ATHYNOS: Helping Children with Dyspraxia Through an Augmented Reality Serious Game

Diego Avila-Pesantez
Computer Science Faculty
San Marcos National University
Lima, Peru
Informatics and Electronic Faculty
Polytechnic School of Chimborazo
Riobamba, Ecuador
davila@espoch.edu.ec

Lourdes Zuniga
Informatics and Electronic Faculty
Polytechnic School of Chimborazo
Riobamba, Ecuador
lourdes.zuniga@espoch.edu.ec

Leticia Vaca-Cardenas
Informatics and Electronic Faculty
Polytechnic School of Chimborazo
Riobamba, Ecuador
leticia.vaca@espoch.edu.ec

L. Miriam Avila
Business & Management Faculty
Polytechnic School of Chimborazo
Riobamba, Ecuador
miriam.avila@espoch.edu.ec

Luis A. Rivera
Mathematical Sciences Laboratory
State University of North Fluminense
Rio de Janeiro, Brasil
rivera@uenf.br

***Abstract*—Emerging technologies and ICT have changed the lifestyle of society, all scientific areas are taking advantage of technology to get a real development. Therapists realize the benefits of using serious games as an assistive tool in psychotherapy. Thus, this research examines relevant issues regarding Dyspraxia disorders in children and presents a comparative study between two therapies methods, one using a manual puzzle and other using ATHYNOS, an Augmented Reality Serious Game developed to help children with the Dyspraxia to improve their motor skills and hand-eye coordination through technology. The analysis of data results showed that exist a significant difference between both methods, proving that children playing with ATHYNOS got less time in the activity execution and also better performance.**

Keywords—serious games; augmented reality; dyspraxia; ATHYNOS.

I. INTRODUCTION

According to World Health Organization's International Classification of Diseases, it exists several definitions of learning disabilities, and some of them require the individual to have an intelligence quotient less than 70 [1]. These disabilities can also interfere with higher level skills such as organization, time planning, abstract reasoning, long or short-term memory and attention. It is essential to be aware that learning disabilities can affect an individual's life beyond academics and can impact relationships [2].

It is well known that each person inherits a significant amount of genetic information from their parents and as they grow up, their environment and experiences also shape their characteristics and development. There are more young people than adults with learning disabilities. Learning disabilities are quite common. These children need additional support at school to get the best chance to learn academic skills [1].

A learning disability is a consequence of a difference in the way that a person's brain is "wired." People, children with learning disabilities are as intelligent as their peers. But they may have difficulty reading, spelling, writing, reasoning, recalling and organizing information if left to figure things out by themselves [2]. With the appropriate support and intervention, children with learning disabilities can succeed in school. Not all minds think alike in the world [3].

Learning disabilities are very variable from one child to another. One person could struggle with reading and spelling, while another loves books but can't understand math. Or maybe another child may have difficulty understanding what others are saying or communicating out loud. The problems are very different, but they are all learning disabilities [4, 5]. Some of the learning disabilities are Auditory Processing Disorder (APD); Dyscalculia, Dysgraphia, Dyslexia, Language Processing Disorder, Non-Verbal Learning Disabilities, Visual Perceptual/Visual Motor Deficit, Attention Deficit Hyperactivity Disorder (ADHD), Dyspraxia and Executive Functioning [2, 3].

For this specific case study, the Dyspraxia disability was analyzed because of the effects that it produces in the attention deficit in children of scholar age. The Dyspraxia or motor difficulty refers to issues with movement and coordination whether it is with fine motor skills (writing, cutting,) or gross motor skills (jumping, running) [6-8].

Signals that a child might have a motor coordination disability include problems with physical abilities that require hand-eye coordination [1, 6-8]. Children can exhibit poor balance; may appear clumsy; may frequently stumble. Also, they show difficulty with motor planning, exhibits weakness in the ability to organize self and belongings, shows possible sensitivity to touch, may break things or choose toys that do not require skilled manipulation. They have difficulty with fine motor tasks such as coloring between the lines, cutting accurately, putting puzzles together, or pasting neatly, irritated by scratchy, rough, tight or heavy clothing [1, 6-8].

