Modeling an AR Serious Game to Increase Attention of ADHD Patients

Saad Alqithami
Department of Computer Science, Albaha University
salqithami@bu.edu.sa

***Abstract*—Attention, as a commodity in the human skills-set, increases through training over a quite relevant period of time. Deficit in attention in the short term may be based on multiple complications to entail stress and mined wondering. On the long term, however, it might be a symptom of chronic diseases that acquire attention such as ADD, ADHD, ASD, etc. In this paper, therefore, we introduce a generic theoretic model that helps patients in short of attention engage in a game-based environment to enhance the behavior of their current state of attention and leads to an improved focus. The model introduces six modular components capturing essential units that are intended to be modularly combined to define an augmented reality gamification therapy.**

***Index Terms*—Agent-Based Modeling, Game Design, ADHD, Cognitive Behavioral Therapy**

I. Introduction

Attention Deficit-Hyperactivity Disorder is an increasing concern in the past few decades. It has undefined etiology as a heterogeneous developmental disorder leading to bias and extensive diagnostic evaluations when examining patients through traditional clinical interviews and rating of patients' behaviors [1], [2]. ADHD in underage patients can be observed in patients' hyperactivity and inability to control their impulses and may have trouble paying attention which, in result, will intervene with their daily lives. In adulthood, patients with ADHD may have trouble managing time, being organized, setting goals, and holding down a job, which may lead to problems with relationships, self-esteem, and addiction. The treatment of many psychological disorders, such as ADHD, can be through a well-known type of psychotherapy called *Cognitive Behavioral Therapy* (CBT). CBT involves patients in multiple psychosocial interventions in order to improving their mental health. This treatment requires patients to go through multiple sessions with specialized therapists. In ADHD, those sessions can be of increasing order of difficulty to help patients expand their cognitive capabilities to overcoming current behavioral limitations.

This highlights the importance of utilizing intelligent and immersive technologies, e.g., Augmented Reality (AR) and Virtual Reality (VR), for their promising results, stated in previous studies [3]–[8]. As the name suggests, Augmented Reality is technology which combines real and virtual contents, registered in 3D, and being interactive in real time [9]. Whereas, Virtual Reality is technology that replaces the real world with a computer-generated graphics via head mounted display [10]. In other words, the user in VR environment totally isolated from his/her real world while the AR optimizes the interactions in the real world [11].

A major benefit of this is the multi-sensory data that we are capturing will be used to provide quantitative support for the diagnosis, care and treatment of ADHD which, in result, can replace current labor-intensive techniques involving paper and pencil, or manual video analysis. Unfortunately, proposed solutions fail to overcome language and cultural barriers for diverse patients and to employ the power of augmented reality by rendering 3D objects and avatars rather than solid textual instructions leading to increase in patients' engagements and speeding-up the recovery. The believe is that there is no statistically significant difference between the ADHD patients who will be treated using our system and those who are treated by traditional CBT; although, online CBT may exceed traditional ones methods by accelerating recovery time and saving money and resources for both government and patients. This is due to achieving a concept of "*a therapist for each patient*" as the system mimics the therapist roles by applying advancements of intelligent virtual agents as well as augmented reality techniques that provide it with features including: adaptiveness, smartness, responsiveness, and accuracy. Other advantages are availability, accessibility, and assurance of the therapist's level-of-experience which cannot be guaranteed in traditional CBT.

In this paper, we propose a generic model to test the validity of using an online system as CBT that we called "*AR-Therapist*". Previous work, presented in [12], [13], have implemented an augmented reality game environment using both Microsoft-HoloLens emulator[1] and Unity[2] applications to design a specialized test-bed for the system. The hypothesis tackled is that an increase in patient correct attention to choosing a predefined object contributes positively to their performance index which means they are following along with their treatment plan; the opposite should be true when they fail to achieve their assigned tasks. The plan in this paper, however, is to extend on the previous work to be more generic and to overcome specialized applications for this treatment model to be implemented efficiently.

