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## Mysterious Bones Unearthed: development of an online therapeutic serious game for children with attention deficit-hyperactivity disorder

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### Abstract

Attention deficit-Hyperactivity Disorder is a disease that affects 3 to 5 percent of children globally. The treatment roots on medication and behavioral exercises. There are unwanted, documented, side effects of the medication, and the behavioral exercises are very demanding for children. In this context the goal of the present research was the development of a serious game for children with 6-8 years old with behavioral exercises as the basis for the action of the game, using a ludic approach. This ludic approach intends to increase the motivation for the game. The present work is part of the research project Therapy4All. The objective of the project is not to replace the traditional form of treatment, but to complement it by allowing a physician to maintain her/his patients under supervision between their regular consultations. The goal is the development of research on serious games to provide patients a better control of their symptoms more than with just traditional therapy. Our first results, with a very small sample, show encouraging improvements in the children's competencies.

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*Keywords:* Serious Games, Attention Deficit Hyperactivity Disorder, Mental Health Information System

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## 1. Introduction

Difficulties with attention, impulsiveness, or hyperactivity, or all three characterize children diagnosed as having Attention Deficit Hyperactivity Disorder<sup>1,2</sup> (ADHD). These difficulties arise relatively early in childhood<sup>3</sup>, are persistent over time in most diagnosed cases<sup>2</sup>, and result in impairment in numerous domains of major life activities<sup>4</sup>. If they are not monitored and treated early, its consequences will impair the adult life of the individual. Studies indicate that about 3-7% of school-age children have ADHD<sup>5,6</sup>. In Portugal, there are between 35000 to 75000 children suffering from disorders of ADHD<sup>7</sup>.

Recent studies of ADHD suggest that these symptoms may be associated with problems in executive functioning<sup>4,8</sup>. That functioning, is believed to involve behavioral inhibition, persistence, working memory, and goal-directed problem solving, reflecting more intentional than attentional activities<sup>2,9</sup>.

The currently available treatments focus on reducing the symptoms of ADHD and improving functioning. Treatments include medication, various types of psychotherapy, education or training, or a combination of treatments. Current medications do not cure ADHD. They control the symptoms for as long as they are taken. Medications can help a child pay attention and complete schoolwork. Adding behavioral therapy, counseling, and practical support can help children with ADHD and their families to better cope with everyday problems.

In this context, a game with visual-verbal, and visual-spatial working memory tasks could help develop the neuropsychological skills that need to be targeted for intervention and training in this process. It is important to carry out tasks for the advancement of Working Memory (WM), particular Visual Memory (VM), Auditory Memory (AM) and Visual-Spatial Memory (VSM). Tasks as encouraging listening and following verbal directions to scan the environment, finding hidden treasures like letters, words, faces and objects will reinforce their organization and attention skills, and stimulates auditory processing.

In this project we intend to bring a different approach to the existing behavioral exercises and use serious games that support behavioral exercises from a ludic perspective. The present research is included in a broader project, the Therapy4All<sup>10</sup>, where the goal of the research team is to develop a games based platform that allows the development of neuropsychological competencies such as the WM, including the VSM and AM, the executive functions e.g., planning tasks and problem resolution, and the speed processing response. This platform is a Mental Health Information System (MHIS) used to promote e-Therapy. It is a modular and scalable architecture that can be easily extended in the future for e-Therapy of other disorders. This research intends to contribute for extending the healthcare services to larger number of children with ADHD, to help the healthcare professionals in their work, and the families in their battle.

In this paper we will focus on the research done in the development of one serious game for ADHD therapy for children with 6 to 10 years old. Our main purposes were: 1) to conceive a serious game for developing the attention, visuospatial working memory, eye-hand coordination, and impulsiveness; 2) to implement the game using a web platform; 3) to study the effects of the game developed in children and establish a statistical correlation between the use of this tool and an improvement of ADHD symptoms; 4) surpass the barriers that limit the access to the services and reduce the use of e-Therapy, namely the resistance to change and technology literacy.

Next section introduces the key concepts about ADHD and serious games for ADHD. Section 3 explain the methods used and Section 4 the main results of the research. Finally, Section 5 presents the conclusions and future work.

## 2. Concepts and related work

This section introduces some key concepts regarding attention deficit hyperactivity disorder and explains how it can be related with serious technological games. It ends with the related existing projects in the field of serious games for ADHD.

