Virtual Reality and Chess. A Video Game for cognitive training in patients with ADHD

Rodrigo-Yanguas, M. [1[0000-0001-6118-2395]], Martin-Moratinos, M. [1[0000-0003-1328-1369]], Gonzalez-Tardon, C. [2[0000-0001-9433-0577]], Blasco-Fontecilla, H. [1, 3, 4, 5[0000-0002-2864-6298]],

[1] Department of Psychiatry, Puerta de Hierro University Hospital-IDIPHIPSA, Majadahonda, Spain
[2] Tecnocampus - Pompeu Fabra University, Mataro, Spain.
[3] Biomedical Research Centre in Mental Health Net (CIBERSAM), Madrid, Spain
[4] Autonoma University of Madrid, Madrid, Spain
[5] ITA Mental Health, Madrid, Spain

* Corresponding author to whom reprint requests should be sent: Hilario Blasco-Fontecilla, M.D., Ph.D., hmblasco@yahoo.es

Abstract. Objective: The treatment of ADHD is multimodal: Pharmacological, psychoeducational and psychotherapy, mainly cognitive-behavior therapy. Unfortunately, cognitive therapy is expensive and unattractive for some patients diagnosed with ADHD, which might lead to halting therapy. To alleviating this deficit, we have created a therapeutic video game -The Secret Trail of Moon (TSTM)-, which is based on a set of Virtual Reality (VR) exercises allied with a gamified version of chess. The combination of VR, video game and chess allows a greater immersion of cognitive load and training, adherence and transference to daily life.
Materials and Methods: The video game is based on both Thomas Brown's model of executive dysfunction in ADHD patients and Barkley's model of Behavioral Inhibition in these patients. TSTM is composed of 6 different mechanics aimed at working with: attention, memory, planning, visuospatial capacity, impulse control and reasoning. The technology used has been VR goggles, an actual gaming console and a standalone application. The software runs on a PlayStation 4 test device
Results: TSTM has been elaborated in three phases: 1) Theoretical foundation, design and programming; 2) Validation and proof of concept phase; 3) Clinical trial phase. The validation and proof of concept phase allowed us to improve TSTM according to the users' experience in order to achieve a more powerful cognitive training. Currently, TSTM is its third phase. The main hypothesis is that TSTM training produces improvements in patients with ADHD.
Conclusions: This article shows the first steps and development of TSTM. Currently, TSTM is undergoing its first clinical trial to demonstrate clinical efficacy to treat ADHD patients.

Keywords: Video Games, Reality Virtual, Chess, ADHD, cognitive training.

1 Introduction

In the last 50 years, the boom of video games as a recreational form is being exponential. However, it is only recently that they have begun to be used successfully as a therapeutic tool in mental health [1,2]. One of the main reasons for the success is the playful character of video games which favours the adherence to the treatment [3,4].

In particular, serious video games have begun to be used for the treatment of Attention Deficit Hyperactivity Disorder (ADHD) [5–8]. ADHD is a neurodevelopmental pathology with a large genetic component affecting between 4-7% of the entire worldwide child population [9,10]. ADHD is characterized by inattention, hyperactivity and impulsivity which is not appropriate to age and should appear in two or more areas of the subject's life [9]. ADHD is more frequent in males, with a male: female ratio of 3:1 [11].

Clinical guidelines recommend multimodal treatment as the first therapeutic option. Multimodal treatment includes a combination of different proportions of: 1) Pharmacological treatment; 2) psychoeducational treatment (parents and teachers); and 3) Psychotherapy, mainly cognitive-behavioral psychotherapy [12]. Currently, cognitive-behavioural treatment is expensive and often unattractive to patients with ADHD, thus leading to difficulties to adhere to treatment and the abandonment of therapy on many occasions.

For this reason, several authors are investigating new, more attractive, cheap and effective alternative tools for treating ADHD. To this end, we have designed a therapeutic video game using virtual reality (VR). The novelty of our video game "The Secret Trail of Moon" (TSTM) is that we inclused a gamified version of chess at the very core of the video game. We used chess as a gamified “excuse” of training executive functions.

