DiagnosTEA: a digital game as a tool for the diagnosis/therapy of Autism Spectrum Disorder

Bruna Barbosa[1], Marcos W. Ribeiro[2], Luciana Berretta[1,3], Sergio Carvalho[1,3]

[1]Institute of Informatics (INF) – Federal University of Goiás (UFG)
Goiânia – GO – Brazil

[2]Institute of Exact and Technological Sciences (ICET) – Federal University of Jataí (UFJ)
Jataí – GO – Brazil

[3]Advanced Knowledge Center for Immersive Technologies (AKCIT)
Federal University of Goiás (UFG)
Goiânia, GO – Brazil.

bruna_mota@discente.ufg.br, marcos_ribeiro@ufj.edu.br

{luciana.berretta, sergiocarvalho}@ufg.br

Abstract. *Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by criteria present in the domains of socio-communicative deficits and behavior. Considered challenging to diagnose and consequently lacking appropriate therapeutic applications, autism presents significant challenges for the scientific community. This study aims to design and develop a digital game as an auxiliary solution for diagnosing and treating ASD. As a methodology, a Systematic Literature Review was conducted to understand, adapt, and qualify specific concepts and methods related to ASD that can be used as particular features of a digital game built using the Unity Game Engine, with a suitable game genre and theme, along with scales and parameters that allow adaptation to the principles associated with the disorder. As a result of this research, a digital game for ASD named DiagnosTEA was created and tested to validate the entire process.*

Keywords *Autism Spectrum Disorder, Digital Games, Diagnosis, Therapy.*

1. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that is defined by a set of criteria in two domains: socio-communicative deficits and behavior. The term "spectrum" was adopted because the manifestation of the disorder presents itself differently in each individual with different impairments. Despite the heterogeneity in autism, all forms of manifestation are related to the deficits mentioned above [Navan e Khaleghi 2020, Silva et al. 2020b]. The Diagnostic and Statistical Manual of Mental Disorders (DSM), published by the American Psychiatric Association (APA), is a reference text designed to assist mental health professionals in qualifying mental disorders. In its 5th edition, the DSM-V (2013), autism is included as a neurodevelopmental disorder and no longer as a Global Developmental Disorder (GDD). The objective is to diagnose individuals more consistently, thereby enabling the implementation of targeted interventions to facilitate their cognitive, motor, and socio-emotional development [Camargos 2005].

Given these considerations, the potential for utilizing digital games in this context has become evident [Yang et al. 2021, Honorato et al. 2021, Dias et al. 2021, Silva et al. 2020b, Silva et al. 2020b, Oliveira et al. 2021]. Consequently, it is imperative to ascertain the viability of this dynamic relationship and identify the characteristics that would emerge from this interaction between the individual and the game.

A review of the relevant literature indicates that digital games have been employed in treating individuals diagnosed with ASD. This type of interactive, playful activity has been shown to facilitate the development of cognitive, communication, and Language skills, which are essential for achieving progress in the disorder [Souza e Barbosa 2015, Elshahawy et al. 2020, Zhang et al. 2021, Carreño-León et al. 2021, Barajas et al. 2017].

This contextualization and problematization contribute to this work, resulting in a set of necessary achievements to reach the work's objective. The contributions are based on the premise that games help create a more comfortable environment for individuals with ASD and help reduce the subjectivity of the diagnosis.

This work aims to develop a game called DiagnosTEA, which will serve as a supporting tool in diagnosing children with ASD. This involves selecting a diagnostic scale that can be applied in digital games related to ASD, analyzing and choosing the game's context (theme and genre), and validating and analyzing the game through tests conducted by specialists in technology and the behavioral area.

This paper is divided into six sections. The second section presents some works related to using games in the therapy and diagnosis of ASD. The third section describes the game development methodology. The fourth section, in turn, presents the implemented game, covering its architecture, mechanics, interface, and operation. The fifth section shows results regarding users' first contact with the game. Finally, the sixth section presents the final remarks and future research work.