### 2.1. Attention deficit hyperactivity disorder

Attention Deficit Hyperactivity Disorder (ADHD) research continues to struggle with what causes this disabling disorder. There are just as many treatment options as there are questions. Donald R. Lyman, Associate Professor of the Department of Psychology at the University of Kentucky and several of his colleagues have declared an "International Consensus Statement on ADHD". They declare, "We cannot overemphasize the point that as a matter of science, the notion that ADHD does not exist is simply wrong. All of the major medical associations and government health agencies recognize ADHD as a genuine disorder because the scientific evidence indicating it is so overwhelming"<sup>11</sup>.

ADHD has three major symptoms, namely hyperactivity, inattention, and impulsiveness. Hyperactivity is considered to be one of the main symptoms of ADHD, however, it is possible a diagnosis of ADHD without the presence of hyperactivity. There are many people that have an inattentive type of ADHD that do not exhibit symptoms that would accompany hyperactivity. The degree of hyperactivity also can diminish as a child becomes older. This is one of the reasons that it was believed that children grew out of ADHD as they become older. While children may act as if they "are driven by a motor," never sitting still for a moment or constantly jumping and bouncing, adults may have a continuous feeling of restlessness. Adults may still have problems sitting still for long periods of time or thrive in high activity situations. Although the symptoms may manifest differently in children and adults, hyperactivity can be present in both.

Inattention is, basically, reacting before thinking. Inattention is one of the major symptoms of ADHD, although it is still greatly misunderstood. Some experts believe that it is "over" attention, rather than inattention. People with ADHD do not have the ability to filter out unwanted stimuli and therefore, they pay attention to everything, rather than being able to focus on one thing. Inattention is also described as being easily distracted. Inattention and hyperfocus also seem to go hand in hand. Hyperfocus is the ability to focus so intently on one thing that everything else seems to disappear. People with problems with inattention, often also report problems with periods of hyperfocus. This can cause them to be late for important events, or get so bogged down completing one task they forget other equally important things to do.

Impulsiveness, however, is not always a negative trait. Being a leader requires people to make quick decisions and to think on their feet. Other situations, such as emergencies, require quick thinking and action rather than thought. Impulsiveness also can add variety and spice to life, letting people be spontaneous or to jump into new situations. Creating a balance can help to enjoy the adventure than impulsiveness can bring to life without becoming frustrated and embarrassed.

ADHD can be mistaken for other problems. Parents and teachers can miss the fact that children with symptoms of inattention have the disorder because they are often quiet and less likely to act out. They may sit quietly, seeming to work, but they are often not paying attention to what they are doing. They may get along well with other children, compared with those with the other subtypes, who tend to have social problems. But children with the inattentive kind of ADHD are not the only ones whose disorders can be missed. For example, adults may think that children with the hyperactive and impulsive subtypes just have emotional or disciplinary problems.

The currently available treatments focus on reducing the symptoms of ADHD and improving functioning. Treatments include medication, various types of psychotherapy, education or training, or a combination of treatments.

Current medications do not cure ADHD. Rather, they control the symptoms for as long as they are taken. Medications can help a child pay attention and complete schoolwork. It is not clear, however, whether medications can help children learn or improve their academic skills. Adding behavioral therapy, counseling, and practical support can help children with ADHD and their families to better cope with everyday problems. Research funded by

the National Institute of Mental Health (NIMH) has shown that medication works best when treatment is regularly monitored by the prescribing doctor and the dose is adjusted based on the child's needs<sup>12</sup>.

Regarding medication, not all children benefit from taking it, some experience intolerable side effects, and many continue to struggle even though medication may be somewhat helpful. Behavior therapy can be difficult for parents to consistently implement, and does not generally reduce behavior difficulties to normative levels.

Because of these limitations, there have been numerous efforts to develop alternative treatments for ADHD that may enhance the benefits offered by medication and behavior therapy. Furthermore, even though both treatments can be extremely helpful in managing ADHD symptoms and reducing oppositional behavior, they do not induce lasting changes in the child that persist after treatments is discontinued. Finally, despite numerous studies documenting the short and intermediate term benefits of these treatments, their impact on children's long-term success remains to be clearly documented. Because of these limitations, there have been numerous efforts to develop alternative treatments for ADHD that may enhance the benefits offered by medication and behavior therapy.