978-1-5386-2521-7/18/$31.00 ©2018 IEEE

Nowadays, with the new Information and Communication Technologies (ICT) and emerging technologies available in the world, several researchers have proposed interventions through gamified structured activities [9]. In this sense, there has been a significant development of therapies for different disabilities based on educational games called as Serious Games (SG) [10, 11].

The SG definition has shifted over time; however, the earliest version was coined by Clark C. Abt, in the 1970 paper entitled "Serious Games." He says: "We are concerned with serious games in the sense that these games have an explicit and carefully thought out purpose and are not intended to be played primarily for amusement." [12] SG is often regarded as promising teaching and learning tools for the 21st century [13, 14].

One of the main arguments is that games are attractive to nowadays students [15]. Furthermore, a significant issue and challenge are developing SG together with technology-enhanced learning approaches such as Augmented Reality (AR) [16]. In this way, emerging technologies are a great promise [17] because they motivate children with new challenges; providing a rapid feedback, that is tailored to the specific interests and individual needs. These Augmented Reality Serious Games (ARSG) should be able to capture their attention and enhances the communication process using experimentation and simulation manipulated by physical movements (interface) [18], working in real environments with virtual elements in order to achieve the augmented effects with AR.

An urgent need exists to plan and propose innovative treatments using technology to help children with Dyspraxia that adapts to the requirements through the motion-based on the natural user interface. It could offer endless possibilities of more natural interaction, which can recognize hand and body gestures, making it an ideal tool to provide creativity to therapeutic activities combined with ARSG.

So that, the primary goal of this study is to show the results obtained after a training process with two groups of children using an ARSG prototype called ATHYNOS. It was designed according to proper intervention practices established by experts in the field of Dyspraxia to improve hand-eye coordination skills, feedback, interactivity, and problem-solving. This prototype took advantage of the AR and natural interface using 3D virtual environments and Kinect, this case study helped to evaluate the effectiveness of ARSG.

Firstly, general information related to dyspraxia, serious games and augmented reality was introduced in this paper. Section 2 presents the ARSG design process. Section 3 describes the research methodology. At last, the article finishes with the conclusion of the study.

II. ATHYNOS DESIGN PROCESS

For this research work, four stages were considered (analysis, design, development, and evaluation) on the software lifecycle [19]. The analysis phase comprises the study of the requirements, taking into account the scenarios, pedagogical aspects, learning contents and playful [20, 21]. This process determines a set of stages whose primary objective is to identify the different elements of the production of the SG. In this phase several criteria were establishing [22]:

- Goal for the game
- Fun add-ons (sounds, video, 3D effect, etc.)
- Rewards (for game progress and game success)
- Desirable child-centered content
- Randomness to provide surprise

Concerning learning activities, five criteria were chosen:

- Organization of the learning material
- Formative feedback on learning
- Appropriate language (even as images)
- Consistency of learning presentation
- Interactivity (to increase engagement)

In the design phase, digital resources necessary for the creation of the SG must be created, including 2D and 3D illustrations, structured objects, sounds and music that reflect the analysis specifications. Also, it defined the interrelation between educational content and training [23]. This stage emphasizes the relationship of the educational objectives and the challenges of the game, which are developed implicitly. It was defined the rules and mechanisms of play. Kinect enables players to control and interact, using a natural user interface with gesture commands.

The development phase describes the tools and software resources required to create the SG. For ATHYNOS, a desktop platform (Microsoft Windows) was established using Unity 3D [24] as a powerful gaming engine, combined with the C# high-level programming language. It has excellent compatibility with Unity, and you can reach the widest audience with 25+ platforms across mobile, desktop, console, TV, AR, VR and the Web.

For the graphic design, Adobe Illustrator [25] allowed the imagery development (characters, props, environments), Adobe After Effects [26] software was used to implement/prototype animations and to optimize output presentation. Finally, Adobe Premiere Pro [27] allowed editing professional videos. On the other hand, audition tools like Ableton Live permitted to create a music sequence, and Adobe Audition [28] was used for audio post-production.

