INCLUSIVE DIGITAL LEARNING THROUGH SERIOUS GAMES: A CLIPPING FOR INCLUSION

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ABSTRACT

Serious games have a great potential to help people developing new skills or improving previously existing ones. Deaf and blind community face considerable challenges and difficulties regarding to the acquisition of skills in literacy. The design of serious games to meet the needs of the target groups where the deaf and blind people are struggling to master literacy would therefore seem to offer a very considerable contribution. With this project, not only we are promoting the knowledge for this restricted community, but we are also encouraging other people to learn and become able to better understand this communities. Therefore, this article aims to discuss the use of serious games for deaf and blind people, as well as illustrate the development methodology of inclusive serious games by presenting specific concepts for each target audience. We have used the cognitive model proposed by Mayer (2005) to describe some fundamental principles behind multimedia learning, defined from his theory and based on the evidences that are essential for the elaboration of serious games for deaf and blind people. We hope that the games developed, and guidelines provided will help game designers to achieve successful implementation in inclusive games.

KEYWORDS

Serious Games, Inclusive Games, Accessibility, Design Model for Inclusive Games, Development Methodologies for Inclusive Games, Assistive Technology

1. INTRODUCTION

The popularity of digital games has skyrocketed in a last couple of decades – the Entertainment Software Association reports that 60% of Americans play digital games daily and 70% of parents believe video games have a positive influence on their children's lives (Entertainment Software Association, 2018).

Game as a concept can be labeled as an activity where components such as temporal limitations, an area defined to play or rules to keep participants rights and duties intact, while providing a competitive environment different than usual (Huizinga, 1970). According to Avedon and Sutton-Smith (1971), "games are an exercise of voluntary control systems, in which there is a contest between powers, confined by rules in order to produce a disequilibrial outcome".

A game represents a subjective and oversimplified emotional reality. It is not objectively an exact representation of reality, in fact is mainly represented enough to fulfil a player expectation. A player's fantasy is the key to make a game psychologically real (Crawford, 1984). When it comes to interaction, which not only is associated with game representation, there's ways to make it dynamic and to change it accordingly through interactions. A player can't distort reality by making simple choices and see the unfolding of those events. There can be physical threats towards the player, however, a game allows the player to experience psychological conflicts without having any physical alteration, resulting in an action / consequence dissonance. Crawford (1984) refers that even though it may not threat the player in real life, it can have a negative impact in the game by missing a reward for instance.

Michael Zyda (2005) pointed that the primary objective is to create daily simulations to offer training for professionals, enterprise critical situations or raise awareness in a diverse age bracket to topics such as education. Serious games combine digital games with entities to fulfil a theoretical practical education. Learning is the guiding force and includes educational games, business games, simulation games, among others, and they cross a whole range of topics, contexts and target groups (Sørensen & Meyer, 2007).

Serious games have a great potential to help the population develop new skills or improve previously existing ones. However, part of the population does not have the means to play these games. Some may be unable to experience all the elements that are present in these games. Besides, larger companies usually do not develop games for these audiences considering their reduced size (Cardoso *et al.*, 2016). That is why inclusive games were created, "games proactively designed to optimally fit and adapt to individual gamer characteristics and to be concurrently played among people with diverse abilities, without requiring particular adjustments or modifications" (Grammenos *et al.*, 2009).

This article aims to discuss the use of serious games for deaf and blind people, as well as show the development of serious games inclusive, presenting specific concepts for each target audience.

2. DESIGN MODEL OF INCLUSIVE GAMES

During the process of designing inclusive games, Mayer's principles on Multimedia Learning (Mayer, 2005) were applied as a form of quality validation. All the examples provided in this section follow these principles, alongside a quality evaluation model.

2.1 Game Development Methodologies for Deaf People

Considering the way in which deaf people organize thought and language, as well as the potential of the students' development in the visual field, the project of serious games needs to be designed through a visual-spatial perspective. Therefore, we develop serious games following the "deaf way", that is, "a way of formulating ideas based on imagery representations capable of being translated in the Sign Language itself and in visual aspects" (Rodrigues & Quadros, 2015).

Such an understanding does not deny the presence of the oral Portuguese language to listeners, who are also part of the audience of the game proposed here. The idea here, as suggested above, is that there are advantages in adopting different languages, Portuguese and Libras. In addition, if the visual-spatial perspective – whether being that through Libras or imagery texts – is essential for deaf people, for the non-deaf it is extremely enriching. Within this context, the use of serious games reveals great potential in the field of educational sciences, because in this modality "thought is mapped by domains of distinct concepts, structured by image schemes" (Galasso, 2014).