[1]It tests mixed reality apps on your PC without a physical HoloLens: https://docs.microsoft.com/en-us/windows/mixed-reality/using-the-hololens-emulator

[2]A cross-platform game engine: https://unity3d.com/

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II. Literature Review

Attention Deficit-Hyperactivity Disorder has undefined etiology as a heterogeneous developmental disorder to involve hyperactivity and distractibility as well as difficulties with constant attention, impulsive control disorder and impaired cognitive flexibility, especially in problem solving and behavioral management [14], [15]. Many studies have indicated the potential benefits of utilizing virtual and augmented reality for exposure therapy to contribute in the treatment of different mental disorders [3]–[8]. In a study by Parsons, et. al. [3], attention performance was compared between 10 children with ADHD and 10 normal control children in a VR classroom. The results showed that children with ADHD are more impacted by distraction in the VR classroom. In spite of that, Ben-Moussa, et. al. [16] proposed a conceptual design of an exposure therapy system called DJINNI for social anxiety disorder (SAD). DJINNI integrates the AR and VR technologies. The DJINNI provides more effective exposure therapy solutions for patient with SAD because it exploits the benefits of AR and VR.

Cho, et. al. [17] conducted a study that examined usefulness in using the virtual reality for rehabilitation. Their study involved thirty participants with ADHD. The participants were trained in one of three groups: a VR group with a head-mounted display, a desktop equivalent training group or a control group. The attention abilities of the participants were assessed based on completing a continuous performance task that required responding to specific target stimuli showed for only 250ms. The results showed that the VR group had significantly higher rates of correct responding and decreased perceptual sensitivity and response bias more than the other two groups. Strickland, et. al. [18] conducted two experimental studies to examine the effectiveness of VR therapy among children with Autism Spectrum Disorder (ASD). The outcome was positive, and the children engaged smoothly in the virtual environments as well as in following the instructions. Thus, learning through virtual reality is effective for children with autism.

Denise Reid [19] has examined the effectiveness of VR treatment for cerebral palsy in several studies. The focus of these studies was on investigating the effectiveness of VR treatment on feelings of self-efficacy, upper-extremity control, postural control and feelings of control and competency. In each of these studies, children diagnosed with different severities of cerebral palsy were involved in a series of interactive VR games. In three controlled studies Reid, [20], the effectiveness of this involvement on children's self-efficacy was examined based on interviews and performance measures. Results showed that VR treatment improved the self-efficacy of the children when compared to previous reports for the children. Tests of motor skills were used in a control study of upper-extremity efficiency [21] to determine the effects of the VR treatment on children's self-efficacy. The results showed a slight improvement comparing to results in [20].

Results from [21] have, however, examined the effect of the VR treatment on postural control which were more definitive. Children participants showed better postural control and alignment comparing to the children who participated in the control studies. In addition, two of the participants in the experimental group showed enhancement in proximal stability and postural. On the other hand, the control group showed no improvements. In a non-controlled study, Denise Reid [21], interviewed children who previously participated in regular VR treatment. The purpose was to determine of the effects of VR treatment based on the children's opinions. Similar to Reid's earlier results, children in this study generally showed positive attitude about VR treatment. In a study by Akhutina, et. al. [22], they examined the influence of the virtual environment on spatial functioning in children with cerebral palsy (CP). The study compared 12-children with CP who received VR therapy to a control group of 9-children with CP who did not receive the VR therapy. A few of children who received VR therapy showed some enhancement when comparing to the control group.

The importance of the simulation used in VR or AR is to predict the capability, limitation and performance of a system and, in result, will lead to a reduction in costs and hazards for experimentations compared with what is observed in traditional/hands-on methods [23]. An enhancement of those virtual/augmented simulated environments can be achieved through Agent-Based Modeling (ABM). The use of ABM will produce a simulation with a high degree of fidelity [24]. In a study by [25], the authors implemented ABM in an augmented simulated environment using wearable computing devices and were able to develop a model that analyzes user activities and predict near-future possible needs. Another study, in [23], has proposed a new approach of introducing synthetic agents in motion at real-time into a real-life video depending on a terrain database and graphical rendering.