Chess is an ancestral game based on simple rules but demands a high cognitive load including attentional processes, executive functions, and memory, among others [13,14]. Recently, chess has begun to be used as a tool for cognitive stimulation in the treatment of different mental health disorders [15–18]. In 2009, Demily conducted a pilot study with a control group of patients with schizophrenia. These patients attended chess sessions for 10 hours. The results showed how the patients in the chess group had a significant improvement in their executive functions [15]. In 2014, Gonçalves and his group conducted a pilot study with a control group of cocaine patients. The patients in the chess group received 10 chess sessions. The results showed that these patients had a significant improvement in their working memory and emotional control [16]. In 2016, Blasco-Fontecilla et al. conducted a pilot study without a control group with children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). The results showed that there was an improvement in the core symptoms of parent-reported ADHD [17]. Recently, in 2019 Nakao has published a systematic review on the benefits of playing board games (chess, go game and shogi) as a therapeutic tool for mental disorders [18]. The recent success of chess as a cognitive tool in mental health is due to its playfulness, adherence and low cost.

On the other hand, VR offers three advantages compared to the use of 2D video games: [17,18] 1) Immersion in the video game in order to keep the patient's attention

focused; 2) The novelty and low accessibility to the use of Virtual Reality games, compared to 2D games, produces greater motivation and adherence to treatment due to the reinforcement produced by the use of Virtual Reality games; and 3) Better transference to daily life,since they are used on a regular basis for training in other areas, such as human resources, phobias and others.

The aim of TSTM is to create an innovative, more immersive and motivating therapeutic tool for the cognitive treatment of patients diagnosed with ADHD.

2 Methods

2.1 Theoretical basis of TSTM

TSTM is a therapeutic video game based on VR for the cognitive training in patients with ADHD.

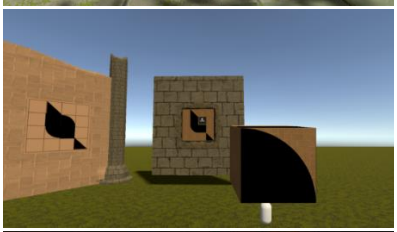
Table 1. Description of TSTM features

Features	Focus
Target population	Patients diagnosed with ADHD
Non-presciption	Patients diagnosed with epilepsy
Age	Over 12 years old
Target player	Individual
Clinical or parental support is need	Clinical support is needed
Short description on the objective of the TSTM	TSTM aimed at cognitive training of the main deficit areas of patients with ADHD
Cognitive training areas	Attention, working memory, visuospatial ability, planning, impulse control and reasoning.
Theoretical psychological models	Thomas Brown's model of executive functions. Barkley Behavioral Inhibition Model.
Behavioral change procedure	Reinforcement by points and progressive level advancement.
Type of game	Adventures and puzzle
Story of the videogame	A kid appears suddenly on a cave and it's greeted by a curious black fox that talks. Travelling with him eventually met a scurry raccoon and together they form the Moon team. Through the adventures in the woods they'll learn about an impending war between two animal factions that wants to fill the power vacuum that the King of the Forest Cernunnos left when it vanished. Wanting to unite all animals again, they set on a quest to find Cernunnos and put an end to the war that threatens the coexistence and the nature of the forest itself.
Objetive of the videogame	This is a VR adventure experience toppled with some specifically designed mechanics. The main goal of the game is to find the King of the Forest through several chapters, following the main storyline of the Moon Team while resolving problems all along the Forest.
Rules of the video-	Cognitive training (25 minutes) and Exploring the forest (10

games	minutes).
Game time estimation	8 hours

In the first phase of development this video game is composed of 6 mechanics. Each mechanism has been designed to stimulate a deficient area in patients with ADHD: attention, working memory, planning, visuospatial capacity, impulse control and reasoning.

Table 2. Game mechanics of TSTM

Game mechanic (Working área)	Purpose of the mechanics	Images of the game
Smasher (Attention)	Focus your attention and press the "X" button on the control when the target sequence appears in order to destroy the rock that is in your way.	
Enigma (Working memory)	For a given time, remember a target sequence and place it in the correct order as quickly as possible.	
Kuburi (Visuospatial capacity)	Make the default drawing using 3D cubes formed by 6 different faces	
Teka Teki (Planning)	Get the key to your lock by moving the walls that are in your way using the fewest possible movement.	

Kitsune (Impulse control)	Avoid objects that are in the way by following the indications that are shown.	
Chess (Reasoning)	12 chess lessons that increase in difficulty, from knowing the pieces to performing checkmate in 1 move.	