For the creation of Augmented Reality application, the Software Development Kit (SDK) Vuforia [29] was selected, which enables that other devices consolidate the game´s interfaces. Kinect for Windows SDK 2.0 [30] was also used to combine all game elements through a natural user interface. All those tools, under an integrated development environment, using the best programming practices.

The SG evaluation phase is complemented by two roles: the end user and the expert, which consolidate the different aspects that were developed in the previous steps. In this process, goal validation, feedback, and testing technic were verified [31].

A. Game Characters

ATHYNOS has eight characters; each one is represented by an avatar of identification and completes actions. A scenario

contains scenes and multimedia elements, which are part of therapeutic challenges. It is important to mention that characters are well-known personalities from Ecuadorian culture (Figure 1).

Figure 1. ATHYNOS characters.

B. *How to play ATHYNOS*

1. The therapist explains the procedure to start the game.
2. Each child has to login into the game through an avatar selection. There are six avatars, which represent children from Ecuadorian regions. Each child must choose one and then write his/her name using a natural interface.
3. A video is shown to explain the characters present in ATHYNOS.
4. After that, a menu of scenarios is displayed, which contents different type of therapies. There are three levels (beginners, intermedium and advanced), the difficulty level corresponds to the skills and capabilities of the player.
5. The therapy showed in Figure 2 represents Shapes scenario. The goal of this scene is to match the character on the right side with the correct shape on the left side. Inside of the game, a database saves registers of time, success, and failures occurred during the play mode.
6. Results are shown on the screen.
7. Finally, feedback sessions were planned.

Figure 2. Screenshot of Shapes scenario in ATHYNOS.

III. METHODOLOGY RESEARCH

A. *Participants*

Study participants were 40 children (20 boys and 20 girls), (M= 50%; F=50%) divided into two groups in randomly and independently manner to avoid possible slant in the sample (20 children in each group). The age average is 7.3 years old (SD=0.73).

To carry out a comparison, the first group was called Control Group (CG), under an only traditional teaching-learning method and on the other hand, the second group, called Experimentation Group (EG), using ATHYNOS game. All of them are receiving therapies in public and private centers located in Riobamba city (Ecuador). Centers' director received the parent´s written permission for children's participation in this work. For this experimentation, two specialized psychologist/therapists had been responsible for conducting and applying intervention sessions.

Each child was invited to attend four sessions, in each meeting a manual puzzle therapy and ATHYNOS game prototype were used. Additionally, a random order of children's participation was established in each session, which lasted approximately 20 minutes. The manual puzzle therapy was a pedagogic game for sensorimotor education, and it consisted on to matching letters and words with figures according to the therapist instructions.

Time of activities execution, and performance were registered by each student, taking into account the grade scale of the Education Ministry of Ecuador (1-10), where 1 means the lowest grade, and 10 is the best one. See Table I.

Table I. Grades scale of the Education Ministry of Ecuador

Grades	**Meaning**
10	Exceeds the learning
9	Master the learnings
7-8	Achieves the required learning
5-6	Is close to achieving the learning
≤ 4	Does not achieve the required learning

Source: Art. 193. Guide for the application of the student assessment [32].

B. *Procedure*

At each session, the time to solve the assigned activities by the children were recorded. With these data, the time average of all meetings for each child was calculated. After that a statistical analysis was made. Using the Shapiro-Wilk test, it was possible to determine that data distribution is not normal. That was the reason why the Wilcoxon method was used since there was a significant difference among the time distributions, obtaining a *p-value = 6.748e-08 < 0.05 (Table II)*. The comparison between time results of both therapies is presented in Figure 3 and Figure 4.