The literature on augmented reality simulation, agent-based modeling and disorders' enhancement therapy has provided our approach with quite valuable inputs. The deployment of those components into this work in order to efficiently exploit their many advantages results in several features of the system that may include: intelligence, adaptiveness, responsiveness, and accuracy. This is because our interest is on developing a software system using an augmented reality simulation to help patients suffering from ADHD to be able to find the treatment they need in the easiest and astest way possible, which has set it apart from traditional prior techniques.

III. AR-Therapist: Generic Design

This section defines the generic assembly for an agent-based model whereas the following section provide a case specific implementation and discussion.

A. Generic Design of the System

The high-level design, shown in Figure 1, represents the main components of the AR Therapist and the therapist-patient relationships within the online AR-environment.

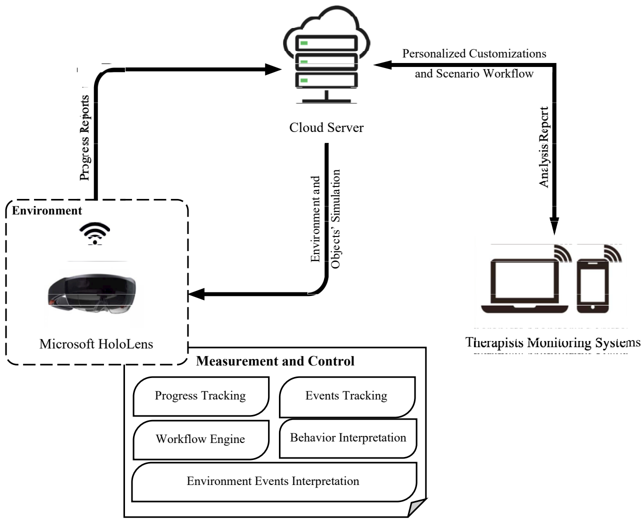

Fig. 1. The System Architecture for AR-Therapist

Patients play-to-win the game that has been designed to attract their attention through the guidance of voice/sign instructions. Movement and actions are measured and then stored in a database to allow a therapist to monitor the treatment progress.

Figure 2 shows the activity diagram for AR-Therapist. Firstly, the traditional human therapist should diagnose a child with ADHD. Then, a treatment plan should be determined to include many parameters like: the number of sessions, the starting game level, external effects, and conditions for transition from one level to the next one. This plan contains the initial game configuration that should be stored in the database inside the storage layer. After the player (a child with ADHD) starts a new game session, the AR-Therapist will start the context agent which performs two basic functions: controlling the game environment and monitoring the patient's performance. The performance of the patient is characterized by many parameters, such as Gaming Time, Response Time, Standard Deviation of the response time, Score, Errors of Commissions, Errors of Omissions, and Response Sensitivity. After the player ends the game session, the context agent will store the values of the parameters in the database. These values will be analyzed by the system to derive some important performance indicators such as: Engagement Factor; which indicates the patient engagement level with the game, Inattention Factor; which represents the percentage of patient's inattention, Impulsivity Factor, which indicates the percentage of the patient's impulsivity observed in his/her behavior within a session, Error Factor, which represents the percentage of the error rate during a session, Correct Response Factor; which is the percentage of the total correct response time relatively to maximum allowed time for all correct tries. Finally, the Performance Index is calculated which reflects a single measure for the overall performance of the patient and depends on the correct response factor, error factor, and engagement factor.