The novelty of the video game is the use of the game of chess as a central axis. The game of chess consists of a board with 64 squares, half white and half black, and two sides, one white and one black. Each side starts with 16 pieces (6 pieces of different type). The aim of the game is to checkmate the opponent's king.

In TSTM, chess appears in three different forms: A) As game mechanics; B) As a central element of mechanics; and C) As a thread in the plot of the video game:

A) Chess as game (Figure 1). A course of 12 sessions has been structured, consisting of tutorials and exercises in each of them. The first lesson is about the knowledge of the board and the pieces. The level increases successively until it reaches checkmate in 1 move.

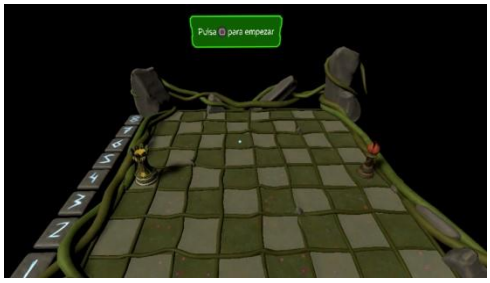


Fig. 1. Chess as game

B) Chess as a central element of the mechanics (Figure 2). The elements of the game of chess, board and pieces, allow us to perform many cognitive exercises in which it is not necessary to know the rules of chess. An example is the attention game "Smasher". The patient must be attentive to the appearance of the "pawn-knight" sequence and then press the X button on the controller.

Fig. 2. Chess as a central element of the mechanics

C) Chess as a thread in the plot and lore (Figure 3). TSTM is located in a forest with chess elements that explain the story of this world. The patient will go together with two animals that accompany him.

Fig. 3. Chess as a thread in the plot and lore

During his trip, the player will unlock information about the forest's relationship with chess. The final test of the video game is to play a game of chess against the enemy.

2.2 Development of the video game

The video game TSTM has been designed with the joint participation of the Traslational Research Group at Puerta de Hierro University Hospital-Majadahonda (Dr. Hilario Blasco-Fontecilla and Maria Rodrigo-Yanguas), the company Gammera Nest (including Marina Martin-Moratinos), and the collaboration of an expert in gamification (Carlos Gonzalez-Gardon). In the design and development has participated an interdisciplinary team formed by a psychiatrist, psychologists, programmers, modelers, art, sound and production.

The initial design of the video game has been modified in an iterative way following a User-Centered Model.[19] During the study of the proof of concept and usability, we obtained feedback from the patients who tested different versions of the video game by giving their opinions. The testing with real patients allowed us to make improvements in the design of the game mechanics adapting it to their needs and preferences. It also allowed us to correct errors or bugs to have a more polished version for

the subsequent clinical trial. This information obtained by the psychologists was transmitted to the programmers. Many of the improvement suggestions from the patients were integrated during the development process.

2.3 Videogame software

We used Unity Game Engine to develop this VR Experience to Sony Playstation VR device. We specifically programmed each one of the cognitive variables that we want to improve. We also use this VR technology to improve this data and provide to the professional with a report that is the more complete as possible. We track head movement, head speed, focus and reaction time and we showed them to the professional so they can render their own conclusions.

3 Results

The TSTM development and validation process is divided into three stages: 1) Theoretical foundation, design and programming stage; 2) Usability stage (Proof of concept); 3) Clinical trial stage (ID: NCT04355065).

A) Theoretical foundation, design and programming stage (See Methodology section).

B) Usability stage (Proof of concept). The objective was to detect errors in the video game and to evaluate the experience of the patients in order to improve the version of TSTM.

C) Clinical trial stage. We are currently in this stage (Trial registration: NCT04355065). The research is being carried out at the Puerta de Hierro University Hospital. It is a randomized, non-blind clinical trial with a control group. 105 patients with a diagnosis of ADHD and in stable pharmacological treatment are randomized to enter one of the three groups: 1) Control group; 2) Online therapeutic chess group; 3) TSTM group. All patients and parents are evaluated pre- and post-intervention. The training is done during 12 weeks. Our main working hypothesis is that patients who perform training in TMT or chess will have improvements in executive functions compared to patients who do not perform any type of intervention (control group). Currently, we have 83 patients evaluated and in active training: Control group (n=28), Therapeutic chess group (n=27) and TSTM group (n=28).