2. Related Work

The methodology for analyzing related works was based on search strategies established in the principles of a systematic literature review. The research sources utilized included the Association for Computing Machinery (ACM), the Scientific Electronic Library Online (Scielo), the IEEE Xplorer, the Periódicos CAPES and SBGames, and articles published in both Portuguese and English between 2017 and 2023. The search strings employed were *ASD*, *Profiles*, *Behaviors*, *Therapy*, *Diagnosis*, *Heuristics*, *Digital Games*, and *Game Genres*.

During this protocol stage, a methodology was developed to analyze the works qualitatively. Four criteria were established to assess if the work had a good presentation, a clear and defined methodology, some form of validation, and addressed the research question. The articles were selected based on their titles and abstracts in the initial phase. Those articles that appeared to be relevant to the objective of this review proceeded to the second phase, during which their content was evaluated, and the aforementioned criteria were applied.

The literature review initially found 209 studies for analysis. After applying inclusion/exclusion and quality criteria, 33 studies were chosen. Finally, seven selected studies aligned with this research and provided essential information regarding their

contribution. These selected works were instrumental in conducting the study and defining its contribution, which involved the construction of the DiagnosTEA.

All the analyzed studies addressed the profile and behavior of individuals diagnosed with ASD. They all synthesized the fundamental characteristics of this population. ASD is a neurodevelopmental disorder that impacts social skills and verbal and non-verbal communication and includes repetitive behaviors [Silva et al. 2020a, Khabbaz et al. 2017, Zhang et al. 2017, Honorato et al. 2021]. While these general characteristics exist, each patient presents a unique combination of symptoms [Navan e Khaleghi 2020]. Therefore, the diagnosis must be personalized, as ASD is a spectrum ranging from mild to severe [Silva et al. 2020a].

Regarding the age range, 70% of the studies fully considered this aspect, emphasizing the importance of early childhood as a basis for research and defining a specific age range for the use and testing of gamification. [Hulusic e Pistoljevic 2017, Silva et al. 2020a, Navan e Khaleghi 2020, Barajas et al. 2017]. The studies focus on early childhood. According to [Khabbaz et al. 2017], symptoms are identified from the beginning of brain development, typically in the 2 to 3-year period, when children express themselves more explicitly [Meng et al. 2021]. Some of the selected works tested children aged 3 to 7 years old [Zhang et al. 2017, Yang et al. 2021, Khabbaz et al. 2017, Carreño-León et al. 2021], while a few extended the range and tested some adolescents up to 15 years old [Barajas et al. 2017, Elshahawy et al. 2020]

All the studies we reviewed focused on using digital games in therapy and diagnosis, emphasizing their important role in assessments [Dias et al. 2021, Hulusic e Pistoljevic 2017, Barajas et al. 2017, Navan e Khaleghi 2020]. The work [Zhang et al. 2017] mentions that diagnosing using the scale can be subjective, depending on the evaluator, mainly because ASD manifests in different degrees. Therefore, using games helps control the child's environment, allowing for real-time data collection through gamification and providing simultaneous stimuli and feedback. This enables a more comprehensive data collection for analysis [Yang et al. 2021, Elshahawy et al. 2020, Mohd et al. 2019].

The studies emphasized the importance of defining attractive patterns for individuals with ASD. Ensuring that the game environment follows heuristics and patterns helps maintain the child's focus, avoids overwhelming them with excessive information, and reduces the subjectivity of diagnoses. The digital games developed should adhere to these heuristics [Silva et al. 2020a, Khabbaz et al. 2017, Silva et al. 2020b, Elshahawy et al. 2020, Hulusic e Pistoljevic 2017, Liu et al. 2021, Carreño-León et al. 2021].

Although the studies do not directly discuss the use of a specific game genre [Dias et al. 2021], they all follow a similar line of reasoning by developing various minigames to stimulate learning, psychomotor development, and social interaction in children with ASD. Therefore, the genre of games is not explicitly addressed.

The aspect of avatarization was not well addressed. Only one study discusses using avatarization in a virtual environment for children with autism [Liu et al. 2021]. Another study briefly mentions using avatars as an example within the game without exploring its applicability or the importance of the child's identification with the

environment to keep them engaged in the game [Meng et al. 2021].