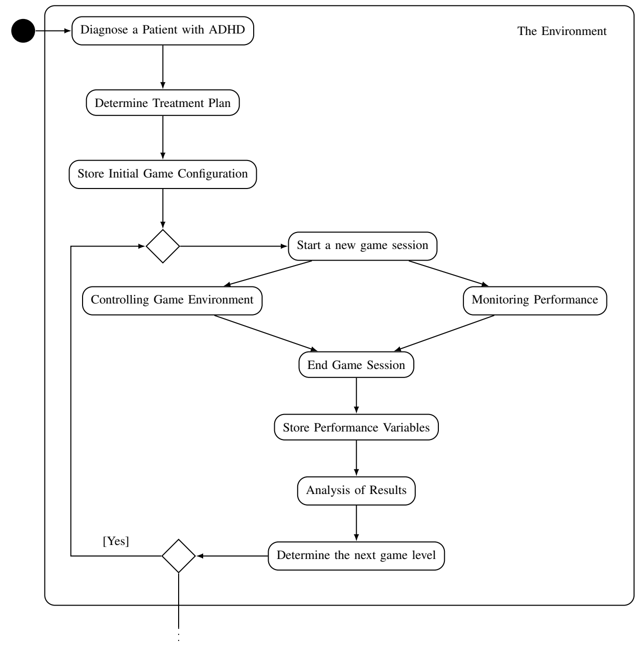

Fig. 2. The activity diagram for AR-Therapist

Based on the derived values of the performance indicators, the next game level is determined.

Figure 3 shows the sequence diagram for AR-Therapist. Firstly, the doctor initiates the system by diagnosing the symptoms of ADHD and also setting up the treatment plan. The ADHD child starts a new game session. The context agent will request the game configuration from the database which is determined based on the treatment plan. The context agent will collect the performance parameters while the child is playing. After ending the game session, the context agent will analyze the collected results and determine the values of performance indicators. The analysis results will be stored in the database for start the game level of the next session.

B. Formal Model

We present in this section a set of formal definitions for modeling the AR-Therapist. In general, the environment are modeled as a game-based system where both patients and therapists are players. The game involves multiple patients whom are under-supervision by their own therapists. Both players are not intervening with any other ones progress nor treatment plans while the session is in progress. There is no interaction between patients nor with their therapists in the game and each session is played by one patient at a time or in parallel. In the game environment, we have a set of patients (i.e., $\text{Patient}_i \in \{Patient\}$) and another set of therapists (i.e., $\text{Doctor}_j \in \{Doctor\}$). The therapist assigns a level of complexity (i.e., $\text{Level}_s \in \{Level\}$) to the patient based on the diagnosis made in the treatment center.

The model of the AR-Therapist can be abstractly observed as a tuple: $\langle$ Environment, Patient_i, Doctor_j, {Game-Session},