Table 3. Stages in development of TSTM

1. Theoretical foundation and programming	2. Usability (Proof of concept)	3. Clinical trial
Psychological Models= Thomas Brown's model of executive functions. Barkley Behavioral Inhibition Model. Chess. **Technology=** It is designed in partnership with Sony Iberia for the Playstation 4 systems, and specifically, to Playstation VR goggles.	**N=** 61 users. **E=** Ad hoc Questionnaire (Usability Satisfaction Scale) **T=** Testing of the video game (random game mechanics). **Time=** 10-40 min (M= 21.31, SD=6.77) **R=** Good acceptance of the video game by the patients. Improvement suggestions integrated in the design. No adverse consequences.	**N=** 105 patients over 12 years old and diagnosed with ADHD. **E=** Pre-post evaluation. Patients: (CPT-3, ATENTO, EQ-i:YV); Parents: (BRIEF, ATENTO y Ad-hoc Questionnaire). **T=** Clinical trial, randomized with control group. Patients randomized in one of the three groups: 1) Control group 2)Therapeutic Chess Group 3) TSTM Group **Time=** Cognitive training for 35 minutes/ 1 time per week, for 12 weeks **R=** Pending

N= Number; E=Evaluation; T=Task; R= Results

4 Discussion

4.1 Discussion and future perspectives

The aim of the TSTM video game is to create an innovative therapeutic tool for cognitive training in patients diagnosed with ADHD. TSTM has been created for the treatment of the main deficits of ADHD as reported from the main theoretical conceptual frameworks on the main deficits of patients with ADHD: inattention, hyperactivity, and lack of impulse control, among others [9]. We included VR because, compared to a 2D strategy, provides: greater adherence, engagement and transferability [17,18]. Chess has been chosen as the main theme given its potential as a cognitive training tool [15–17] and the possibility of creating many mechanics by combining the pieces and the chessboard.

Before testing the therapeutic properties of TSTM, we had to overcome a second stage, testing the usability and proof of concept. The question at this second stage was: would it make sense creating a VR videogame with good therapeutic properties

but boring that anyone else would like to play? We have surpassed this second phase and our results are really good. Unfortunately, we did not have the time to writte this paper, but we can advance that more than 90% of the users reported that they liked TSTM, and the scores in most of the mechanics surpassed this 90% (Rodrigo-Yanguas and Martin-Moratinos et all, unpublished, in elaboration).

Currently, TSTM is being validated through a first clinical trial in patients stabilized on medication following an add-on strategy in a three-arm randomized design (https://clinicaltrials.gov/ct2/show/NCT04355065). The completion date will be October/November 2020. The main objective is to test if TSTM can be used as a cognitive training tool in patients diagnosed with ADHD.

4.2 Strengths and limitations

TSTM is the first VR serious video game developed for the cognitive treatment of patients with ADHD that includes chess at its very core. TSTM has a solid theoretical basis and has been validated in a proof of concept before starting the clinical trial.

In the future, we hope to be able to design more mechanics to achieve more complete cognitive work and to be able to integrate artificial intelligence to be able to train from home.

Ethical responsibilities

We have followed Play Station's recommendations about not using Virtual Reality glasses for long periods of time on children under 12.

Protection of people and animals. The authors state that the procedures followed conformed to the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Confidentiality of data. The authors state that they followed their centre's protocols on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondent author.

Acknowledgments

The development of TSTM has been made possible thanks to support from I-PFIS, CDTI and the material support from Sony Interactive Entertainment.

Conflict of interest

In the last two years, Dr. Hilario Blasco-Fontecilla has received lecture fees from Takeda. He is the recipient of a MINECO grant (RTI2018-101857-B-I00; 2019-

2021). He was the Spanish IP of a clinical trial comparing neurofeedback (Mensia Koala®) with Medikinet® (www.mensia.com). He has also received funding from a clinical trial sponsored by Janssen (ESKETINSUI2002). The remaining authors report no conflict of interest.