Based on the analyzed studies, none have a data storage system that relies on feedback from interactions within the virtual environment. Only one study includes this feature, creating a medical record for patients within the game, but it does not store data based on diagnostic or therapy scales. Instead, it captures EEG data during the child's gameplay [Yang et al. 2021].

The research emphasizes digital games' significance in diagnosing and treating ASD. Establishing patterns and heuristics in the virtual environment ensures patients feel fully engaged. Therefore, it is important to target early childhood for diagnosis, as symptoms are more identifiable during this stage, and early intervention leads to better long-term results. This work aims to create a digital game for use in diagnosis and, potentially, therapy. The key differentiator of this project is the integration with a clinical scale, which would allow the collected data to be directly available to the evaluators. Additionally, the game would feature an avatarization component, enabling a more immersive and personalized user experience. The presented contribution will support the entire game development process.

3. Game Development Methodology

Figure 1 depicts the various stages of the development of the DiagnosTEA game. The stages are outlined in the following subsections.

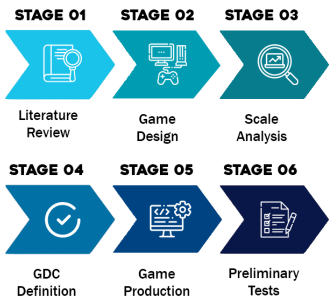

Figura 1. The DiagnosTEA game: development methodology.

3.1. Literature Review

A systematic literature review was conducted to provide a theoretical foundation for using digital games for diagnosis and therapy [Barbosa e Ribeiro 2023]. The review yielded insights indicating that integrating digital games with established scales and methods is a promising approach for diagnosing and treating Autism Spectrum Disorder (ASD). The studies with the highest scores based on presentation, methodology, and validation were selected by the inclusion and exclusion criteria and addressed the research questions. In this context, the PEP-R scale was identified to identify patterns in individuals suspected of having ASD. Based on this, the game design process was initiated, encompassing the entire conceptualization and focusing on demonstrating the applicability of scales in a digital game context.

3.2. Game Design

The game design process entails conceptualizing a game to create a virtual environment with designed scenarios and interactions. Initially, the game's context was meticulously considered through a creative process called brainstorming, which involved individuals with expertise in digital games and the subject of autism spectrum disorder (ASD). Scales, patterns for the child to identify with the environment, and targeting the pediatric audience were taken into account to achieve a harmonious relationship between the game and the patient.

The selected game genres, namely role-playing games (RPG) and simulations, permit players to assume various roles within the game context. This allows players to develop their narratives and progress through predetermined rule systems. The RPG and simulation genres provide a framework for players to immerse themselves in the game world, assuming specific personas and navigating the experience through established game mechanics.

By selecting these genres, the researchers can create an environment where users can engage with the content more effectively and personally. The RPG and simulation elements facilitate the players' ability to explore, make decisions, and shape the game's progression in alignment with their preferences and playstyles.

This genre selection aligns well with the research objectives, as it allows for creating a tailored gaming experience that can potentially benefit the target audience, in this case, autistic children. The RPG and simulation mechanics provide a flexible and dynamic platform for developing meaningful interactions and fostering engagement within the game world.

3.3. Scale Analysis

The scales in the seven analyzed works from the previous section were studied to establish criteria for diagnosing Autism Spectrum Disorder (ASD).

The PEP-R scale, addressed in [Zhang et al. 2017], defines the developmental age of autistic children. This scale is based on two areas: one grounded in development, constructed from empirically established norms based on performance obtained in children, and the second focused on behavior based on the CARS scale (Childhood Autism Rating Scale to Diagnose) [Pereira et al. 2008] and Creak's criteria [Leon et al. 2004]. PEP-R scale can be used for children aged 1 to 12 years and includes the assessment of the following dimensions:

- Development: Imitation, Perception, Fine motor skills, Gross motor skills, Eye-hand coordination, Cognitive development and Verbal cognitive development.
- Behavior: Relationship and affection, Play/materials interest, Sensory responses, and Language.