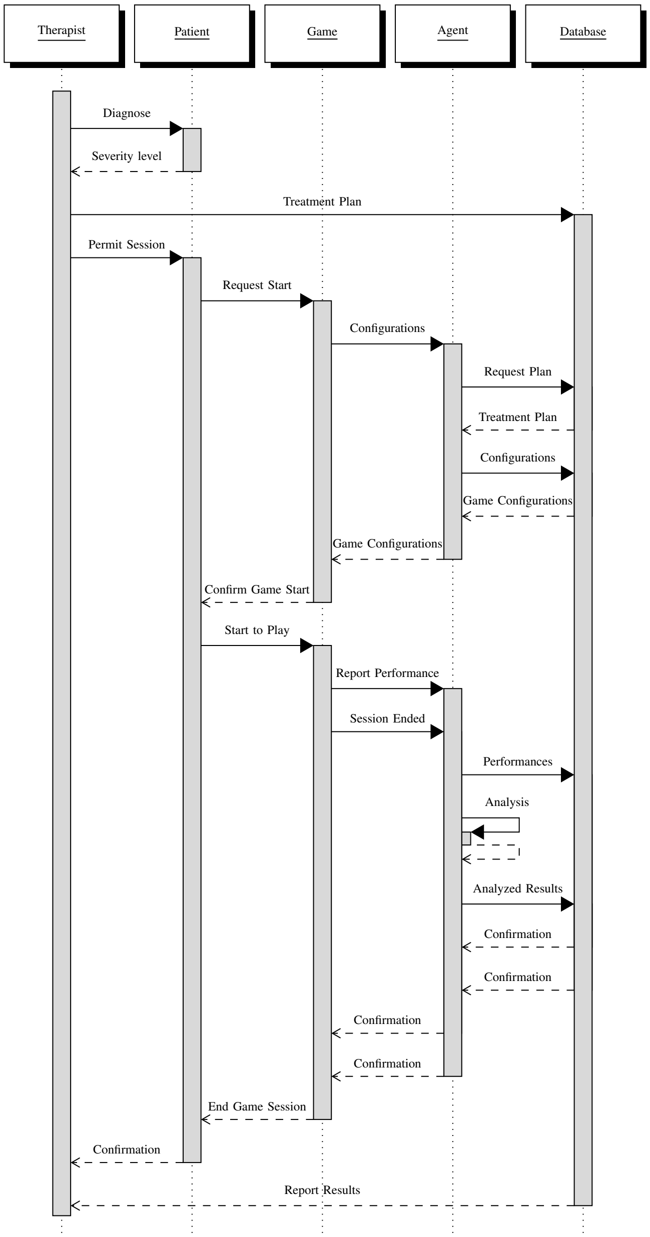

Fig. 3. The sequence diagram for AR-Therapist

{Object}, {Level} ⟩. Those six-profiles play an important role in defining the model and are connected to one another to forming the model. We follow with a detailed description for each one of them.

Definition 1: **Environment**, which is the functioning system for the AR-Therapist, is a tuple of ⟨ {Object}, {Patients}, {Doctors}, {Level} ⟩, where:

- {**Patient**}: Each patient will have his/her own profile. The profile has to be complete for the patient to join the environment and start the game as stated in Definition 2.
- {**Doctor**}: Each doctor will have his/her own profile.
- {**Object**}: The set of virtual objects that a patient will interact with throughout the game. A detailed description of it is in Definition 6.
- {**Level**}: It defines the current mental state for the patient defined at an early stage by the doctor. Definition 5 gives more descriptive overview.

Definition 2: **Patient**$_i$ ∈{Patient} for whom this treatment is designed: ⟨ ID$_i$, {Preference}$_i$, Performance-Index$_i$, Level$_s$, Location$_i$ ⟩

- **ID**$_i$: is a short identification as a name or a referral number used to define a patient in treatment (i.e., used by a doctor to define a specific patient).
- {**Preference**}$_i$: The set of predefined preferences for a patient considering other psychological disorders that may affect current design and methodology of the treatment plan.
- **Performance-Index**$_i$: The current value of performance the patient has achieved throughout the game. It accumulated throughout multiple levels the patient has achieved within a session.
- **Level**$_s$: The level to where the patient has arrived in the treatment plan, which is ∈ {Level} as presented in Definition 5. Since the set of the complexity levels that the patient has to go through is sorted and passing from one level to another is of a predefined precedence, previous level that has been completed are omitted from the patient profile.
- **Location**$_i$: Current location of the player (i.e., Patient$_i$) has to be known in order to define the precedence of an object and to guide them to achieving the task.

Definition 3: **Doctor**$_j$ ∈ {Doctor} is a tuple implemented for the {Patient}s' supervision to include: ⟨ ID$_j$, Experience$_j$, Involvement$_j$, {Patient}, {Level} ⟩

- **ID**$_j$: The doctor has to have his/her own profile that is different from other therapists or psychological centers. This will give the doctor an access to the patient profiles and progress reports to allow for further evaluations.
- **Experience**$_j$: Experience level of the doctor is useful in allowing access to more complex/detailed data of the patients.
- **Involvement**$_j$: The level of engagement within the treatment process which allow the doctor to get access to the reporting progress along the way of the patient assigned treatment.
- {**Patient**}$_j$: The set of patients that Doctor$_j$ is allowed to supervision. Those are ⊆ {Patient} involved with the treatment and currently assigned within the environment.
- {**Level**}$_j$: The doctor is able to assign levels to certain patients as well as to predefine its suitability for the treated patient (e.g., Doctor$_j$ is able to select specified preferable shapes and less saturated ones for a patient$_i$ before starting the session.) This set is assigned directly to a registered patient and does not intervene with original specifications of any level.

