The protocol of a serious game based on Virtual Reality to aid in the literacy of children with Intellectual Disability

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Figure 1: Starting screen of the game "*Aprendendo com Tarefas*"

ABSTRACT

The usage of serious games as learning support tools for children, with specific and dynamic content may be helpful in many educational challenges, exploring cognitive aspects that favor learner's development. This work aims to develop an educational game titled *Aprendendo com Tarefas*, in order to facilitate the literacy of children with Intellectual Disability. In order to implement the game, it was used a Unity 3D game engine and programmed with C Sharp. The three-dimensional objects and the virtual environment were modeled using 3ds Max 2017. Through the Virtual Reality technology, a protocol was created to support the teaching of the writing and pronunciation of various day-to-day objects. Based in three different activities, the child must search for many objects at home and at a shopping mall, in order to complete the proposed activities. During the game's tasks, children have the opportunity to learn how to speak, write and even spell the words used during the activity. The set of words and activities was established by a group of professionals who work with these children in the classroom. After finding all objects, the child must return home to conclude the proposed activity, thus finishing the game. The protocol for facilitating the alphabetization of Intellectual Disability children was approved by teachers and professionals of the educational field, validating the game as a tool for supporting education.

Keywords: intellectual disability, literacy, serious games, virtual reality.

1 INTRODUCTION

The discussions about inclusive education had a considerable increase in recent years and, consequently, actions and interventions for students presenting any of these types of disabilities.

In this way, it is necessary to understand the current context of inclusive education in Brazil. To specify the intellectual deficiency picture first is important to define it.

1.1 Intellectual Disability

Over the past few decades, many scientific explanations and definitions about Intellectual Deficiency (ID) have been topic of discussions [1]. For a long time, the quantification of the intellectual quotient (IQ) was used as a way to define and classify the individuals' cases, however this assessment is not considered the primordial indicator of ID today, since great importance has been given to the adaptive behavior of the individual with this kind of deficiency [2].

According to Almeida [3], the definition of Intellectual Disability is related to the individual's incapacity characterized by significant limitations regarding intellectual functioning and adaptive behavior, being expressed in social, conceptual and practical skills, always originating before 18 years old.

According to Schalock et al. [4], ID is characterized by intellectual functionality being below average in a significative way, according to limitations associated with two or more areas of adaptive behavior or the individual responsiveness in relation to social demands, considering the aspects related to communication, personal care, locomotion, health and security, scholar development, leisure and work.

According to 2010 Census [5], Brazil has a total of 2,844,937 individuals with permanent intellectual disabilities. In relation to children up to 14 years old, this number is 482,025 individuals, being: 104,048 between 0 and 4 years, 159,970 between 5 and 9 years and 218,007 between 10 and 14 years.

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According to Cárnio and Shimazaki [6], two ways to teach people with Intellectual Disability are found in the literature: the first one related to reductionist interventions, supported by training and routine practices for the teaching of specific skills, performed in isolation of a context. The second is related to the elaboration of integrated methods with the different areas of human knowledge and therefore contextualized. Thus, this second way of teaching includes the combination of oral teaching, writing and reading.

1.2 Traditional techniques used in the literacy of children with Intellectual Disabilities

In what concerns to the literacy of children with intellectual disabilities, some techniques are traditionally worked in the classroom, being divided for the purpose of this study in computerized and non-computerized.

It is important to emphasize what Malaquias [2] affirm regarding of the importance of mediation of an adult in the learning process of the apprentice with Intellectual Disability, considering that it has slow progress.

1.2.1 Traditional non-computerized techniques

Lima et al. [7] elucidates about some activities the teacher could work with the student, like pretend play, story counts, rules games and other classroom techniques that encourages the knowledge of letters and spelling.

Thus, the process called Phonological Awareness begins, with the characterization of the perception and distinction of words, manipulation of syllables and phonemes, and thus relating the oral and written, always interacting with things, people and activities.

