model that will be augmented is a dog. Once the application detects that it is in frame, it superimposes the dog on top of the image target and changes the UI to have a name input field and a start button. Once the user enters his/her name and presses the start button, a barking sound plays and the game starts. The game augments floating items around the dog. The items have a tag of "food" and "nonfood", and is selected at random on what will be spawned next. The "food" items contain models of chicken, steak, fish, and sausages; while "nonfood" items contain 3 different colors of bottles, fishbone, and a rolling pin. Whenever the player presses an item, it plays a sound that corresponds to what type of response was made; a "correct" sound whenever a food item is pressed or a nonfood item is ignored; and a "wrong" sound whenever a

nonfood item is pressed or a food item is missed. The score and the total items spawned can be seen on top of the screen together with the name of the player. For the metrics, it is collected as follows:

1. Score - records all of the correct responses which are pressing the food items, and ignoring the nonfood items

2. Errors - records the wrong responses which are pressing the nonfood items and missing the food items

3. Success/Error rate - scores/errors divided by the total number of spawned items

4. Average response time - collected via a script attached to the items that calculates the time when the item have been pressed minus the time when the item was spawned - adds it to the int totalResponseTime and to the list of success response times or error response times, if the item is a food object and it is ignored, 3 seconds is added to the totalResponseTime corresponding to an error, the totalResponseTime is then divided by the total number of items spawned to get the averageResponseTime

5. Average error and success response times - calculated by adding up the elements in the list(successResponseTimes or errorResponseTimes) and divides it by the number of elements in the list.

Once 100 items have been spawned, a script calculates the average metrics before it sends the metrics collected to the Firebase Realtime Database that stores it in a certain layer under “users”, the name of the player, and the time and date of the session.

B. Database

The application is connected to a database hosted using Google Firebase. To connect the game to the database, the developer created an email which is to

be shared with the medical professional handling the sessions which gives them access to the data/metrics collected by the game. After creating a new project and following the prompts, the developer must go to project settings to add the Unity Application to the project.