Definition 4: $\{$**Game-Session**$\}_i$ are a set of treatment sessions a patient$_i$ goes through within an AR environment in order to complete a predefined treatment plan from the therapist. It is presented as a tuple of: $\langle$ Patient$_i$, Type, $\{$Level$\}$, Completion-Time$_i$, Tries$_i$ $\rangle$

- **Patient**$_i$: A player in the treatment which is $\in$ $\{$Patient$\}$. The complete profile is retrieved to include:
  - the current location of the player to define the precedence of an object and to guide them to achieving the task,
  - the set of predefined preferences for a patient considering other psychological disorders that may affect current design and methodology of the treatment plan, and
  - to update the current value of performance the patient has achieved throughout the game.
- **Type**: The type of the game to be played that has to be suitable for the patient. E.g., drag-and-drop and multiple-choices.
- $\{$**Level**$\}$: The set of complexity gradients the patient will go through to complete a session starting from the current complexity level defined in the patient profile (i.e., Level$_s$ which is the current level to where the patient has arrived in the treatment plan.)
- **Completion-Time**: is the time a patient has successfully completed a session which to be used later in measuring the performance index (i.e., to count the response time for patient$_i$.)
- **Tries**: The number of tries within one session to include correct, incorrect and uncompleted tries. E.g., the number of collected target objects the patient has correctly collected in one session.

Definition 5: $\{$**Level**$\}$ is a set of gradient complexities that maximize patients direct attention with each level. It can be seen as a tuple: $\langle$ $\{$Patient$\}$, $\{$Object$\}$, Max-Time, Effects $\rangle$

- **Patient**$_i$: A player in the treatment which is $\in$ $\{$Patient$\}$. This allows for assigning a predefined complexity levels based on their current preferences and therapist's recommendations.
- $\{$**Object**$\}$: Maximum set of objects used in this level.
- **Max-Time**: A predefined maximum time for the whole level to be completed or aport otherwise.
- **Effects**: Simple directional voice or instructions used for guidance in case of a remote following.

Definition 6: $\{$**Object**$\}$ is a set of virtual things a player interact with during a session. Specification of those objects are different from one complexity level to another as well as from one type of a game to another. In short, it can be represented as a tuple: $\langle$ Feature, $\{$Precedence$\}$, $\{$Inheritance$\}$, Localization $\rangle$

- **Feature**: The structure, size, color, etc. of an object has to be predefined beforehand the start of a session.
- $\{$**Precedence**$\}$: This sorts the order of the object and which one is visible before another. This will depend on the location and closeness from the player focal point.
- $\{$**Inheritance**$\}$: The relation between objects in case one object is consecutive after another one. This allows for the visibility of an object after another.
- **Localization**: The initial distribution of simulated objects around the real-environment.

C. Process of the reference model

To this point, we have described the components necessary in game design through a reference model. In order for a game utilizing this model to function properly, those components are connected to each others through multiple functions. We stride, in this section, to describe the steps required to set up a game for the best usability of the model.Let us restate that repeated pattern of actions performed by a single person shapes his/her behavior. Players behaviors, at this stage, have benefited from role enforcement through norms. Even though in a simple form of games, roles still exist. People will be possessing normative behaviors from day-to-day activities and societal boundaries. A game exits, in this case, to direct the enforced behaviors toward a certain charter that might not directly benefit one player in particular. For this, the formation of a game from governed players behaviors allows them to inherit some regulations. Those inherited regulations, nevertheless, will not directly force players to form certain connections or perform expected actions but will be able to change the directions of certain behaviors for their own benefits.

The environment profile allows the player to be concerned with their goals. It is merged with the functioning of a game and does not belong to particular player. This allows for instantaneous updates in the functioning of the game to cope with outside or inside changes (i.e., those changes may result in a transformation of a player's objectives and the way she tackles problems). The environment of a game is in control of generating subsequent activities that satisfy the goal as well as to identify each of the corresponding profiles. Such generations will also consider external needs in order to make sure that a game merges perfectly within the environment where it belongs. Also, those generations will consider internal needs for continual updates in strategies and processes of problems allocations and handling. Goal formation in a game can be a result of two things: 1) a bottom up approach where a player in the game decide on achieving some objectives and work along towards the completion of those objectives in a suitable environment that cherishes him/her, or 2) directly or indirectly enforced goals through inheritance of dominant designs. In both cases, game designs result in multiple effects on players' behaviors that we identify as regulated protocols through their games. Players may not always commit to such regulations where a huge number of mis-commitments may lead to a transformation of a game to other designs.