Currently, there are several research projects exploring multimedia instruction and learning focusing on hearing students; however, studies focusing on deaf students or students with some kind of hearing impairment are rare. When developing serious games for deaf people, we also take into account some principles based on knowledge about how the brain processes information during learning. According to Mayer (1997), one of the most important areas of Cognitive Psychology is the understanding of technology as a tool to promote efficient learning. Through the main theories of cognition, concrete and effective learning occurs following a few steps or stages. In Figure 1, we provide how information processing occurs according to Mayer's Cognitive Theory of Multimedia Learning (2005), adapted to the perspective of the deaf student.

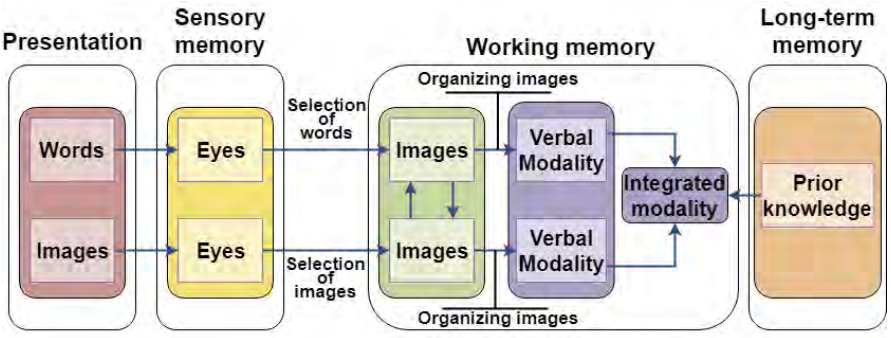

Figure 1. Mayer's (2005) information processing model adapted to the perspective of a deaf person

The processing of information starts from the moment the deaf student assimilates images and words from a multimedia presentation, which can be, for example, a game in Sign Language. To capture this presentation, written words and images enter through the eyes of the deaf student and are briefly represented in the sensory memory. Then, in the working memory, the deaf student selects the main words and images and organizes them, categorizing written words in a verbal model, and images in a pictorial model. From this organization an integrated model of information is structured. This integrated model is directly linked to the long-term memory, where the student can activate pre-existing knowledge to be integrated with verbal and pictorial models in the working memory, storing the resulting knowledge in the long-term memory.

2.1.1 Evidence-based Principles in Serious Games for Deaf People

The cognitive model proposed by Mayer (2005) describes some fundamental principles behind multimedia learning, defined from his theory and based on the evidences that are essential for the elaboration of serious games for deaf people:

1. *The Multimedia Principle – Words and images are better than words alone*

This principle proposes the combined use of images and words, as it allows the brain to process more information in the working memory (Paas & Sweller, 2014). Thus, people learn better with words and images than words alone. In this context, words include written and spoken text, and images include videos, animations, and static graphics. In the education of deaf people, which uses Sign Language as a means of communication, images are essential for understanding academic concepts and, when words are used as well, they help students in the learning process. Due to the visual-gestural characteristic, Sign Language can be presented along with the Portuguese Language, respecting the phrasal structure of each one of these languages, composing two informational processing channels necessary for bilingual education. Similarly, in the serious games developed, we present simultaneity between the presentation of Sign Language and characters. This simultaneity enables deaf students to have a variety of integrated learning styles, broadening their understanding of the content worked. The interaction between image and caption constitutes student-oriented meaning, proposing the textual interpretation of the video and its occurrences.

When we use serious games, we strengthen the compatibility of the readings, establishing singular dynamics in the learning process. The application of the concept in the development of bilingual teaching materials also privileges the hearing, since the signaling in Sign Language appears to the students synchronized with the caption and speech in Portuguese Language within the scope of the statement, respecting the syntactic and grammatical structures of each language.