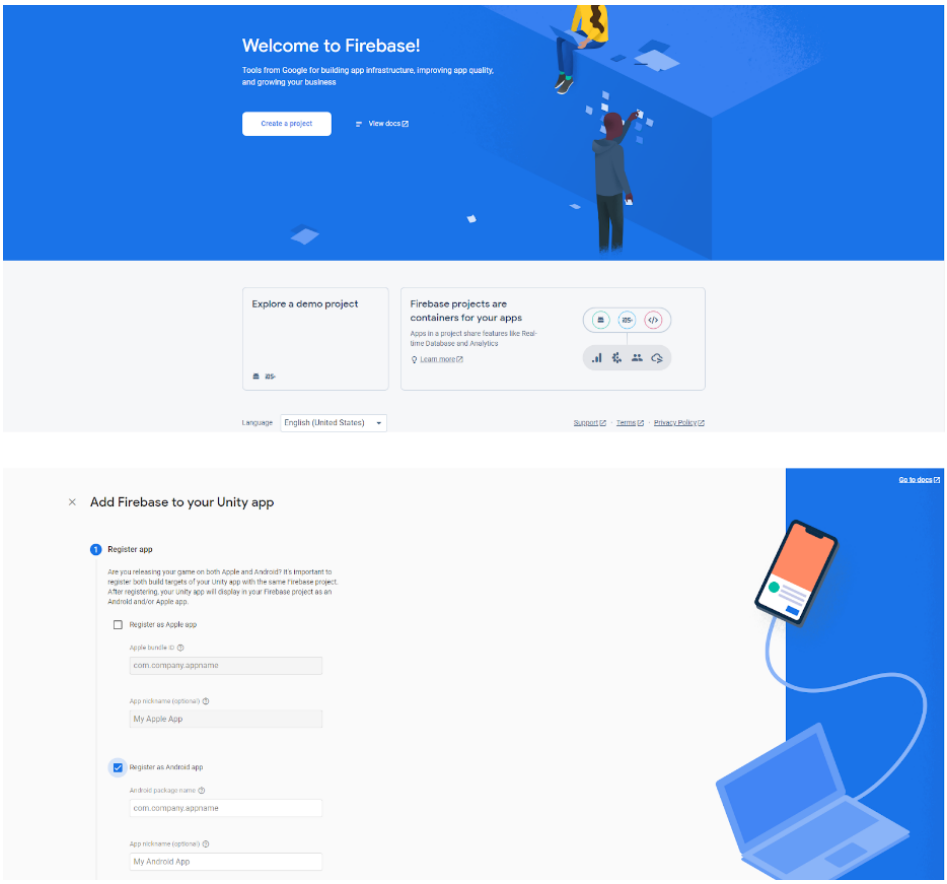

Figure 10: Setup screen of Firebase

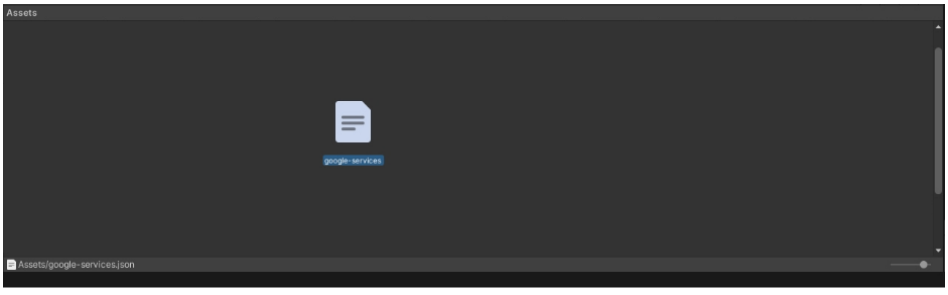

Figure 11: JSON file imported to Unity

Firebase then provides a .json file that will be imported to the Unity Project. Combine that with importing the Firebase SDK, and the application already has access to the Firebase Realtime Database for the specific project.

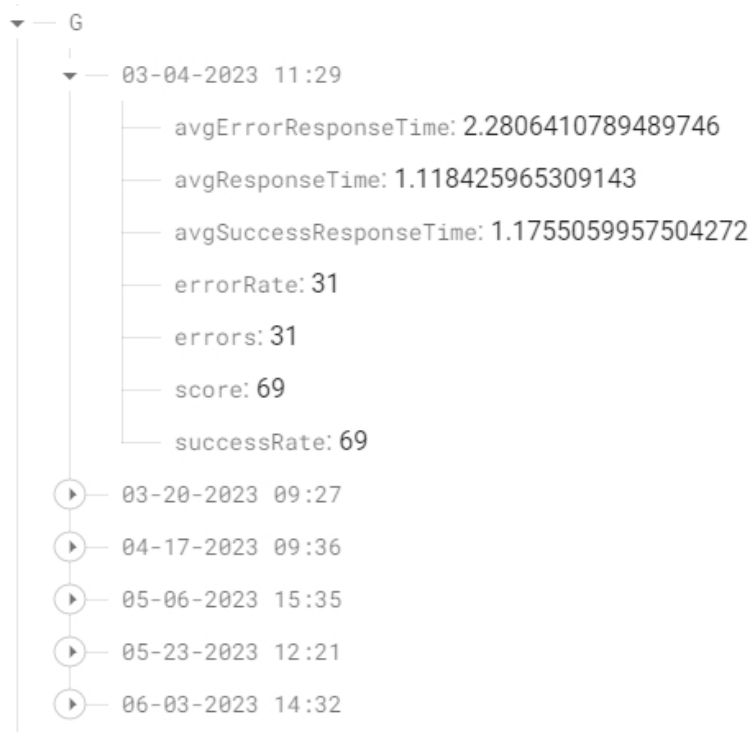

Figure 12: Sample of data stored in DB

Figure 12 shows an example of how the data are stored in Firebase. The first

Name	avgErrorResponseTime	avgResponseTime	avgSuccessResponseTime	errorRate	errors	score	successRate
03-04-2023 11:29	2.280641079	1.118425965	1.175505996	31	31	69	69
03-20-2023 09:27	2.34514761	0.818257451	1.196116209	15	15	85	85
04-17-2023 09:36	1.928502798	1.389606476	1.001241326	51	51	49	49
05-06-2023 15:35	2.495463371	0.807294309	1.269596815	41	41	59	59
05-23-2023 12:21	1.565092564	0.996580482	1.411268711	35	35	65	65
06-03-2023 14:32	1.913692474	0.413083613	0.885620892	38	38	62	62