Regulations inherited from design are not static, and a game should allow the environment to keep up with continual changes in the surroundings. The game should make sure that such protocols do not interfere with other games as well as to not contradict them. The environment-profile will continually generate a set of goals that need to be completed in order to best satisfy a big part of the game charter. Each goal will have its own profile that shows its priority among others in the set. This set should be updated continuously in order to prioritize the set before assignment. When a plan is determined and levels need to be assigned, the game-session should account for the different types of games it produced as well as the expected quality of achieving them. Different types of games have different priority levels and independences that, in result, distinguish the time consumed for processing them. The performance measure is case specific, and we will not propose a single equation that determines it in this work. Apart from traditional methods that may primarily have a scientific merit as they generate knowledge about the overall effectiveness of online treatments, the online therapists may have more practical implications: It becomes difficult to find evidence for the superiority of specific treatments, such as collaborative activities, feedback-based treatment, or game-based treatment in therapy.

IV. Conclusion and Future Directions

The paper proposed a theoretical cognitive model for enhancing the behavior of patients with a predefined ADHD using a game-based augmented reality environment, we termed as "AR-Therapist". The purpose is to replace traditional CBT with a more advanced virtual one that may exceed traditional CBT methods by accelerating recovery time and saving money and resources for both government and patients. AR-Therapist achieves an excellent accessibility level to every patient in need as our system mimics the therapist roles by applying advancements of intelligent virtual agents as well as augmented reality techniques that provide it with features including: adaptiveness, smartness, responsiveness, and accuracy. Other advantages are availability and assurance of the therapist's level-of-experience which cannot be guaranteed in traditional CBT. Future work will provide more extensive empirical case studies that will provide this area of research with a rich and valuable data when collected ethically and will introduce interesting findings when analyzed.

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References

[1] R. A. Barkley, "The ecological validity of laboratory and analogue assessment methods of adhd symptoms," *Journal of abnormal child psychology*, vol. 19, no. 2, pp. 149–178, 1991.

[2] H. Abikoff, M. Courtney, W. E. Pelham, and H. S. Koplewicz, "Teachers' ratings of disruptive behaviors: The influence of halo effects," *Journal of abnormal child psychology*, vol. 21, no. 5, pp. 519–533, 1993.

[3] T. D. Parsons, T. Bowerly, J. G. Buckwalter, and A. A. Rizzo, "A controlled clinical comparison of attention performance in children with adhd in a virtual reality classroom compared to standard neuropsychological methods," *Child Neuropsychology*, vol. 13, no. 4, pp. 363–381, 2007.

[4] A. Gorini, A. Gaggioli, C. Vigna, and G. Riva, "A second life for ehealth: prospects for the use of 3-d virtual worlds in clinical psychology," *Journal of medical Internet research*, vol. 10, no. 3, 2008.

[5] L. Beard, K. Wilson, D. Morra, and J. Keelan, "A survey of health-related activities on second life," *Journal of medical Internet research*, vol. 11, no. 2, 2009.

[6] T. D. Parsons, A. A. Rizzo, S. Rogers, and P. York, "Virtual reality in paediatric rehabilitation: a review," *Developmental neurorehabilitation*, vol. 12, no. 4, pp. 224–238, 2009.

[7] T. W. Bickmore, S. E. Mitchell, B. W. Jack, M. K. Paasche-Orlow, L. M. Pfeifer, and J. O'Donnell, "Response to a relational agent by hospital patients with depressive symptoms," *Interacting with computers*, vol. 22, no. 4, pp. 289–298, 2010.

[8] K. Meyerbröker and P. M. Emmelkamp, "Virtual reality exposure therapy in anxiety disorders: a systematic review of process-and-outcome studies," *Depression and anxiety*, vol. 27, no. 10, pp. 933–944, 2010.

[9] R. T. Azuma, "A Survey of Augmented Reality," *Presence: Teleoperators and Virtual Environments*, vol. 6, no. 4, pp. 355–385, Aug. 1997. [Online]. Available: https://doi.org/10.1162/pres.1997.6.4.355

[10] G. C. Burdea and P. Coiffet, *Virtual Reality Technology*. John Wiley & Sons, Jun. 2003.