These traditional non-computerized techniques have a role in the classroom and are a fundamental part of the literacy process of these children. However, they have the disadvantage that they do not cover many daily activities of an individual. Thus, a greater difficulty in aiding the memorization of day-by-day objects and things and may make the literacy process even slower.

1.2.2 Traditional computerized techniques

The use of games to aid the children's literacy process can be an excellent support, taking advantage of these children's interest in playing games and child plays, learning the activities proposed by the rules of the game. In this way, the electronic games can contribute a lot to the process, considering the current technological development and the children's propensity to this type of entertainment.

Thus, several serious games have been developed with the purpose of supplying many existing demands in several fields of knowledge. Therefore, traditional computerized techniques also have an important role in the literacy process of children with intellectual disabilities, since they can replicate the daily activities and some of the interests of these individuals in general.

However, even the traditional computerized techniques alone cannot solve all of the questions related to the child's involvement with the game proposal, and it is necessary to use solutions that provide greater immersion and interactivity for the proposed computer activities.

1.2.3 Virtual Reality as support for serious games

Virtual Reality (VR) is a technology that allows the creation of a graphical environment with realistic appearance, allowing the user to move in three dimensions, in addition to an interaction where the virtual objects can be sensed and manipulated. Thus, VR can offer a natural human-computer interface, providing immersion in a computer-generated environment through the multisensory channels of vision, hearing, touch, smell or taste [8].

This technology has great potential to contribute to the cognitive process of the student, providing an environment that brings a practical experimentation and similar to the reality of the interactions that the child has with the real-world and his/her daily activities.

In this way, Standen and Brown [9] states that children with intellectual disabilities are generally deprived of real-world experiences. These experiences, for a non-disabled child, provide the opportunity to acquire the skills and abilities to become independent in the future.

Thus, the characteristics and benefits of VR can improve the cognition and practice of social skills, justifying its use as a technology to support the literacy process of intellectual disabilities children.

2 Related Work

As related work, five games developed to aid in the teaching and education of children with intellectual disabilities were evaluated.

Software's "Programa Participar" [10] goal is to help children and young adults with mental disabilities learn how to read. In addition, it allows students to interact with society and social networks. This software utilizes multimedia resources, and other tools that provide decent user's interaction, but do not have the immersion aspect provided by VR.

MoviLetrando [11] is a game developed to associate movements and activities that help children with Down's syndrome, considered a mental disability. The game uses a webcam to capture the player's image and the game's scenario to use them in a virtual reality projection technique. The player must move in order to complete the tasks, touching the virtual symbols showed on the screen and keeping a score of right movements.

MoviLetrando possesses different levels that work on movements and symbols that can assist on literacy. However, the game is not to help on everyday tasks and objects.

The game *My Appearance* [12] is part of a serious game project, developed to assist students with mental disabilities on morning activities, simulating a series of everyday duty, giving users feedback in the end. In the game, the player is at his home, with a clean cartoonish type of interface. The game, as the others, does not support aspects of VR immersion, and its interactions are already predefined.

VirtualMat [13] is developed with VR technology and it has a virtual environment that assists students with mental disabilities to learn math.

In order to serve as learning auxiliary tool, the game has some usual interactive activities such as to search for some object or comparing products in the grocery. Thus, the game meets the aspects of immersion and environment interaction, but as mentioned, its goal is to serve as a math auxiliary tool, not as a literacy-learning tool.

Developed with augmented reality technology (AR), the work "*Aplicação de Realidade Aumentada Móvel para apoio à alfabetização de crianças com autismo"* [14] created an application to help literacy learning using smart devices, showing pictures as if they were real using AR.

With the usage of markers, the system exhibits letters and syllables, creating words. The app contains various distinct sections to display images. The system provides an attractive interface to children, considering the use of a mobile device and AR. However, it works only with objects and isolated words, and not with daily tasks and activities.

Considering the related works, we perceived a gap in a system that provides an interactive bridge between everyday tasks and literacy and speaking of the objects used in the children activities.