Table II. Time statistic summary (Minutes)

Method	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Manual	3.530	3.697	3.840	3.798	3.913	3.990
ATHYNOS	2.010	2.330	2.605	2.590	2.945	3.010

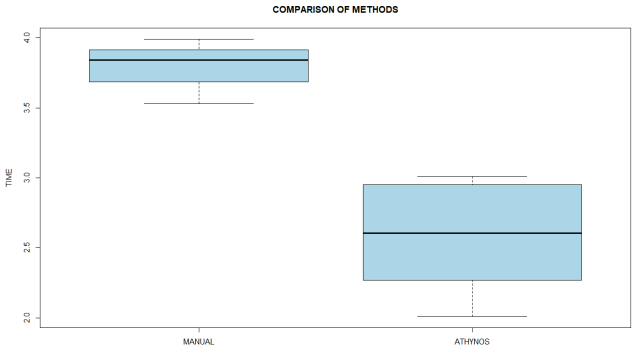

Figure 3. Boxplot of results obtained by Comparison of Time Distributions.

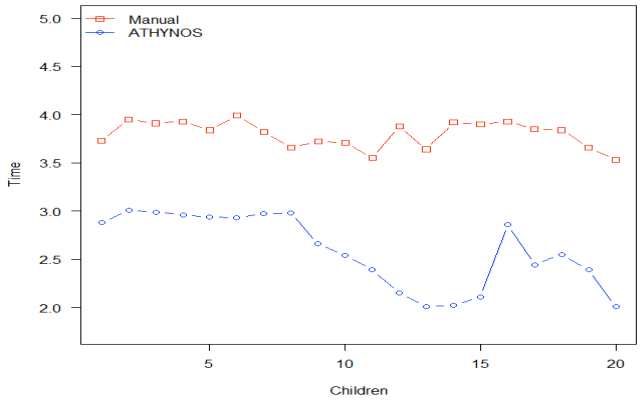

Figure 4. Exploratory analysis of Time.

A score was given for each student in each session as an assessment of children, considering the right answers and failures. After that, the ratings were registered, and with this data, averages were calculated for each student, and they are called in this work as academic performance.

So that, in an analog way, using the Shapiro-Wilk test, it was possible to determine that distribution of the data is not normal. That was the reason why the Wilcoxon method was used since there was a significant difference among the grades distribution, obtaining a *p-value =0.0001077 < 0.5 (Table III)*.

Table III. Student Performance statistic summary (Grades scale)

Method	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Manual	6.250	6.500	7.000	7.013	7.500	8.000
ATHYNOS	7.250	7.250	8.125	8.012	8.500	9.000

The comparison between performance results of both therapies is presented in Figure 5 and Figure 6. The statistical analysis was made using R software in both cases with time and academic performance.

C. Results

The boxplot and the descriptive analysis of data confirm that the execution time of children's activities is longer when they work with manual therapy activities. Meanwhile, when children used ATHYNOS game, there was a significant decrease in the time used by children at the therapies. As a result, there was an improvement in their motor level and hand-eye coordination based on boxplot of performance. Also, it was observed that the variability of the times obtained by children was homogeneous in both cases, which shows that all children have similar abilities in both methodologies.