References

1. Lau H. M., Smit J. H., Fleming T.M., Riper H. Serious Games for Mental Health: Are They Accessible, Feasible, and Effective? A Systematic Review and Meta-analysis. Front Psychiatry;7:209 (2016).
2. Kokol P, Vošner HB, Završnik J, Vermeulen J, Shohieb S, Peinemann F. Serious Game-based Intervention for Children with Developmental Disabilities. Curr Pediatr Rev.;16(1):26-32 (2020).
3. Yuri Quintana, Oscar García. Serious Games for Health. Mejora tu salud jugando. Gedisa; (2017).
4. Jane McGonigal. ¿Por qué los videojuegos pueden mejorar tu vida y cambiar el mundo? Siglo Veintiuno Editores Argentina S.A.; (2013).
5. Rajabi S, Pakize A, Moradi N. Effect of combined neurofeedback and game-based cognitive training on the treatment of ADHD: A randomized controlled study. Appl Neuropsychol Child. 8 de febrero de 2019;1-13 (2019).
6. Flynn RM, Colón-Acosta N, Zhou J, Bower J. A Game-Based Repeated Assessment for Cognitive Monitoring: Initial Usability and Adherence Study in a Summer Camp Setting. J Autism Dev Disord. mayo de 2019;49(5):2003-14. (2019)
7. García-Redondo P, García T, Areces D, Núñez JC, Rodríguez C. Serious Games and Their Effect Improving Attention in Students with Learning Disabilities. Int J Environ Res Public Health. 11 de julio de 2019;16(14). (2019)
8. Bikic A, Christensen TØ, Leckman JF, Bilenberg N, Dalsgaard S. A double-blind randomized pilot trial comparing computerized cognitive exercises to Tetris in adolescents with attention-deficit/hyperactivity disorder. Nord J Psychiatry. agosto de 2017;71(6):455-64. (2017)
9. American Psychiatric Association (APA). Diagnostic and statistical manual of mental disorders. DSM-5. Washington, D.C.: American Psychiatric Association. Washington, DC: American Psychiatric Association.: (2013).
10. Thomas R, Sanders S, Doust J, Beller E, Glasziou P. Prevalence of attention-deficit/hyperactivity disorder: a systematic review and meta-analysis. Pediatrics. abril de 2015;135(4):e994-1001 (2005).
11. Biederman J, Faraone SV, Monuteaux MC, Bober M, Cadogen E. Gender effects on attention-deficit/hyperactivity disorder in adults, revisited. Biol Psychiatry. 1 de abril de 2004;55(7):692-700 (2004).
12. Dalrymple RA, McKenna Maxwell L, Russell S, Duthie J. NICE guideline review: Attention deficit hyperactivity disorder: diagnosis and management (NG87). Arch Dis Child Educ Pract Ed. 27 de noviembre de 2019;
13. Song L, Peng Q, Liu S, Wang J. Changed hub and functional connectivity patterns of the posterior fusiform gyrus in chess experts. Brain Imaging Behav. junio de 2020;14(3):797-805 (2020).

14. Langner R, Eickhoff SB, Bilalić M. A network view on brain regions involved in experts' object and pattern recognition: Implications for the neural mechanisms of skilled visual perception. Brain Cogn. 2019;131:74-86 (2019).
15. Demily C, Cavézian C, Desmurget M, Berquand-Merle M, Chambon V, Franck N. The game of chess enhances cognitive abilities in schizophrenia. Schizophrenia Research. enero de 2009;107(1):112-3 (2009).
16. Gonçalves PD, Ometto M, Bechara A, Malbergier A, Amaral R, Nicastri S, et al. Motivational Interviewing combined with chess accelerates improvement in executive functions in cocaine dependent patients: A one-month prospective study. Drug and Alcohol Dependence. 1 de agosto de 2014;141:79-84 (2014).
17. Blasco-Fontecilla H, Gonzalez-Perez M, Garcia-Lopez R, Poza-Cano B, Perez-Moreno MR, de Leon-Martinez V, et al. Efficacy of chess training for the treatment of ADHD: A prospective, open label study. Rev Psiquiatr Salud Ment. marzo de 2016;9(1):13-21 (2016).
18. Nakao M. Special series on «effects of board games on health education and promotion» board games as a promising tool for health promotion: a review of recent literature. Biopsychosoc Med. 2019;13:5 (2019).
19. Fullerton T. Game Design Workshop, 3rd Edition: A Playcentric Approach to Creating Innovative Games.AK Peters/CRC Press (2014).