3 Proposed System

The game *Aprendendo com Tarefas* is a virtual environment modelled on 3ds Max 2017 software, developed in the game engine

Unity 3D, using the C Sharp programming language, and aims to be a serious game to support the literacy of children with intellectual disabilities, observing aspects of interaction with the environment and providing a simple and close to reality gameplay.

The target audience for the game is students with intellectual disabilities enrolled between the first and fifth years of elementary school.

3.1 Requirements and Protocols

The requirements and protocols that guided the development of the game were raised together with two professionals of Education area, who have direct action with special education, listing a set of guidelines necessary for validation of a game that serves as support for the literacy process.

3.1.1 Requirements

The requirements raised and proposed for the game were:

R01 (Requirement 01): The literacy process must be supported in a playful way, arousing children's interest and providing an environment of interaction and creativity in everyday contexts.

R02: Work with objects and situations that may be part of the child's daily life, categorizing them and working with their particular aspects as a function and visual characteristics.

R03: Provide different situations in which children can interact with specific objects according to these situations.

R04: Show the written form of the objects, their syllabic separation and pronounces when the children interact with these objects.

R05: Dispose the objects in the environment in order to teach the students where to find them and their purpose.

R06: Allow the mediator teacher to intervene in the development of the objectives to work with the fundamental concepts in the literacy process.

R07: Intuitive and familiar for the children and their learning processes, using upper case in the texts, besides a simple font, which the students are accustomed.

R08: Have spoken instructions that direct the development of the game to the fulfillment of its goal. Even the spoken instructions should have the text seen by the students, in order to stimulate reading and comprehension of text and speech.

R09: Work with the objects' color.

R10: Stimulate the student through feedbacks according to his actions and successes encouraging him, and in the mistakes do not discourage the user, but help him to pursue the goal.

R11: At every game's transition, give instructions and stimuli through speech and written texts on the screen.

R12: Represent a house with living room, kitchen, bedrooms and bathroom, where are arranged some objects that will be sought by the student. Represent a city with several houses and a mall.

R13: Have two distinct types of objects to look for: objects found in the house, and objects that are not at home and that will be found and bought in the different stores of the mall.

R14: Guide the child in relation to the place where the object sought can be found.

R15: Use of non-immersive Virtual Reality technology, supporting student interaction using mouse, keyboard and monitor.

These raised requirements directed the entire process of game development and all activity is carried out in order to understand them.

3.1.2 Protocols

The game development protocol was elaborated considering the various aspects related to the importance of the issue of literacy of individuals with Intellectual Disability. Thus, given the need for an approach regarding the activities of teaching reading, writing and speaking of words that are associated with the context of the activities lived in the routine of children.

In this way, the activities performed in the game meet the requirements described, which were specified exactly to fit the approach described. Thus, a review of the systems developed related to serious games for the teaching of individuals with intellectual disabilities was carried out, in order to understand which of these requirements are being met and how they are used as a support for inclusive education.

As a directional strategy, the study will be carried out in two distinct public schools at Uberlândia City, Minas Gerais State, with children enrolled between the first and fifth year of elementary school, as defined by the target public. The children will be oriented by their teachers in the use of the game, intervening for the correct use and encouraging the fulfillment of its objectives. Thus, all support for the literacy process using a serious game will be contemplated.

Prior, at the beginning of the *Aprendendo com Tarefas* application, each student will receive a story that discusses various elements that the child will encounter in the game, in order to evaluate the understanding of the text and later learning through the system.

In addition, questionnaires will be applied to the teachers to evaluate the game and the students, regarding the performance of each student. The game will be evaluated in how it was effective as a tool to support the literacy process of children with intellectual disabilities.

Finally, also as an object of evaluation, the game measures the time spent performing the task and the number of errors choosing the objects by the player.

3.2 System Architecture

In order to meet game's protocol, the system architecture was designed to contemplate the interface between the activities proposed to aid literacy and the child's playful involvement with the game.