This method is suitable for research because it can be applied in digital gameplay and covers various dimensions [Zhang et al. 2017]. The process involves playing a set of minigames, interacting with the environment and Non-Player Characters as guides, quest-givers, or sources of information to help advance the player's progress in the game, and collecting data from the feedback generated by the game's interactions. This data can

then be used to calculate and establish a scale. Using a virtual environment can lead to less subjective diagnoses for patients with ASD, as it makes them more comfortable and reduces the reliance on the evaluator's expertise.

3.4. GDC Definition

In this stage, the Game Design Canvas (GDC) was developed. The GDC is a simplified document that contains all the relevant information for game design, organizing the conceptual ideas in a clear, single-page format. The document is structured into 11 topics: platform, concept, gameplay, game flow, controls, interfaces, game world, bosses and enemies, mechanics and powers, characters, and cutscenes.

3.5. Game Production

The game production stage entails implementing the game, which is influenced by decisions about its architecture, the tools used, and the platform on which it will run. The game was created using the Unity Game Engine[1] and is compatible with the Windows operating system.

3.6. Preliminary Tests

To assess the tool for validation purposes, a form was created divided into three sections: one about user information, one concerning software usability, and one evaluating the integration of the PEP-R scale into gameplay.

The form collected user information, including gender, age, and educational institution. Users also answered questions regarding their level of knowledge of digital games. It was found that hardcore gamers tend to understand gameplay more succinctly than casual gamers.

Finally, the usability of the developed software was evaluated using the System Usability Scale (SUS), a widely used instrument for assessing the usability of software. The SUS is based on three main criteria: effectiveness, efficiency, and satisfaction [Brooke et al. 1996], [Geraldes et al. 2019], [Majer e Duduchi 2019].

The game DiagnosTEA was evaluated using the Goal/Question/Metric (GQM) approach [Caldiera e Rombach 1994] and [Petri et al. 2018]. GQM establishes a measurement system directed toward goals by raising goal-oriented questions and identifying metrics that provide answers to those questions according to the following levels: Conceptual level (goals), Operational level (questions), and Quantitative level (metrics).

Based on the SUS model by [Brooke et al. 1996] and the procedure proposed by [Rosenkind 2015], the following goals, questions, and metrics were developed:

- **Goal 1:** Analyze the digital game to assess the impact of usability in the design.
- **Question 1:** What score was obtained using the SUS method?
- **Metric 1:**
  - AVERAGE_OK: The average score obtained in SUS is greater than or equal to 68 points.

[1] `http://www.unity.com`

  - AVERAGE_WEAK: The average score obtained in SUS is less than 68 points.
- **Goal 2:** Evaluate the use of PEP-R within the gameplay of the virtual environment.
- **Question 2:**
  - Does the game provide a welcoming environment for individuals with ASD?
  - Are the chosen minigames relevant in identifying the evaluative dimensions of PEP-R?
  - As a healthcare professional, would you use the game as an evaluative aid?
  - Was the data collection of interactions relevant for evaluation?
- **Metric 2:**
  - PROTOCOL_OK: Average percentage of responses of "strongly agree" or "partially agree."
  - PROTOCOL_WEAK: Average percentage of "strongly disagree" or "partially disagree" responses for all questions.

Regarding Goal 1, if the obtained metric is AVERAGE_OK, it can indicate that the proposed digital game allows users to understand the game mechanics correctly. Regarding Goal 2, if the minimum average of PROTOCOL_OK is greater than 60% and PROTOCOL_WEAK is less than PROTOCOL_OK, it can be interpreted that the PEP-R scale is suitable for the game context.

4. The DiagnosTEA Game

The game was developed as a tool designed for healthcare professionals to be utilized as one of the mechanisms in the diagnostic process to create a comfortable and relatable environment for the child. The familiar environment with family interactions within daily life gives the child greater immersion. The game mechanics enable the child to contemplate the parameters established by the PEP scale, which assesses fine/gross motor coordination, eye-hand integration, and cognitive development. Additionally, it allows for the simulation of relationships and affections, play/interest in materials, and sensory responses. The game's functionality is shown through the game trailer[2].