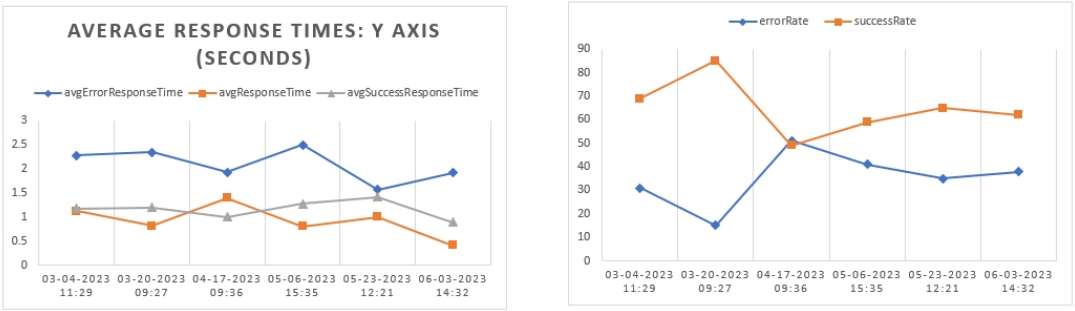

Figure 13: Sample of how data can be visualized in Excel

layer is the name of the patient, the next layer are all the game sessions which are labeled by date and time in the format of "MM-dd-yyyy HH:mm", and the metrics are the children of that record. Figure 13 shows an example of the metrics across 6 sessions, it allows for easier visualization of the developments of the patient's impulse control. For example, the graph on the left shows the average response

times of the patient across the 6 sessions, the success and error rates are shown on the graph on the right.

VI. Discussions

The final application developed is able to achieve the goal of creating a videogame-based objective assessment tool for ADHD that is streamlined towards the inhibition/impulse control of the patient. The application is able to utilize Augmented Reality as the technology in which the game revolves around by augmenting the entity and items around it. It is also able to collect metrics that are also found to be collected by previous studies that are in the domain of using games for ADHD. Certain metrics found to be collected by previous studies are "mistakes made/errors done", "correct and wrong clicks", and the reaction time. According to [20], a study on children with ADHD where each child completed 5 neuropsychological tasks which allowed trial-by-trial assessment of reaction times, RT variability and task accuracy were highly correlated between the tasks contained in the study. Children with ADHD had poorer task accuracy across all tasks. The metrics collected by the application developed can supply data which can be interpreted to reaction time and task accuracy as the main test that the application revolves around is the Go/No-Go test which measures the response inhibition and processing speed of the patient. The application is able to collect the following metrics: score, errors, success rate, error rate, average response time, average response time on success, and average response time on errors. The application is also able to send these data to a database hosted in Google's Firebase which allows for 1 click exportation of data which makes it easier for the medical professional to generate visualization tools via Microsoft Excel. Aside from tests in Unity's built-in simulator, the application has been tested in 2 different Android devices with different specifications (one lower specced device running Android 8.0 and another a Samsung Galaxy S9 running Android 10) which flags the success of the application being a mobile application.

The application developed in this study differentiates itself from previous studies mentioned as it is a mobile application that utilizes Augmented Reality to provide an objective assessment tool for the inhibition/impulse control performance that

can supply the medical professional quantitative data on the developments of the patient. Being a mobile application, it is easily deployable given that the there is no specialty device required such as a VR headset when using VR applications. Previously mentioned studies focus on either being used as a screening for ADHD, or to enhance the performance of children with ADHD, that run either as a mobile game, a web game, or a VR game. An important note to remember with this application is that the data collected is not intended to be more prominent or not to be the only basis of the developments of the patient. It is to supply the medical professional with quantitative data which can either back up or counter the observations made on the behavior of the patient.

Since the app is also to be used during clinical sessions only that happen 1-2 times a month depending on the therapy program of the patient, there is a controlled setting as the environment will be the same everytime the tool is used, the data can also be presumed to be authentic as the patient will not be able to practice the game and improve his/her own performance due to familiarity of the game. Also given the limited frequency of the exposure to the game, there is little to no risk for addiction on the patient as he/she will only be able to play the game on the clinical sessions with the medical professional.

VII. Conclusions

This study aimed to develop a mobile application utilizing Augmented Reality as a gamified objective assessment tool for the impulsivity/inhibition control of children with ADHD. It runs on Android devices with Android versions 8.0 and later. The gameplay of the application uses the Go/No-Go test as its main mechanic where food and nonfood items will appear around the augmented animal and the patient must only click on the food items – which acts as the go stimulus, and ignore the nonfood items – which acts as the no-go stimulus. The application collects metrics: score, errors, success rate, error rate, and average response times and sends it to a Firebase realtime database. The data collected is not intended to be the only basis of the development of the patient, whereas it is to provide quantitative evidence that can be interpreted by the medical professional together with his/her own observations regarding the behavior of the patient. From the database, the medical professional can export the data as a JSON file and input it to a visualization program such as Microsoft Excel to produce graphs for easier visualization and interpretation either for their own record, or to be presented to the parents of the patient. The study holds as a feasibility study that an application of this nature can be built.