The virtual environment consists of a small city with some houses, the outdoor environment with sidewalks, streets and trees, and a mall with seven different shops: a clothing store, shoe and accessories store, toy store, pharmacy, snack bar, supermarket and ice-cream parlor.

The game's flow follows three distinct tasks, which the child will choose to play in the initial scene. Each of these tasks has two separate lists: a house objects list and a shopping list. Each list has eight objects. These lists vary according to the chosen task, but the objects' layout in the virtual environment is the same for the three planned activities.

Although the lists are distinct, the objects to be found are shown to the child in the same list, always available on the upper right corner of the screen. Three objects from each list are randomly selected at the beginning of the game, totaling altogether six objects that the child must look for to complete the task.

While searching for these objects in the environment, the child has the opportunity to interact with all other objects of the city, providing learning of those objects that are not in the lists.

After finding the three objects in the house, the player receives a message to find the other three objects in the mall. Thus, the child is directed to leave the house and go to the mall, strolling through the city. After completing the purchase of all items, the player is directed back home, completing the activity and winning the game.

In the final screen, the results obtained by the child are shown with a button to record on a text file these results.

The activity diagram of Figure 2 illustrates the description of the activities of the game.

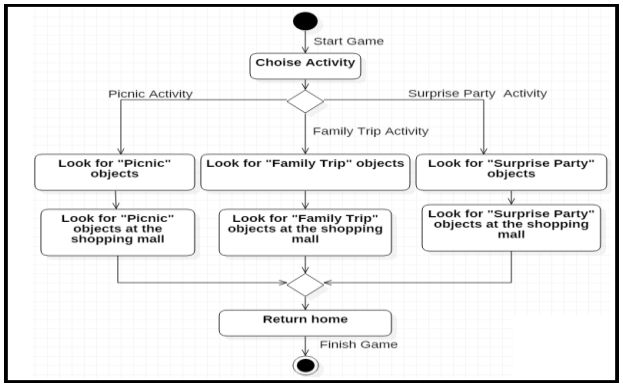

Figure 2: Game's Activity Diagram

The Use Case Diagram presented in Figure 3 demonstrates the interaction between the actors (child and teacher) and the system tasks.

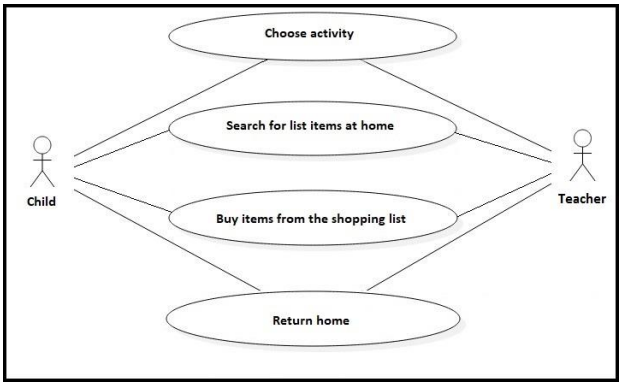

Figure 3: Game's Use Case Diagram

A diagram of game's architecture overview was also elaborated, as shown in Figure 3, which demonstrates the interaction between the game's user and the graphical interface, as well as the interaction between the virtual environment and all programming logic with the same graphical interface presented to the user, and the recording of results on the hard disk.

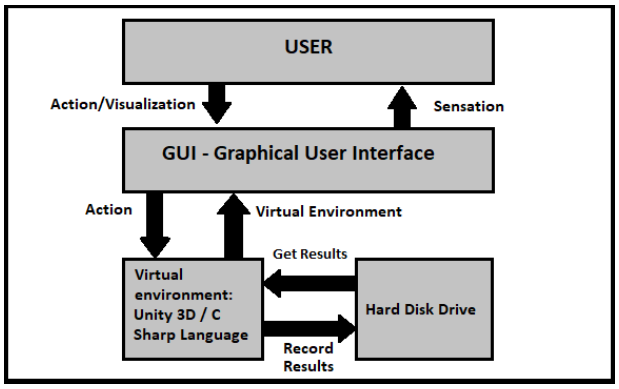

Figure 4: Game's Architecture Overview

4 Experiments and Results

In order to meet the protocol, VR technology was used in the game's development, in which the interactivity aspect of the student with the virtual environment was met, according to the requirements proposed in R01 and R15.