The game's architecture is structured as shown in Figure 2. From this, a main module was defined for the game environment encompassing the graphical interface. Inherent to this module are the Avatar, the Home Environment, which interacts with two other minigames (Puzzle and Memory Game), and the School Environment, which also interacts with two minigames (Matching Game and Expressions). In this way, the player interacts with all the modules within the main module.

Figure 3a depicts the primary interface of our game. This interface enables the player to start gameplay and select the game options menu, where they can adjust the ambient sound (BGM) and special effects sound (SFX) levels, as illustrated in Figure 3b.

Pressing the "Start" button will load the "Load Menu" screen. This additional menu allows the evaluator to create multiple games for different patients and save the progress separately, as Figure 3c exemplifies. By clicking on one of the "Load + number"

[2]Available at `https://www.youtube.com/channel/UCzbrpgSrgk57fdAhlhvyJlg`

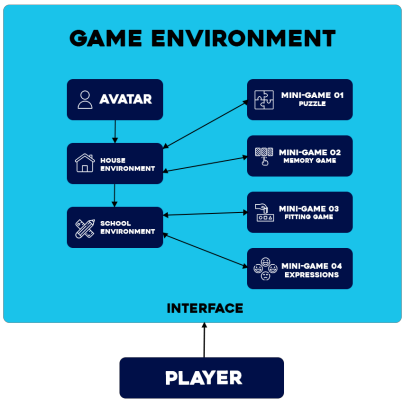

Figura 2. General Architecture

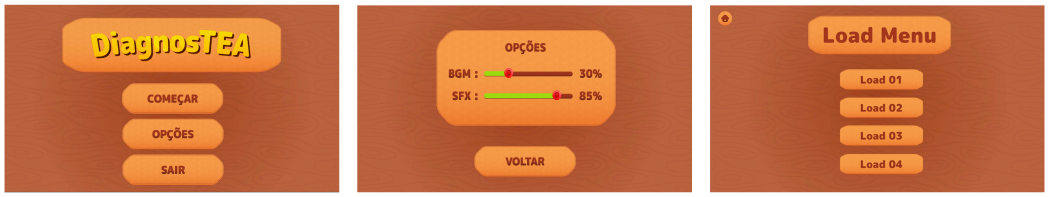

Figura 3. (a) Main Menu (b) Options (c) Load Menu

buttons, it will be verified if a character has already been created, and if so, the game will start from the point at which it was previously left.

Otherwise, users can choose one of twelve avatars to start their adventure. Figure 4a presents the avatar selection menu. The game begins with the character waking up in their room, as shown in Figure 4b.

Figura 4. (a) Avatar Menu (b) Running game (c) Inventory

The player uses the computer keyboard keys to move the main character. In addition, the character needs to interact with the NPCs so that they can earn rewards at the end of the proposed activities to compose the missing items in their inventory. To access the inventory, simply press the button with the available icon in the top left corner of the screen, as shown in Figure 4c. Figure 5a shows the NPC behaving normally without interacting with the main character. Figure 5b shows an interaction between the main character and the NPC and its result. After interacting with the NPCs, collectible item boxes appear in the environment, as shown in Figure 5c, so the player can contact them to load the minigames.

When approaching the item, a panel opens, like the one in Figure 6a, inviting the

Figura 5. (a) Before the main character's interaction with the NPC (b) Main character interaction with NPC (c) Collectible item

player to enter the minigame. The user can accept or decline entering this activity, but this implies that the character will not move on to the next phase, as they need to complete their inventory to progress in the story. If the patient chooses to decline, they will remain in the environment and can return to the activity whenever they want. Otherwise, when accepting the challenge, the scene of one of the minigames will be loaded.