In this context, a game with visual verbal, and visuo-spatial working memory tasks could help develop the neuropsychological skills that need to be targeted for intervention and training in this process, it is important to carry out tasks set for the Advancement of Working Memory, particular Visual Memory, Auditory Memory and visuo-spatial memory. Tasks as encouraging listening and following verbal directions to scan the environment, finding hidden treasures like letters, words, faces and objects will reinforce their organization and attention skills, and stimulates auditory processing. This relation between serious games and ADHD is the topic of the next subsection.

## *2.2. Attention deficit hyperactivity disorder and training programs*

As important example for the ADHD is the Cogmed Working Memory Training as a computer-based solution for attention problems caused by poor working memory. Cogmed combines cognitive neuroscience with computer game design and close professional support to deliver substantial and lasting benefits to your users. Cogmed's solutions include the use of the software and personal support<sup>13</sup>. The program challenges the user's working memory capacity. The computerized, cognitive exercises are designed by neuroscientists to target this key cognitive function that has been proven to be fundamental to executive function and attention. The details of the exercise design allow the program to be much focused and yet provide slight variations. The logic is very much like in the case of the fitness machines used for building muscle strength in a gym. The difficulty level of the training is adjusted in real time by the software based on the user's performance.

Two other training studies of school-aged children with ADHD<sup>14,15</sup> investigated the effects of attentional training (30–60 min, twice weekly for 8 weeks). These attentional training programs have included a wide variety of attentional processes such as vigilance, selective attention, divided attention, the ability to switch attention between stimuli or tasks, and inhibitory control. Kerns and colleagues<sup>14</sup> found significant training effects on sustained attention, inhibitory control, mazes, and a math test but no effect on WM. Shalev and colleagues<sup>15</sup>, who only studied academic outcomes, found no effects of attentional training on mathematics, although significant effects on passage copying and reading comprehension. Finally, Rueda and colleagues<sup>16</sup> studied normally developing preschool children and found that after 5 days of attentional training, the intervention group had improved significantly more than a control group on the Kaufman Brief Intelligence Test (K-BIT) in their community-based sample of 4-year-olds.

## *2.3. Games improving disorders of ADHD*

Alongside the evolution of the study of ADHD, there were emerging ideas for reducing the symptoms displayed by these disturbances. One of the findings relates the use of games as a tool for therapeutic intervention.

Serious games dealing with health issues are a growing field<sup>17</sup>. Some promote increased physical activity, improving patient compliance, promoting better personal health, improve hospital operations, and provide for training more attractive for health professionals. Serious games as a term exists for over 40 years. There are several definitions of serious games. Zyda<sup>18</sup> defines serious games as “a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives”. Myer and Sorensen<sup>19</sup> consider serious games as “digital

games and equipment with an agenda of educational design and beyond entertainment". There is no one single definition of the term "serious games", although it is widely accepted that they are games "with a purpose". In other words, they move beyond entertainment per se to deliver engaging interactive media to support learning in its broadest sense<sup>20</sup>. The first "serious game" was Army Battlezone<sup>†</sup>, a project developed by Atari in the 80's. This game was designed to train soldiers in battle situation. Over the years many "serious games" were designed for a growing variety of areas: education, vocational training, health, advertising, and public policy.

There are many evidences for using games, entertainment and serious, simulations and virtual worlds in schools and vocational training to enhance and support learning<sup>21,22,23</sup>. Content is integrated into the game so that learning is intrinsic to the game and evaluation of learning may be part of the game or may occur through the mediation of around the game. These variations could cause confusion amongst educators, trainers and policy makers when trying to identify what digital game can be successfully used to achieve a learning goal.

Smith<sup>24</sup> compared traditional teaching and training using virtual reality and game technology-based tools in laparoscopic surgery. He found the latter was less expensive, took less time, resulted in less medical errors when surgery is actually performed, and allowed multiple symptoms and repetition<sup>24</sup>.

Qinyin Qiu et al<sup>25</sup>, states that "games can be applied for treatment and rehabilitation of patients with cerebral palsy" along with physical therapy. There is a vast, growing field of evidence that says that the brain can be reorganized by stimulation. This is field with a large spectrum of research, varying from active gaming, to rehab and physical therapy, considering disease management, epidemiology, training, cognitive exercise, nutrition and health education<sup>26</sup>.

