**“Hop a Doodle doo”: A Virtual Reality Game for Training Children with ADHD**

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**1 Background**

Attention Deficit Hyperactivity Disorder (ADHD) is a mental disorder frequently diagnosed in children, featuring inattentiveness, hyperactivity, and impulsivity. Around 8%-12% children among the world have ADHD and suffer from the consequent difficulties in education, employment, and high medical cost (Parsons et al., 2007). Virtual reality technology has been used for attentional assessments to diagnose ADHD by mimicking the real-world situations (Parsons et al., 2019) and the efficacy of computerized continuous performance tests (CPTs) were proven to be more effective in delineating ADHD symptoms because stimuli used in the test can be precisely adjusted in the virtual world (Adams et al., 2009).

Applying VR in the treatment of ADHD is also promising. Cognitive rehabilitation of ADHD includes restorative and functional approaches and VR was considered able to combine the best practices of these two approaches and render systematic training (Rizzo et al., 2000). There were two major ways to implement ADHD therapy into VR environments. Previous research investigated creating virtual classrooms that simulated the real-world class experiences and added distractors such as 3D flying paper airplane within the view of children, rumbling cars outside the virtual window, singing birds, and people coming in and out of the door (Adams et al., 2009). Researchers found that using VR classroom as treatment for ADHD children is significantly more effective than traditional treatment using presentation (Doulou & Drigas, 2022). Other researchers gamified the cognitive therapy, for example, Yanguas et al. (2021) designed a game called “The secret trail of moon” (TSTM), targeting the improvement of attention, working memory, planning, spatial capacity, impulse control, and reasoning. (Hakimirad et al., 2019) designed a game, EmoGalaxy, aimed at improving the social skills of ADHD children. The pre- and post- comparison of participants suggested that it significantly facilitated abilities including collaboration, assertiveness, responsibility, and self-control. Other gamified VR applications also reported significant positive effects in attention and self-regulation (Blandón et al., 2016) as well as abstract reasoning and complex information processing (Ou et al., 2020).

Our project aims to design a VR game to build the attention control ability for ADHD children, which has the potential to be launched as an accessible application for ADHD treatment, which is extremely beneficial to children in underdeveloped areas without affordable and accessible offline treatment clinics.

# 2 Method

**2.1 Virtual Experience Overview**

**The environment:** The virtual environment is within a forest scenery where there are rivers, mountains, and trees, as well as sounds of bird chirping and water flowing. VR forest was proven to be a restorative environment and benefit ADHD children (Annerstedt et al., 2013; Lähtevänoja et al., 2020). The children will play a game within this scene because the previous literature indicated that gamification is an effective way for children with ADHD to be engaged (Ou et al., 2020).

**The game:** This game is designed to train kids with ADHD to retain attention and avoid distractors. Specifically, the children need to arrive a destination by following the instructions and landing on the right circle within the limited time while distractors will randomly appear within the field of view. Once the children stand on the starting point, they will see instructions telling which circle they should land on (e.g., circle in a particular color), the timer will start to count down, and the distractors will appear simultaneously. If the children successfully jump to the right circle as instructed, the instruction for the next step will be automatically issued and more complicated distractors will appear. To encourage a greater sense of immersion and boost motivation, we also added game elements such as item collecting, missions, and achievements based on the evidence from previous studies (Blandón et al., 2016).

The game can be tested with a controlled group of kids with and without ADHD to measure the differences in impact the game causes on behavioral and habit development in the children. In the future by comparing the length of time that it takes the child to complete tasks (following a successful finish, a reward will be unlocked that can be used to practice and sharpen their motor skills) and their proficiency with each in-game exercise over time on how quickly the children can complete each exercise and if there is an increase or decrease in completion time for certain exercises following game use.

**The distractors**: Two types of distractors- visual and auditory distractors, were pointed out by previous literature (Adams et al., 2009). We designed various levels of distractors according to the size and animation level of the distractor agents. Our demo includes two levels of distractions: an easy level of distractors using small and static animals and a difficult level of distractors using big and animated animals.

**Possible interactions**: As the children enter VR environment, there will be an optional orientation session where kids being guided to learn how to use VR headset and hand controllers to play this game “NAME XX”. There will be different games for individuals and groups. The children are enabled with various interactions including walking, jumping, Children can control the perspective of the avatar to see around, move the orientation of the hand to point to the direction they want to trans, and “jump” to the circle.

**Safety concern:** There is a 15-minute limit per time that this application will automatically exit to avoid negative experiences such as nauciousness (Bailenson, 2018).