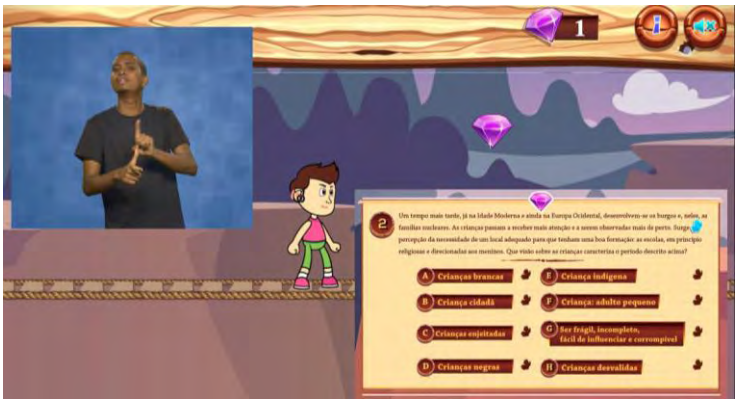

Figure 2. Representation of the Multimedia Principle. In this example, a game designed for deaf and hearing-impaired people that consists of multiple-choice questions about Education

2. *Principle of Spatial Contiguity – Words should appear close to images*

This principle includes spatiality as a didactic element to the learning of deaf students. Animation, as a figuration of reality, ratifies the meaning that the text should convey. From the point of view of bilingual education, the use of images close to words composes a mechanism of interface between the two languages (Sign Language/Portuguese Language), as they are part of the linguistic daily life of the deaf and the hearing. Considering the spatiality of Sign Language, written words should be part of the discourse of the deaf presenter,

since there is spatial interference between the written register of the Portuguese Language and the movements of the Sign Language. Thus, a truly bilingual learning object is structured with the integration of the two languages into the same statement.

3. Segmentation Principle – Contents must be presented by parts

This principle states that people learn best when a multimedia lesson is presented in segments of the user's rhythm instead of a continuous unit. In this context, games are developed at various levels of theoretical depth, so that the student may learn through videos with segmented content.

2.2 Serious and Inclusive Games for Blind and Deaf People

Regarding blind people, the project of serious games needs to be designed with audio-based gameplay. Using this architecture during development allows the user to enjoy the game without the need of a graphical user interface either to interact or understand the application context (Beksa *et al.*, 2015). Even though its target audience is a niche market, these games are often omitted from general population due to its accessibility standards.

Audio games focus group are blind and visually impaired people because they are developed with audio only in mind. With the growth of text-to-speech software and major improvements related to digital assistant voices such as Cortana, Alexa or Siri, serious games targeted to blind people became a must, because "this type of video game has been growing and its use has spread to several areas of education" (Salvador-Ullauri *et al.*, 2017). These tools follow two very important principles in multimedia learning, introduced by Mayer - the Personalization Principle and the Voice Principle. The former states that people learn better when words are in conversational style rather than formal style and the latter promotes learning through hearing a friendly human voice rather than a machine voice (Mayer, 2005). Voice assistants have gradually become more human-like and less formal, trying to make their users feel more comfortable.

These games' narrative is created mainly through sound sources, typically with the help of pre-recorded sounds or text-to-speech limited to the languages implemented by the developers. Moreover, audio games have a tactile or haptic feedback (e.g vibration and/or sound) which can result in an immersive video game atmosphere to blind people (Csapó *et al.*, 2015).

2.2.1 An Example of a Game for Blind People

The Field Trip is a single-player digital game being developed for desktop computers and mobile systems, set in a real-world forest, that develops the player's spatial awareness and orientation, by creating an environment where the player is guided exclusively by sound. It is being developed in Unity3D, using C#. It revolves around the use of 3D audio sources – objects in the world that emit sound depending on the position of the player. This means that if the player is to the right of the audio source, he/she will hear the sound coming from the left, and if the player is to the left of it, the sound will be coming from the right. Moreover, the sound from an audio source only becomes hearable when the player steps into its range, and it becomes louder as the player approaches the center of the source. These audio sources are being developed in accordance to Mayer's multimedia learning principles mentioned in section 2, in order to provide a good player experience.

The game is separated in several layers, each with its own responsibilities, displayed in Figure 3. The user only interacts with the interface layer, which handles the player's inputs and the sounds that the player hears. This layer then interacts with two layers – the game engine and the business layers. The game engine layer is responsible for executing the game, in this case represented by Unity. The business layer manages the logic behind the game, the rules and mechanics that will be described in this section. Lastly, these two layers communicate with the hardware layer, which is the device that is used to play the game.

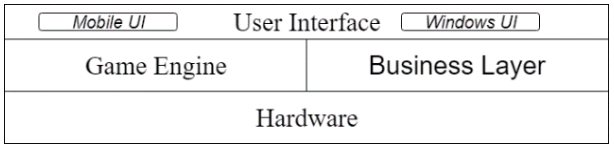

Figure 3. *The Field Trip*'s application architecture

As the player traverses through the world and collects items, he/she learns about the forest they are in, as well as the fauna and flora that is being collected. This allows the player to enhance abilities that are useful not only in the context of this game, but also in real-life scenarios where a person must be guided by sound.