VIII. Recommendations

Regarding the gameplay and the visuals of the game, a few recommendations can be made. To be able to cater to different age groups of patients, the theme and the visuals of the game can be modified to something more age appropriate by changing the image target, changing the augmented animal, and the items that spawn around it can be changed to be more age appropriate. This can be done by using more famous characters from other games which are age appropriate to the target patients. As for the data collection/database feature of the application, there has been a recommendation to find a way to eliminate the use of Firebase and instead take advantage of SQLite to store the data offline and eliminate the need of internet connection during the use of the application.

Another recommendation is to add the feature to automatically generate the graphs as part of the application to eliminate the use of 3rd party spreadsheets and to have a more seamless user experience for the part of the medical professional where it will eliminate a few steps for them to generate the graphs.

As it is, since the application is already working and can be installed on devices that meet the minimum requirements, the next step for this application is to gather data to be able to set standards/baseline on the performance of a population without ADHD, and a population with ADHD. Once a study with that topic has been done, it can be used by medical professionals that will use the application as a comparison to the performance of their own patients. If the game is to modified to cater to different age groups, a comparison can also be studied between the ages and/or genders.

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X. Appendix

A. Source Code

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;


public class GameController : MonoBehaviour
{
    UIController UIController;

    public GameObject[] foodItems;
    public GameObject[] nonfoodItems;
    private GameObject imageTarget;
    public GameObject theAnimal;
    public GameObject GameControllerHandler;
    private GameObject[] activefoodItemsArray;
    private GameObject[] activenonfoodItemsArray;

    public List<float> successResponseTimes = new List<float>();
    public List<float> errorResponseTimes = new List<float>();

    public float totalResponseTime;

    public int totalItemsSpawned;
    public int activeItems;
    private int activeFoodItems;
    private int activeNonfoodItems;
    public int totalSuccessCount;
    public int totalErrorCount;
    private float averageResponseTime;
    private float averageResponseTimeSuccess;
    private float averageResponseTimeError;
    private float successRate;
    private float errorRate;

    public AudioSource successSound;
    public AudioSource errorSound;

    private void Start()
    {
        activeItems = 0;
        totalItemsSpawned = 0;
    }

    private void Awake(){
        UIController = GameObject.Find("UIController").GetComponent<UIController>();
    }


    private void Update()
    {
        countActiveItems();
        updateTexts();
    }

    public void countActiveItems()
    {
        activefoodItemsArray = GameObject.FindGameObjectsWithTag("food");
        activenonfoodItemsArray = GameObject.FindGameObjectsWithTag("nonfood");
        activeFoodItems = activefoodItemsArray.Length;
        activeNonfoodItems = activenonfoodItemsArray.Length;
        activeItems = activeFoodItems + activeNonfoodItems;

        if(activeItems < 6 && totalItemsSpawned < 100){
            GenerateItems();
        }
        else if(totalItemsSpawned == 100 && activeItems == 0){
            UIController.toggleGameOverText();
            CalculateMetrics();
        }
    }

    public void GenerateItems()
    {
        GameObject[] items = (Random.value < 0.6f) ? foodItems : nonfoodItems;

        GameObject itemPrefab = items[Random.Range(0, items.Length)];

        SpawnItem(itemPrefab);

        activeItems++;
        totalItemsSpawned++;
    }

    private void SpawnItem(GameObject item)
    {
        bool isValidPosition = false;
```

```
    while (!isValidPosition)
    {
            Vector3 randomPosition = GetRandomPosition();
            Collider[] colliders = Physics.OverlapSphere(randomPosition, 0.05f);

            if (colliders.Length == 0)
            {
            isValidPosition = true;

            if (Random.Range(0, 2) == 0)
                Instantiate(foodItems[Random.Range(0, foodItems.Length)]);
            else
                Instantiate(nonfoodItems[Random.Range(0, nonfoodItems.Length)]);

            item.transform.position = randomPosition;
            }

            Debug.Log("Spawned item at:" + item.transform.position);
    }
}

private Vector3 GetRandomPosition()
{
    theAnimal = GameObject.Find("theAnimal");

    Vector3 randomPosition = new Vector3(
        Random.Range(theAnimal.transform.position.x - 1f, theAnimal.transform.position.x + 1f),
        Random.Range(theAnimal.transform.position.y - 1f,theAnimal.transform.position.y + 1f),
        Random.Range(theAnimal.transform.position.z + 0.3f, theAnimal.transform.position.z + 0.5f));