When playing *Aprendendo com Tarefas*, the child is expected to progress gradually in the linguistic aspects considering writing, reading and speaking. Thus, the virtual environment was developed meeting the requirements proposed to fulfill its objectives. Figures 5 and 6 show, respectively, the child's room in the virtual environment and the full city view, as proposed in R12.

Figure 5: Child's room in the virtual environment

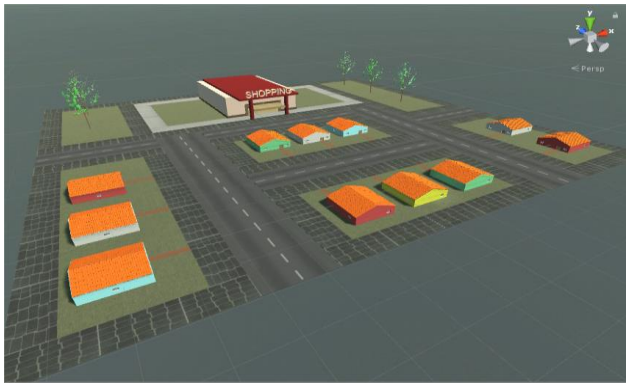

Figure 6: Complete city on Unity 3D engine.

As the game possesses three distinct activities for children, contemplating R02 and R03, the list is always available on the screen so that the player can always see the objects to be searched for. The objects that have already been found are marked with the green background and those that have not yet been found have a white background.

Figure 7 shows how the objects list is represented.

Figure 7: List of objects to be found on the upper right corner of the screen.

After finding the objects that are at home, the player is oriented to go to the mall to buy objects that are not at home. Thus, as shown in Figure 8, the child should look for the objects in the stores, fulfilling requirement R13.

After the object is chosen correctly, it will be marked yellow in the list, indicating that the object was found and needs to be purchased in the store. After purchasing the item found in the store, it will be marked with green in the list.

Figure 8: Player in the mall searching for the objects

The interaction between environment and child must be continuous, the player must be oriented about what he must do and how he will find what he needs.

Throughout the game, various messages are showed and spoken to the child, as long as necessary for them to listen and gradually associate then.

All the feedback, notices and the narrative itself are given to the student in both visual and audio stimuli, always at the beginning and the ending of an activity.

Figures 9 and 10 illustrate how written messages appear on the screen, always in uppercase to provide the best understanding of the child with Intellectual Disability, which appears at the same time as their corresponding audio is played, paused and clear, for a correct understanding of what he/she should do.

Thus, with these feedbacks and guidelines in spoken and written forms, the game meets the requirements described in R08, R10 and R14.

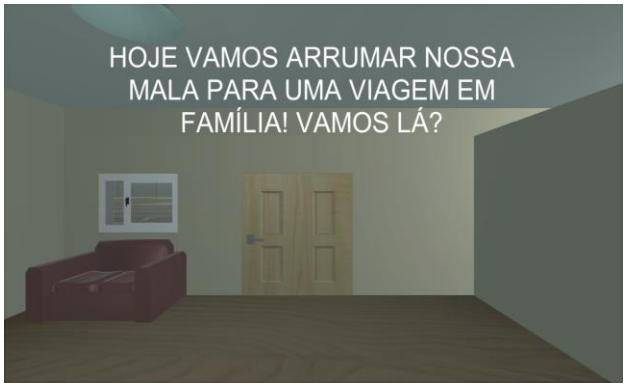

Figure 9: Message to the child on the proposal activity

Figure 10 also shows how the messages are displayed to the player according to its progress in the game, alongside with the audio description and the written text, serving as feedback to the player.

Figure 10: Orientation and stimuli message to the child

In the interaction between players and the virtual objects, some precautions were taken to fulfill the system requirements.