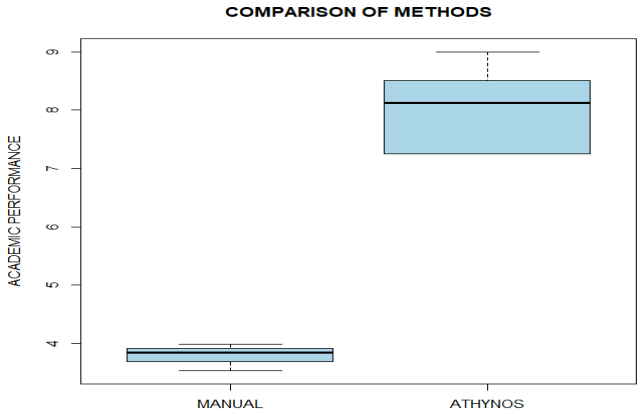

Figure 5. Boxplot comparison of performance Distributions

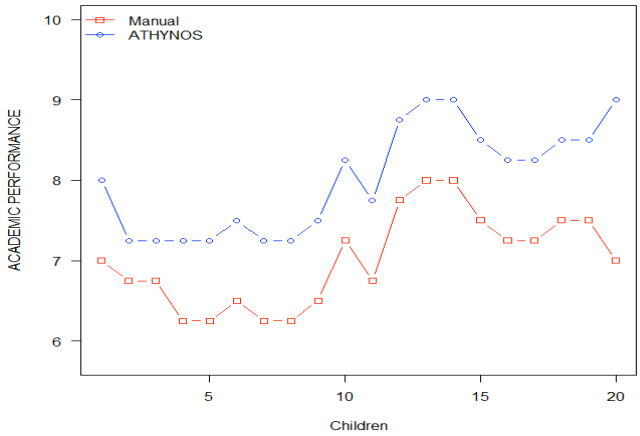

Figure 6. Comparative analysis of Academic Performance between CG & EG.

IV. Conclusions

The primary goal of this study was to improve children motor skills through ATHYNOS game. It helps children to be more engaged in physical training and improving their bodily-kinesthetic intelligence taking into account that children are digital natives. They had the chance to acquire a particular pattern of thinking and be more satisfied with fine motor skills. In the game, the difficulty level corresponds to the skills and capabilities of the player.

The proposed research methodology regarding the times and performance given by ATHYNOS prototype presents statistically significant improvements at 95% confidence concerning manual method. The children improved their learning about hand-eye coordination, bilateral integration, and sequencing. The fun element is one of the essential characteristics of the game. Also, ATHYNOS provide feedback on player achievements and let know what activities

are doing successfully. It is relevant since it motivates children to meet the challenges set in the game.

ATHYNOS Serious Game can be used as a good alternative in the age of the Information and Communication Technologies (ICT) and emerging technologies. Several studies have proposed interventions of therapies for different disabilities based on emerging technologies (AR) using natural user interface.

For future work, authors consider improving the game integrating new levels and activities. In addition, it is required to test ATHYNOS with more children of different experimental groups in order to validate the preliminary results obtained in this study.

REFERENCES

[1] S.-A. Cooper, A. Henderson, M. Jacobs, and E. Smiley, "What Are Learning Disabilities? How Common are Learning Disabilities," ed: Scottish Learning Disabilities Observatory, 2016.

[2] G. R. Lyon, "Learning disabilities," *The future of children,* pp. 54-76, 1996.

[3] C. E. Kass and H. R. Myklebust, "Learning disability: An educational definition," *Journal of Learning disabilities,* vol. 2, pp. 377-379, 1969.

[4] N. Crane, A. Zusho, Y. Ding, and A. Cancelli, "Domain-specific metacognitive calibration in children with learning disabilities," *Contemporary Educational Psychology,* vol. 50, pp. 72-79, 2017.

[5] S. Graham, "Attention-deficit Hyperactivity Disorder (ADHD), Learning Disabilities (LD), and executive functioning: Recommendations for future research," *Contemporary Educational Psychology,* 2017.

[6] A. Alfrey, J. Mishell, J. Burks, S. Contiguglia, H. Rudolph, E. Lewin*, et al.*, "Syndrome of dyspraxia and multifocal seizures associated with chronic hemodialysis," *ASAIO Journal,* vol. 18, pp. 257-261, 1972.

[7] M. Dziuk, J. Larson, A. Apostu, E. Mahone, M. Denckla, and S. Mostofsky, "Dyspraxia in autism: association with motor, social, and communicative deficits," *Developmental Medicine & Child Neurology,* vol. 49, pp. 734-739, 2007.

[8] L. A. Kurtz, *Understanding motor skills in children with dyspraxia, ADHD, autism, and other learning disabilities: A guide to improving coordination*: Jessica Kingsley Publishers, 2007.

[9] G. Charitaki, "The effect of ict on emotional education and development of young children with autism spectrum disorder," *Procedia Computer Science,* vol. 65, pp. 285-293, 2015.

[10] K. C. Bul, I. H. Franken, S. Van der Oord, P. M. Kato, M. Danckaerts, L. J. Vreeke*, et al.*, "Development and user satisfaction of "Plan-It Commander," a serious game for children with ADHD," *Games for health journal,* vol. 4, pp. 502-512, 2015.