In this game the player has been separated from his/her field trip group and must move through the forest in order to find them, going from the starting (spawn) point to the ending area. To do this the player must rely on his/her senses to figure out where he/she is in the map, given audio cues such as the sound that is made when walking through a certain type of terrain or when stepping on tree branches.

To make the movement through the map more challenging, obstacles block the path that the player is trying to take. Elements such as trees or knocked down logs, big rocks or shrubbery that isn't traversable force the player to make slight detours so that he/she can avoid these barriers. By memorizing which the obstacles and terrain in each area, the player can build a mental map of the forest he/she is in, making movement more effective. The second goal of the game is to collect items that are spread out on the map. These range from animals that the player must interact with, to plants that the player can pick up or water from a waterfall that must be collected. When interacting with these items, voice lines give a short description of the item that is picked up.

When the player reaches the end of the level, his/her score is calculated. Each item has an associated score. Items that are harder to get have a higher score than those that are in the natural path the player walks through. At the end of the level, the final score is the sum of all items collected and a previously determined level completion bonus, minus the time the player took to go from the spawn point to the ending area and the number of times the player died.

Lastly, the player would have the objective of surviving threats that would be placed in the environment. These threats are described in Table 1.

Table 1. Action table for the *The Field Trip* game

Player Event	**Player Response**	**Effect**
Hears bear sound	Moves	Player loses a life and enemy disappears
Hears bear sound	Does not move	Enemy disappears
Hears snake sound or turbulenc in water	Does not press the spacebar	Player loses a life and enemy disappears
Hears snake sound or turbulenc in water	Presses the spacebar	Enemy disappears
Hears bees sound	Stays in range for longer than 3 seconds	Player loses a life
Hears bees sound	Leaves range before 3 seconds have passed	No effect
Is near item	Presses the spacebar	Player gets points, item disappears, and voice line describes item
Loses a life when no lives left		Player respawns in last checkpoint or start of the level
Reaches the end of the level		Player receives level completion points, advances to next level, and voice lines informs player of points
Walks on terrain		Specific terrain sound is played
Walks into map edge		Informative sound is played

Figure 4 displays some of the elements that exist in the game, such as items (represented as small spheres), enemies (the larger sphere acts as a swarm of bees and the cube represents a bear) and different types of terrain (the larger one serves as grass and the smaller one acts as water).

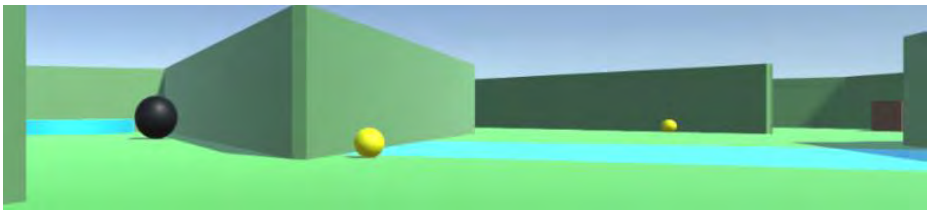

Figure 4. Example of the world in *The Field Trip*

2.2.2 An Example of a Game for Deaf and Blind People

Morseline is a multiplayer serious game in development for computer and mobile systems in order to help users learn Morse code. To that end same tools are integrated to achieve proper support for both blind and deaf people. To assist blind users, a text-to-speech and speech-to-text functionalities are integrated by using Microsoft's Cortana digital assistant Portuguese voice package, while on Android, Google's own text to speech voice packages. In order to support deaf people, GILT's (Graphics Interaction Learning Technologies) own sign language avatar is used to translate all text in-game to Portuguese Sign Language.

The serious game is not only capable to help on learning Morse code, but also lets users test their knowledge against each other. To this end, three game modes were developed. A one-on-one matchup where both users must finish a course that consists in hearing Morse code being transmitted by three telegraphs, and when in close range they will be presented with two options, one being the correct answer and the other one a decoy. The player who decodes more Morse messages by the end of the match wins. A cooperative mode where both users try to get correct answers in order to achieve success. Using implemented chat system, both players can communicate and share their opinion on what the correct answer is by either using voice or text which is adapted on the other player's end following accessibility needs as defined in Section 2. Last but not least, a four-player mode which consists on the same rules as one-on-one mode, but with the purpose to lay foundations for a massive multiplayer online serious game. To this end, an action table was planned to understand game flow since the game start until the game has ended.