**2.2 Equipment (1-2 paragraph):**

We will use Unity, the most prevalent VR development application, to program and test the environment and render the environment using the Meta Quest 2 VR headset, which has high resolution and update rate, decreasing the chances of eliciting simulator sickness. Using a VR headset rather than a 2D screen can create more immersive experience for the users because broader field of view and stereoscopy have significant positive influences on sense of immersion (Cummings & Bailenson, 2016). This headset is also embedded with stereophony which can simulate stereophonic sounds in the forest environment, e.g., birds singing and water flowing.

In addition, it is possible to integrate eye-tracking technology to the VR headset which can record the eye movement of the ADHD children, for example, the fixation time on the distractors and speed of eye movement, to produce nuanced analysis of their behaviors and provide psychiatrists and parents with treatment insights.

**2.3 Measures**

We will measure the performance of ADHD children during the game and their real-life behavior which can reveal the long-term effect and sustainability of this game. Except for measuring treatment related variables, sense of presence and sickness will also be measured to evaluate the user experience during the game, which can be used to improve game design in the future.

**Game performance:** We used multiple measurements to measure the game performance and real-life behaviors of ADHD children. In the game, the score of children is calculated by how many circles have the children successfully targeted on, which can be used to encourage the children to continuously proceed as well as indicators to track the performance children and show the data to the therapist and parents.

**Real-life behavior:** In the long-term, we will use The Behavior Assessment System for Children (BASC) Monitor (Angello et al., 2003) for the parents of ADHD children to track kids’ behavior and evaluate their performance in real life. This scale is widely used to assess the long-term behavior changes of children. This scale requires the parents to choose “never,” “sometimes,” “often,” or “always” based on four subscales: attention problems, hyperactivity, internalizing problems, and adaptive skills.

**Sickness**: We intended to use Simulator Sickness Questionnaire (Kennedy et al., 1993) to measure whether the children experience symptoms of sickness, which is a byproduct of simulation technology, considering avoiding sickness is one of the basic requirements of a good VR design (Bailenson, 2018).

**Presence in VR experiences**: Presence is essential to VR experience because it contributes to the level of enjoyment of VR participation (Spanlang et al., 2014) and efficacy of treatment. We measure presence by adopting the self-location and possible actions scales (Tussyadiah et al., 2018). Both of them are measured with four items in a 5-point Likert scale with “Strongly disagree” –“Strongly agree”.

# Discussion

The purpose of this project is to use the capacity of VR to intervene and train children with ADHD. We anticipated that ADHD children will engage with this game since our VR game affords a high-level immersion featuring 3D visual display and stereophonic sounds, which can provide a distinct experience comparing to traditional treatment scenarios of real or simulated classrooms. Engaging with this game can further nudge their behaviors and improve their abilities in a gamified way which will benefit to their real-life behaviors in attention control.

**Investigate long-term effects of VR in treating ADHD**. Although multiple empirical studies reported significant results of the effectiveness of VR applications in ADHD treatment, most of them measured abilities regarding attention, comprehension, memory, and emotional regulation immediately after the treatment. Identify influential factors of VREs in ADHD treatment effect of gamification and VR classroom.

**Identify influential factors of ADHD treatment in VREs.** If time permits, we will make the critical parameters in the VREs adjustable, so that the therapists or parents can monitor the relationships between certain environmental features and treatment efficacy. For example, parents can experiment on various levels of difficulty of distractors find out the most suitable VRE setting. These data can also be used for research purpose to understand general correlations between VREs and treatment effectiveness.

**Enable data sharing and collaboration between therapists and parents**. In the future, we hope to design functions supporting behavioral data being shared with therapists remotely, based on which the therapists can guide the parents to change the parameters of the VREs for personalized solutions. The cooperation function can also provide possibilities for children in rural areas get remote treatment guided by professional suggestions.

Reference

Adams, R., Finn, P., Moes, E., Flannery, K., & Rizzo, A. “Skip.” (2009). Distractibility in Attention/Deficit/ Hyperactivity Disorder (ADHD): The Virtual Reality Classroom. *Child Neuropsychology*, *15*(2), 120–135. https://doi.org/10.1080/09297040802169077

Angello, L. M., Volpe, R. J., DiPerna, J. C., Gureasko-Moore, S. P., Gureasko-Moore, D. P., Nebrig, M. R., & Ota, K. (2003). Assessment of Attention-Deficit/Hyperactivity Disorder: An Evaluation of Six Published Rating Scales. *School Psychology Review*, *32*(2), 241–262. https://doi.org/10.1080/02796015.2003.12086196

Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen, Å. M., & Währborg, P. (2013). Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study. *Physiology & Behavior*, *118*, 240–250. https://doi.org/10.1016/j.physbeh.2013.05.023

Blandón, D. Z., Muñoz, J. E., Lopez, D. S., & Gallo, O. H. (2016). Influence of a BCI neurofeedback videogame in children with ADHD. Quantifying the brain activity through an EEG signal processing dedicated toolbox. *2016 IEEE 11th Colombian Computing Conference (CCC)*, 1–8. https://doi.org/10.1109/ColumbianCC.2016.7750788

Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology*, *19*, 272–309. https://doi.org/10.1080/15213269.2015.1015740

Doulou, A., & Drigas, A. (2022). Electronic, VR & Augmented Reality Games for Intervention in ADHD Education. *Technium Social Sciences Journal*, *28*, 159–169.

Hakimirad, E., Kashani-Vahid, L., Hosseini, M. S., Irani, A., & Moradi, H. (2019). Effectiveness of EmoGalaxy Video Game on Social Skills of Children with ADHD. *2019 International Serious Games Symposium (ISGS)*, 7–12. https://doi.org/10.1109/ISGS49501.2019.9046992

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology*, *3*(3), 203–220. https://doi.org/10.1207/s15327108ijap0303\_3

Lähtevänoja, A., Holopainen, J., Mattila, O., & Parvinen, P. (2020). The Use of Virtual Reality as a Potential Restorative Environment in School During Recess. In D. A. Alexandrov, A. V. Boukhanovsky, A. V. Chugunov, Y. Kabanov, O. Koltsova, & I. Musabirov (Eds.), *Digital Transformation and Global Society* (pp. 436–446). Springer International Publishing. https://doi.org/10.1007/978-3-030-65218-0\_32

Ou, Y.-K., Wang, Y.-L., Chang, H.-C., Yen, S.-Y., Zheng, Y.-H., & Lee, B.-O. (2020). Development of virtual reality rehabilitation games for children with attention-deficit hyperactivity disorder. *Journal of Ambient Intelligence and Humanized Computing*, *11*(11), 5713–5720. https://doi.org/10.1007/s12652-020-01945-9

Parsons, T. D., Bowerly, T., Buckwalter, J. G., & Rizzo, A. A. (2007). A Controlled Clinical Comparison of Attention Performance in Children with ADHD in a Virtual Reality Classroom Compared to Standard Neuropsychological Methods. *Child Neuropsychology*, *13*(4), 363–381. https://doi.org/10.1080/13825580600943473

Parsons, T. D., Duffield, T., & Asbee, J. (2019). A Comparison of Virtual Reality Classroom Continuous Performance Tests to Traditional Continuous Performance Tests in Delineating ADHD: A Meta-Analysis. *Neuropsychology Review*, *29*(3), 338–356. https://doi.org/10.1007/s11065-019-09407-6

Rizzo, A. a., Buckwalter, J. g., Bowerly, T., Van Der Zaag, C., Humphrey, L., Neumann, U., Chua, C., Kyriakakis, C., Van Rooyen, A., & Sisemore, D. (2000). The Virtual Classroom: A Virtual Reality Environment for the Assessment and Rehabilitation of Attention Deficits. *CyberPsychology & Behavior*, *3*(3), 483–499. https://doi.org/10.1089/10949310050078940

Rodrigo-Yanguas, M., Martin-Moratinos, M., Menendez-Garcia, A., Gonzalez-Tardon, C., Sanchez-Sanchez, F., Royuela, A., & Blasco-Fontecilla, H. (2021). A Virtual Reality Serious Videogame Versus Online Chess Augmentation in Patients with Attention Deficit Hyperactivity Disorder: A Randomized Clinical Trial. *Games for Health Journal*, *10*(4), 283–292. https://doi.org/10.1089/g4h.2021.0073

Spanlang, B., Normand, J.-M., Borland, D., Kilteni, K., Giannopoulos, E., Pomés, A., González-Franco, M., Perez-Marcos, D., Arroyo-Palacios, J., Muncunill, X. N., & Slater, M. (2014). How to Build an Embodiment Lab: Achieving Body Representation Illusions in Virtual Reality. *Frontiers in Robotics and AI*, *1*. https://www.frontiersin.org/articles/10.3389/frobt.2014.00009

Tussyadiah, I. P., Wang, D., Jung, T. H., & tom Dieck, M. C. (2018). Virtual reality, presence, and attitude change: Empirical evidence from tourism. *Tourism Management*, *66*, 140–154. https://doi.org/10.1016/j.tourman.2017.12.003