    Collider[] colliders = Physics.OverlapSphere(randomPosition, 0.05f);

    if (colliders.Length > 0)
    {
        return GetRandomPosition();
    }

    return randomPosition;
}

public void itemClicked(GameObject item, float startTime)
{
    if (item.CompareTag("food"))
    {
        successSound.Play();
        float responseTime = Time.time - startTime;
        totalResponseTime += responseTime;
        totalSuccessCount++;
        successResponseTimes.Add(responseTime);
        Debug.Log(totalSuccessCount);
    }
    else if (item.CompareTag("nonfood"))
    {
        errorSound.Play();
        float responseTime = Time.time - startTime;
        totalResponseTime += responseTime;
        totalErrorCount++;
        errorResponseTimes.Add(responseTime);
        Debug.Log(totalErrorCount);
    }

    Destroy(item);
}

private void updateTexts(){
    UIController.totalItemsSpawnedText.text = totalItemsSpawned.ToString();
    UIController.scoreText.text = totalSuccessCount.ToString();
}

float CalculateAverage(List<float> times)
{
    if (times.Count == 0)
        return 0f;

    float sum = 0f;
    foreach (float time in times)
        sum += time;

    return sum / times.Count;
}

float CalculateSuccessRate()
{
    if (totalItemsSpawned == 0)
        return 0f;

    return (float)totalSuccessCount / totalItemsSpawned * 100f;
}

float CalculateErrorRate()
{
    if (totalItemsSpawned == 0)
        return 0f;

    return (float)totalErrorCount / totalItemsSpawned * 100f;
}

private void CalculateMetrics()
{
```

```
        averageResponseTime = totalResponseTime / totalItemsSpawned;
        averageResponseTimeSuccess = CalculateAverage(successResponseTimes);
        averageResponseTimeError = CalculateAverage(errorResponseTimes);
        successRate = CalculateSuccessRate();
        errorRate = CalculateErrorRate();
        Debug.Log("Average Response Time: " + averageResponseTime);
        Debug.Log("Average Response Time (Success): " + averageResponseTimeSuccess);
        Debug.Log("Average Response Time (Error): " + averageResponseTimeError);
        Debug.Log("Success Rate: " + successRate + "%");
        Debug.Log("Error Rate: " + errorRate + "%");

        UIController.sendToFirebase(totalSuccessCount, totalErrorCount, averageResponseTime, averageResponseTim
        TargetLostResetGame();
    }

    public void TargetLostResetGame()
    {
        totalItemsSpawned = 0;
        totalSuccessCount = 0;
        activeItems = 0;
        activeFoodItems = 0;
        activeNonfoodItems = 0;
        totalErrorCount = 0;
        averageResponseTime = 0;
        averageResponseTimeSuccess = 0;
        averageResponseTimeError = 0;
        successRate = 0;
        errorRate = 0;
        if (GameControllerHandler.activeSelf){
            StartCoroutine(shutdownTheGame());
        }
    }

    private IEnumerator shutdownTheGame()
    {
        yield return new WaitForSeconds(1f);
        GameControllerHandler.SetActive(false);
    }

}
```

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class ItemController : MonoBehaviour
{
    GameController itemCont2GameCont;

    float startTime;

    void Awake()
    {
       itemCont2GameCont = GameObject.Find("GameController").GetComponent<GameController>();
       StartCoroutine(DelayedFunction(3f));
       startTime = Time.time;
    }

    private IEnumerator DelayedFunction(float delay)
    {
        yield return new WaitForSeconds(delay);
        itemNotClicked();
    }

    private void itemNotClicked(){
        if(gameObject.CompareTag("nonfood"))
        {
            itemCont2GameCont.totalSuccessCount++;
            itemCont2GameCont.successSound.Play();
        }
        else
        {
            itemCont2GameCont.totalErrorCount++;
            itemCont2GameCont.totalResponseTime += 3f;
            itemCont2GameCont.errorResponseTimes.Add(3f);
            itemCont2GameCont.errorSound.Play();
        }
        Destroy(gameObject);
    }

    void OnMouseDown()
    {
    itemCont2GameCont.itemClicked(gameObject, startTime);
    }

}
```

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using TMPro;
using Firebase;
using Firebase.Database;

public class UIController : MonoBehaviour
{
    public TextMeshProUGUI playerTitle;
    public TextMeshProUGUI playerText;
```