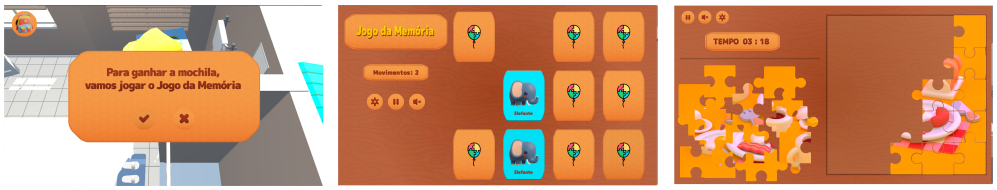

Figura 6. (a) Panel to start minigame (b) Memory game (c) Puzzle

The memory game has a panel of 12 cards on its left side, all with the background facing the player. When clicking on the cards, an image of animals (Sloth, Snake, Elephant, Lion, Rhinoceros, and Bear) will appear with their names written on the bottom. When the player matches the combination correctly, the cards will disappear from the screen, or, in case of an error, they will return to their initial reverse side. Figure 6b shows the minigame in progress.

Figure 6c shows the interface of this minigame, where 25 shuffled pieces are arranged on the left side of the screen, while on the right side, there is a grid to position the pieces properly. The auxiliary menus (Pause, Settings, and Mute) have the same functions as the previous minigame. Instead of showing the number of moves, this minigame displays the timer since the number of moves, in this case, does not need to be evaluated.

5. Results

Data collection was carried out through an online form in which the users answered the questions after their first contact with the game. Eighteen (18) participants between 18 and 65 years old agreed to participate in the evaluation process. Fifteen participants (15) are from the Federal University of Jataí, with the remaining from outside the institution.

Regarding the users' experience with digital games, 60% consider themselves casual players, and all confirmed that they have already played simulation games. This data balance affirms that the users most likely did not have difficulties understanding the game objectives and were aware of the possible functions involved in this genre.

The first metric proposed by the GQM model in section 3.6 is to evaluate the system's usability. The average obtained by the SUS was approximately 91 points. Thus,

it is concluded that the metric **MEDIA_OK** was achieved, proving that the instructions for the game operation were sufficient. The second metric proposed by the GQM was to evaluate the presence of pedagogues, teachers, and psychologists who had worked with ASD patients to check if the protocols (PEP-R) were contemplated.

Based on the values presented in Figure 7, it can be concluded that the metric **PROTOCOLO_OK** was achieved with a 100% response rate, being higher than the established average and that none of the evaluators answered ”strongly disagree”or ”partially disagree,”confirming that the protocol parameters were explicitly present in the gameplay. It should be noted that the ”WEAK”assessment considered whether the majority of the PEP-R scale items were contemplated.

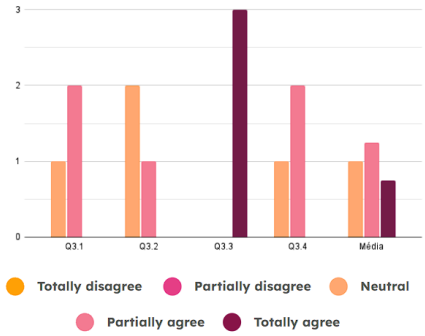

Figura 7. Result from questions about protocols.

6. Conclusion

From this, it is understood that autism is not considered a disease but a developmental disorder that can be identified based on behavioral signs during early childhood. Its signs range from mild to moderate and severe, and with the intervention of qualified professionals, they can be attenuated through therapeutic support. The diagnostic indication typically starts around 2 or 3 years old to minimize the impact on the child’s development. Still, family members often resist getting the autism test, leading to avoidance.

Due to this necessity for intervention, the use of digital games plays an essential role in the diagnosis and therapy for identifying signs of ASD. In this context, the virtual environment offers, for example, a more pleasant medium for the child and helps overcome resistance barriers from family members. The results were obtained through evaluations or observations, demonstrating that the professionals involved showed interest in applying the DiagnosTEA with their patients as a diagnostic tool. The game incorporates evaluative parameters from the PEP-R scale within its gameplay to enable data collection resulting from this interaction. It is understood that there is a need to improve how current diagnostic assessments are conducted to reduce subjectivity. Therefore, as future work, there is the intention to add an interface for evaluators to have the ability to track patient records within the application itself, to test the game with both neurotypical children and those with ASD to make a comparison based on the data collected from the game. This will enable the creation of a diagnostic guideline based on this survey, as we would have a comparative study of the behaviors of children with and without ASD within the same age range.

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