The fact that games are available to everyone, at any time, makes possible the creation of platforms that help reduce the symptoms of ADHD. In addition, using technological games, may captivate users and because of that they may do the exercises better and may get better results. In return, the fact that users use the computer with a higher frequency may cause vision problems.

#### 2.4. Existing projects in the field

There are several efforts in implementing serious games as therapy for ADHD, such as Ranj Serious Games project, consisting of an adventure game called Plan-It Commander meant to be played at home for children with ADHD.

The goal is to solve a situation with several different issues. At the same time, the child will learn how to deal with the problems arising from ADHD and learning to seek assistance of his team when needed. The game can only be played by children during a specific number of minutes per day. A commercial version of the product was released to the market, in June 2013. It is being developed a clinical study with 170 children. No scientific publication has been identified with either the intermediate data or the end data. Although it is pointed out that the study data were submitted for publication in July 2014. Not yet known any adaptation of Plan-It Commander for mobile platforms and not found a language localization of the game except for the Dutch language.

Another project is MIND360<sup>27</sup> (MIND360 2013) that provides access to several tools, where, using online tests, you can perform self-diagnosis of ADHD, also providing various games designed to improve the symptoms of ADHD through a training program. The user can make the registry on the site and have access to resources. Registration is free requiring only a valid e-mail. MIND 360 does not present any scientific supporting study either for the diagnosis or for the therapy<sup>27</sup> (MIND360 2013).

Flanders' Care<sup>28</sup> has created a serious game for children from eight to twelve years with ADHD that allows the child to play the role of a space captain with the job of collecting minerals on distant planets.

The game trains children in time management, planning, organization and social interaction.

The game has been tested with children to assess their level of entertainment and had some effect on children's behavior, with positive preliminary results. They are currently trying to perform a large-scale clinical trial<sup>28</sup>.

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<sup>†</sup> <http://www.arcade-history.com/?n=battlezone&page=detail&id=210>

So far, any scientific publication with final results of these projects was identified. Also, all these effort are not considered for the Portuguese language. Finally none focuses the six to eight years old children. In this way there are research opportunities to follow. Next section explain the methods used in this project.

### 3. Methods

The research team is multidisciplinary. It includes competencies from computer science, psychology, designer, and game developer. The methodology followed seven steps: 1) the conceiving of the game; 2) the development of the game; 3) pre-test of the game by selected children and with video recording; 4) analysis of the video; 5) reformulation of the game; 6) testing the gaming with 12 children; 7) analysis of the results.

The first step was the conceiving of the game. The conceiving of the game started with a literature review of the therapeutic exercises to stimulate the attention, visuospatial working memory, eye-hand coordination, and impulsiveness. These exercises are the basis to think about an appealed narrative and a challenge. A short, simple but interesting narrative was developed using the concepts of bones and the challenge of a treasure hunt. The story and the elements of the game were developed in order to be agnostic according to the respective culture and education level.

A character and other design elements were developed to support the game. Sound effects and animation completed the game after several cycles of careful revisions. To increase the motivation three levels with different time limitations and number of bones to unearth were developed. As some of the target children may have difficulty in reading, a tutorial was added and also a practical exercise. The game was developed with a close relationship with children from 6 to 8 years old.

The second step consisted in the development of the game using Unity 3D and a kernel to gather and store the statistics of the game. As the child plays with the game, all data of her/his experience is recorded: the time for each action, the number of hits and errors in each level, and the position of each click.

After the first and the second step it was possible to pre-test the game. Four children with ADHD, two girls and two boys and four children without ADHD, also to girls and two boys with ages between 6 to 8 years old, were selected. The inclusion criteria were: 1) children with some proficiency using a computer, namely using a mouse; 2) four children, two girls and two boys, having ADHD diagnostic; 3) four children, two girls and two boys, not having ADHD diagnostic; 4) the consent of their legal responsible. A term of consent was signed by each legal responsible of the children allowing the participation in this research project as pre-testers of the game. The test conditions were careful prepared. All the distractive elements were removed from the pre-test room, the light and the temperature were also studied in order to guarantee the maximum environment comfort and focus in the game. The video camera position was determined to guarantee that the child was not aware of the camera during her/his game session. Her/his legal responsible, in all the cases were the mother or the father, was close enough to support the child but also far enough to not interfere.