[11] M. Billinghurst, A. Clark, and G. Lee, "A Survey of Augmented Reality," *Foundations and Trends® in Human–Computer Interaction*, vol. 8, no. 2-3, pp. 73–272, Mar. 2015. [Online]. Available: https://www.nowpublishers.com/article/Details/HCI-049

[12] S. Alqithami, M. Alzahrani, A. Alzahrani, and A. Mustafa, "Ar-therapist: Design and simulation of an ar-game environment as a cbt for patients with adhd," in *Healthcare*, vol. 7, no. 4. Multidisciplinary Digital Publishing Institute, 2019, p. 146.

[13] S. Alqithami, M. Alzahrani, A. Alzahrani, and A. Mostafa, "Modeling an augmented reality game environment to enhance behavior of adhd patients," in *International Conference on Brain Informatics*. Springer, 2019, pp. 179–188.

[14] J. Biederman, "Attention-deficit/hyperactivity disorder: a selective overview," *Biological psychiatry*, vol. 57, no. 11, pp. 1215–1220, 2005.

[15] R. Schachar, V. L. Mota, G. D. Logan, R. Tannock, and P. Klim, "Confirmation of an inhibitory control deficit in attention-deficit/hyperactivity disorder," *Journal of abnormal child psychology*, vol. 28, no. 3, pp. 227–235, 2000.

[16] M. Ben-Moussa, M. Rubo, C. Debracque, and W.-G. Lange, "Djinni: a novel technology supported exposure therapy paradigm for sad combining virtual reality and augmented reality," *Frontiers in psychiatry*, vol. 8, p. 26, 2017.

[17] B.-H. Cho, J. Ku, D. P. Jang, S. Kim, Y. H. Lee, I. Y. Kim, J. H. Lee, and S. I. Kim, "The effect of virtual reality cognitive training for attention enhancement," *CyberPsychology & Behavior*, vol. 5, no. 2, pp. 129–137, 2002.

[18] D. Strickland, L. M. Marcus, G. B. Mesibov, and K. Hogan, "Brief report: Two case studies using virtual reality as a learning tool for autistic children," *Journal of Autism and Developmental Disorders*, vol. 26, no. 6, pp. 651–659, 1996.

[19] D. Reid, "Changes in seated postural control in children with cerebral palsy following a virtual play environment intervention: a pilot study," *Israel J Occup Ther*, vol. 11, pp. E75–E95, 2002.

[20] D. T. Reid, "Benefits of a virtual play rehabilitation environment for children with cerebral palsy on perceptions of self-efficacy: a pilot study," *Pediatric rehabilitation*, vol. 5, no. 3, pp. 141–148, 2002.

[21] D. Reid, "Virtual reality and the person–environment experience," *CyberPsychology & Behavior*, vol. 5, no. 6, pp. 559–564, 2002.

[22] T. Akhutina, N. Foreman, A. Krichevets, L. Matikka, V. Narhi, N. Pylaeva, and J. Vahakuopus, "Improving spatial functioning in children with cerebral palsy using computerized and traditional game tasks," *Disability and rehabilitation*, vol. 25, no. 24, pp. 1361–1371, 2003.

[23] E. Gelenbe, K. Hussain, and V. Kaptan, "Simulating autonomous agents in augmented reality," *Journal of Systems and Software*, vol. 74, no. 3, pp. 255–268, 2005.

[24] A. Shendarkar, K. Vasudevan, S. Lee, and Y.-J. Son, "Crowd simulation for emergency response using bdi agents based on immersive virtual reality," *Simulation Modelling Practice and Theory*, vol. 16, no. 9, pp. 1415–1429, 2008.

[25] T. Starner, S. Mann, B. Rhodes, J. Levine, J. Healey, D. Kirsch, R. W. Picard, and A. Pentland, "Augmented reality through wearable computing," *Presence: Teleoperators & Virtual Environments*, vol. 6, no. 4, pp. 386–398, 1997.