As shown in figure 11, the objects names and their syllabic representation are presented to the player and he can choose either to pick the object or to hear its pronunciation. The objects are disposed according to their category and are colorful because then, colors can also be used as a teaching tool. Therefore, the requirements R04, R05 and R09 were fulfilled.

Figure 11: Screen of child interact with game objects

Figure 12 illustrates the feedback given to the player when he chooses correctly an object, by means of text and accompanied by his respective speech.

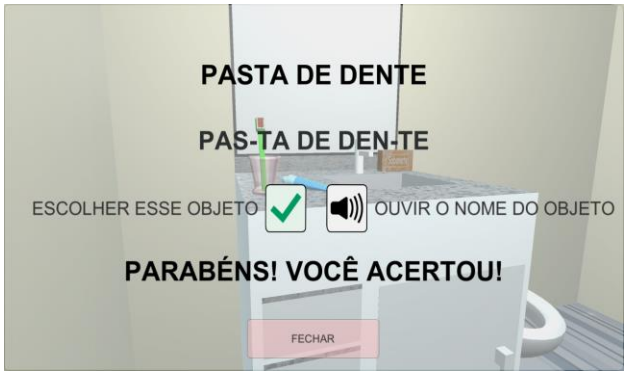

Figure 12: Feedback screen on object selection

In the end of the activity, a new screen is presented. In this moment, the teacher must help the child to write his own name for the result be recorded in a file for post.

The information presented are: theme's name, time spent and error count, which is the metric to the amount of wrong picked objects. The final screen is presented in figure 13.

Figure 13: Final Game Screen

The game has a screen for viewing children's results, which can be accessed from the main menu. In this screen, the results of each child are presented, as shown in figure 14.

Figure 14: Children's Results Screen

Throughout the game, as mentioned before, the text presented to the child is according to the system requirement R07, making the understanding of the word clearer to the apprentice.

Thus, the specified requirements and protocols proposed to the game underwent by both teacher's and educator's evaluation. They were approved to be used as an auxiliary tool in literacy of intellectual disabled children, as specified in requirement R06. Hence, the game is apt for usage and evaluation.

5 Conclusions and Future Works

With this work, we build a protocol to develop a serious game entitled *Aprendendo com Tarefas*, an educational virtual environment, on which the requirements were determined according to studies related to the theme, to serve as a supporting tool for the teaching and learning of children with intellectual disabilities.

Therefore, we evaluated the requirements and the protocols used by teachers and educators involved with intellectual disabilities.

The results appointed that requirements and protocols are valid to corroborate the developed game, enabling it to be evaluated as a serious game, suggesting a positive impact on literacy processing overall. This is due to a profound interaction with the virtual environment, its dynamics and activities flow.

VR techniques and its characteristics provided the construction of a friendly environment for the children's interaction with objects and tasks. This makes the exercise more ludic and attractive, making it a tool the assists but not replace the traditional literacy techniques.

Therefore, with the use of the support of other activities or even other software, *Aprendendo com Tarefas* can contribute on surpassing the limitations of these individuals [4], regarding aspects of communications, personal care, social skills, community and family behavior, school performance, work among other aspects.

Considering individuals with intellectual disabilities as a heterogeneous group, presenting distinct cognitive style [2], we hope to apply and evaluate the developed game regarding each individual student in this condition.

As future work, the system will be applied in two different schools to assess the game's capacity to assist in the literacy process. There will be a qualitative and a quantitative evaluation throughout questionnaires and students performance before and after the usage of the game.

6 Acknowledgements

The authors thank FAPEMIG *(Fundação de Amparo à Pesquisa do Estado de Minas Gerais)* and CAPES *(Coordenação de Aperfeiçoamento de Pessoal de Nível Superior)* for the financial support, which made this project possible.

We also thank the Federal University of Uberlandia, to Biomedical Engineering Laboratory (BioLab – FEELT/UFU) and Graphic Computing Laboratory (LabCG - FEELT/UFU) for the technological and structural support.

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