Next step was the analysis of the videos. The multidisciplinary team took a careful analysis of the movement of the head, shoulders and hands of the children at each pace of the game in order to verify: 1) if the child was understanding the purpose of the game; 2) the level of motivation and stress; 3) the difficulties; 4) the success rate. With this information it was possible to improve the design elements, the coordination of the scenes and the sound effects.

After the reformulation of the game, it was possible to do a final testing with twelve children with ages between 6 to 8 years old, sorted in two groups: group with ADHD and group without ADHD. The first group was selected at random from the children population with ADHD of Centro Hospitalar de Leiria. The second group was selected from children without ADHD at convenience from the relations of the research team. Again, children's parents or legal responsible signed a legal participation agreement authorizing the participation of her/his child in the study.

All the children were subject to initial and standardized assessments based on a Neuropsychological Assessment Battery, namely the Conners Continuous Performance Test (CPT II)<sup>29</sup>, and the Wechsler Intelligence Scale for Children (3<sup>rd</sup> Edition) (WISC III)<sup>30,31</sup>, to register her/his score before the intervention based on the tasks developed with the computer program. These tests are a reliable indicator for the evaluation and monitoring of the response of the child to a specific treatment for ADHD. Then, all the children started using the game during three (3) months. During this period, the research team performed a daily monitoring of the experience in order to guarantee that all

the children perform the games and the therapeutic tasks. Finishing the trial period, all the children were again evaluated. The data was then analyzed.

#### 4. Results and discussion of results

The results presented here are preliminary data that constitute an integral part of a study with a larger sample. Here we refer to a preliminary sample of twelve subjects, six of the clinical group and six of the control group.

The cognitive assessment presented reflects only the subtests of the WISC-III, described in the literature as more sensitive to symptoms of Hyperactivity Disorder and Attention Deficit. A continuous performance task, continuous performance test, or CPT, is any of several kinds of neuropsychological test that measures a person's sustained and selective attention. You can see the differences in the scores obtained by the subjects in the pretest and posttest for both groups and both tests in tables 1 and 2.

Table 1. WISC- III scores, of subjects with and without ADHD, before (pretest) and after (posttest), performing the serious games.

		Group with ADHD <i>N</i> = 6		Group without ADHD <i>N</i> = 6	
		Pretest	Posttest	Pretest	Posttest
<b>WISC-III Subtests</b>	Coding-Digit Symbol	7,50	11,00	10,50	11,33
	Arithmetic	9,17	11,00	12,83	10,67
	Block design	10,50	10,33	11,50	13,33
	Symbol Search	9,50	12,83	11,67	13,17
	Digit span	9,33	11,00	10,50	9,50

Table 2. CPT- II scores, of subjects with and without ADHD, before (pretest) and after (posttest), performing the serious games.

		Group with ADHD <i>N</i> = 6		Group without ADHD <i>N</i> = 6	
		Pretest	Posttest	Pretest	Posttest
<b>CPT-II</b>	Commissions	28,66	19,66	9,83	8,50
	Omissions	25,16	27,00	20,50	19,50

#### 5. Conclusions and future work

It is possible to infer, in accordance with the data presented herein, that the use of the game brought improvements in most areas which, commonly, persist in deficit on children diagnosed with ADHD. Moreover, the literature also indicates that the use of behavioral exercises, as an intervention vehicle, has shown in a longitudinal perspective, favorable outcomes for these children. With regard to the promotion of attention, there are at least three controlled research projects showing better attention in everyday life<sup>32,33,34,35,36</sup>. Improvements in WM, after

intervention with digital tools, were generalized to a reduction of cognitive impairment in the academic component<sup>37</sup>.

Children with ADHD, that revealed moderate to major damage in WM, recorded major improvements in the fields of WM Visual-Space and in the field of WM Auditory-Verbal<sup>38</sup>.

As the limitations of this study, we can point out the fact that we are facing a small test sample of subjects (n = 12/6 6 Group with ADHD and Group without ADHD), in this way it is not possible to generalize to other populations.

The games were created with the purpose of training the patient without becoming boring. This is a crucial factor as by and large the majority of sufferers from ADHD are children, and as such, other tools which might normally be used would find their effectiveness significantly diminished.

Considering existing projects, this game differs from the language localization, the age group. It was not identified scientific publications of those projects.

The next step in the research is continuing the tests for a larger number of subjects. Also it was possible to identify the need of a platform connecting physicians, therapists, parents, teachers and all the other actors involved in the process.

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