[11] K. Caro, A. I. Martínez-García, M. Tentori, and I. Zavala-Ibarra, "Designing exergames combining the use of fine and gross motor exercises to support self-care activities," in *Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility*, 2014, pp. 247-248.

[12] C. C. Abt, *Serious games*: University press of America, 1987.

[13] M. Qian and K. R. Clark, "Game-based Learning and 21st century skills: A review of recent research," *Computers in Human Behavior,* vol. 63, pp. 50-58, 2016.

[14] I. Bortone, D. Leonardis, M. Solazzi, C. Procopio, A. Crecchi, L. Bonfiglio*, et al.*, "Integration of serious games and wearable haptic interfaces for Neuro Rehabilitation of children with movement disorders: A feasibility study," in *Rehabilitation Robotics (ICORR), 2017 International Conference on*, 2017, pp. 1094-1099.

[15] J. Bourgonjon, M. Valcke, R. Soetaert, and T. Schellens, "Students' perceptions about the use of video games in the classroom," *Computers & Education,* vol. 54, pp. 1145-1156, 2010.

[16] R. T. Azuma, "A survey of augmented reality," *Presence: Teleoperators and virtual environments,* vol. 6, pp. 355-385, 1997.

[17] R. McHaney, *The new digital shoreline: How Web 2.0 and millennials are revolutionizing higher education*: Stylus Publishing, LLC., 2012.

[18] K. de Greef, E. D. Van der Spek, and T. Bekker, "Designing Kinect games to train motor skills for mixed ability players," in *Games for Health*, ed: Springer, 2013, pp. 197-205.

[19] N. Yusof and R. M. Rias, "Serious game based therapeutic: Towards therapeutic game design model for adolescence," in *e-Learning, e-Management and e-Services (IC3e), 2014 IEEE Conference on*, 2014, pp. 40-45.

[20] E. Boyle, T. M. Connolly, and T. Hainey, "The role of psychology in understanding the impact of computer games," *Entertainment Computing,* vol. 2, pp. 69-74, 2011.

[21] S. Cano, J. M. Arteaga, C. A. Collazos, C. S. Gonzalez, and S. Zapata, "Toward a methodology for serious games design for children with auditory impairments," *IEEE Latin America Transactions,* vol. 14, pp. 2511-2521, 2016.

[22] J. C. Read, G. Sim, A. Gregory, D. Xu, and J.-B. Ode, "Children designing serious games," *EAI Endorsed Transactions on Serious Games,* vol. 1, pp. 1-9, 2013.

[23] J. Hamari, D. J. Shernoff, E. Rowe, B. Coller, J. Asbell-Clarke, and T. Edwards, "Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning," *Computers in Human Behavior,* vol. 54, pp. 170-179, 2016.

[24] *Unity 3D*. Available: https://docs.unity3d.com/Manual/UnityOverview.html

[25] *Adobe Illustrator*. Available: http://www.adobe.com/products/illustrator.html

[26] *Adobe AfterEffect*. Available: http://www.adobe.com/la/products/aftereffects.html

[27] *Adobe Premiere Pro*. Available: http://www.adobe.com/la/products/premiere.html

[28] *Adobe Audition*. Available: http://www.adobe.com/la/products/audition.html

[29] *Developer SDK Vuforia*. Available: https://developer.vuforia.com/

[30] *Kinect for Windows SDK 2.0*. Available: https://www.microsoft.com/en-us/download/details.aspx?id=44561

[31] I. Mayer, G. Bekebrede, C. Harteveld, H. Warmelink, Q. Zhou, T. Ruijven*, et al.*, "The research and evaluation of serious games: Toward a comprehensive methodology," *British Journal of Educational Technology,* vol. 45, pp. 502-527, 2014.

[32] W. Ortega, "Instructivo para la aplicación de la evaluación estudiantil," ed: Quito: Ministerio de Educación del Ecuador, 2013.