```
public TextMeshProUGUI scoreTitle;
public TextMeshProUGUI scoreText;
public TextMeshProUGUI totalItemsSpawnedTitle;
public TextMeshProUGUI totalItemsSpawnedText;
public TMP_InputField nameField;
public TextMeshProUGUI gameOverScoreText;
string playerNameOnDB;
string dateToday;

public GameObject playerTitleGO;
public GameObject playerTextGO;
public GameObject scoreTitleGO;
public GameObject scoreTextGO;
public GameObject totalItemsSpawnedTitleGO;
public GameObject totalItemsSpawnedTextGO;
public GameObject nameInputFieldGO;
public GameObject startButton;
public GameObject gameOverScoreTextGO;
public GameObject gameOverTitleGO;
public GameObject gameOverScoreTitleGO;
public GameObject gameTitleGO;
public GameObject exitButtonGO;

DatabaseReference dbReference;

GameController UICont2GameCont;

public GameObject UICont_GameObjectController;

public AudioSource bark;

void Awake()
{

}

void Start()
{
    dbReference = FirebaseDatabase.DefaultInstance.RootReference;
    dateToday = System.DateTime.UtcNow.ToLocalTime().ToString("MM-dd-yyyy HH:mm");
}

// Update is called once per frame
void Update()
{

}

public void getName()
{
    playerText.text = nameField.text;
    string playerTextString = playerText.text.ToString();
    playerNameOnDB = playerTextString.ToUpper();
}

public void ToggleUIonTargetLost()
{
    scoreText.text = "0";
    gameTitleGO.SetActive(false);
    nameInputFieldGO.SetActive(false);
    startButton.SetActive(false);
    playerTitleGO.SetActive(false);
    playerTextGO.SetActive(false);
    scoreTitleGO.SetActive(false);
    scoreTextGO.SetActive(false);
    totalItemsSpawnedTitleGO.SetActive(false);
    totalItemsSpawnedTextGO.SetActive(false);
}

public void toggleGameOverText()
{
    playerTitleGO.SetActive(false);
    playerTextGO.SetActive(false);
    scoreTitleGO.SetActive(false);
    scoreTextGO.SetActive(false);
    totalItemsSpawnedTitleGO.SetActive(false);
    totalItemsSpawnedTextGO.SetActive(false);
    gameOverTitleGO.SetActive(true);
    exitButtonGO.SetActive(true);
}

public void sendToFirebase(int score, int errors, float avgRT, float avgSuccessRT, float avgErrorRT, float
{
    dbReference.Child("users").Child(playerNameOnDB).Child(dateToday).Child("score").
    SetValueAsync(score);
    dbReference.Child("users").Child(playerNameOnDB).Child(dateToday).Child("errors").
    SetValueAsync(errors);
    dbReference.Child("users").Child(playerNameOnDB).Child(dateToday).Child("avgResponseTime").
    SetValueAsync(avgRT);
    dbReference.Child("users").Child(playerNameOnDB).Child(dateToday).Child("avgSuccessResponseTime").
    SetValueAsync(avgSuccessRT);
    dbReference.Child("users").Child(playerNameOnDB).Child(dateToday).Child("avgErrorResponseTime").
    SetValueAsync(avgErrorRT);
    dbReference.Child("users").Child(playerNameOnDB).Child(dateToday).Child("successRate").
    SetValueAsync(successRate);
    dbReference.Child("users").Child(playerNameOnDB).Child(dateToday).Child("errorRate").
    SetValueAsync(errorRate);
}
```

```
    public void CreateSessionRecord()
    {
        // Add this function to button
        dbReference.Child("users").Child(playerNameOnDB).SetValueAsync(dateToday);
    }

    public void CloseGame()
    {
        // Close the application
        Application.Quit();
    }

    public void isInputFieldEmpty()
    {
        if (!string.IsNullOrEmpty(nameField.text))
        {
            getName();
            UICont_GameObjectController.SetActive(true);
            playerTitleGO.SetActive(true);
            playerTextGO.SetActive(true);
            scoreTitleGO.SetActive(true);
            scoreTextGO.SetActive(true);
            totalItemsSpawnedTitleGO.SetActive(true);
            totalItemsSpawnedTextGO.SetActive(true);
            nameInputFieldGO.SetActive(false);
            startButton.SetActive(false);
            gameTitleGO.SetActive(false);
            bark.Play();
        }

    }

}
```

Figure 14: Image target used on the application

XI. Acknowledgment

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