Table 2. Action table for Morseline game

Type of Game Mode	Trigger	Object	Action	Result
All types	Check if players have joined game lobby	Player	Load proper game scenario	Game starts
All types	Move to checkpoint	Player	Listen to Morse code on telegraph	Player chooses correct answer
All types	Choose letter that matches listened Morse code	Letter	Reply sent to server	Server waits for all players answers and then proceed them to next checkpoint
All types	Last checkpoint	Lobby	Players reached final checkpoint	Triggers game as finished
1v1 and 1v1v1v1	Check results	Lobby	Calculates new player ratings	Updates player ratings on the server and marks lobby as finished
Cooperative	Check checkpoints progress	Lobby	Players met the necessary criteria	Quest is marked as successful or failed
All types	Game has ended	Server	Verifies if all preceding criteria is verified	Removes players from lobby and sends them back to main menu

After a user picks his desired game mode, he's placed in a queue where he will meet users that are in his range of skill level. With the help of a DDA (Dynamic Difficulty Adjustment), the user will never matchup with someone of much higher or lower skill, but instead with someone of similar competitive level.

When the server meets the necessary players to start a game and allocates them to a game lobby, a message is broadcasted using sockets meaning that an opponent is found and therefore the game will start. Afterwards, when both users connect to the lobby, they are shown a different scenario, and while blind users have audio support given by the implemented voice assistant, deaf users will have their accessibility needs fulfilled by the Portuguese Sign language avatar. Moving towards to the first checkpoint, both players will have Morse cues (either by sound or image) and they have unlimited time to pick the correct answer. Next, a reply is sent to the server where user's answers will be processed and saved while the game is running. It was mentioned before that a DDA is used, and when playing the game, difficulty is adjusted using both user's correct answer streak.

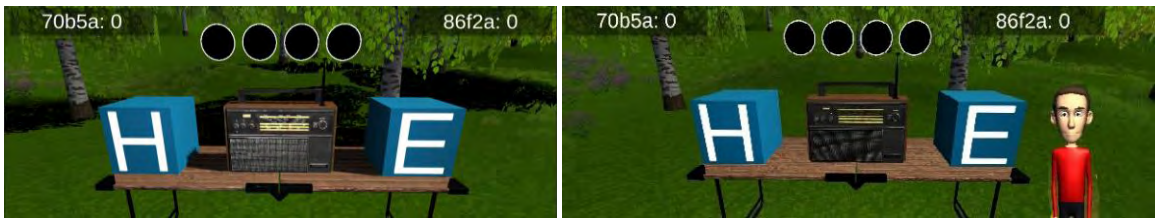

Figure 5. Checkpoint example in a matchup between a deaf user (left) and blind user (right) accessibility point of view

Since it is a multiplayer game, real time difficulty adjustment must be fair for both users so that one won't have a significant advantage against the other. Reaching the final checkpoint and answering the last Morse code message, judging by the answers given, server will then calculate the final score and present it via audio or image to all users inside the game lobby. While one-on-one and four users' modes have a competitive rating, cooperative mode doesn't have that, since its purpose is to let users help with each other along the way.

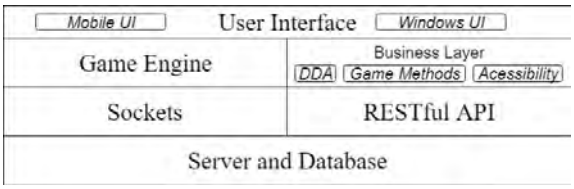

Figure 6. Morseline application architecture

The game is divided into four layers. At the top level there is the user interface. All game functionalities can be accessed through this layer by the user on his preferred device. Actions transmitted by the user go through the following layers. The second layer is where all client-side code is developed, with business layer component containing the DDA, game and accessibility scripts which linked with Unity offer an accessible front-end for its users. The next level which contains sockets and a RESTful API, help pass through information sent and received on users end between the game and server. The fourth layer represents the game back-end, where persistent data is stored with the help of an online hosted database hosted.

3. EVALUATION

We normally use three steps of the Social Networking Learning (Krouska *et al*, 2019) model to evaluate our learning objects:

1) Pedagogical module
- Teaching strategies: The principles and methods that are used for instruction.
- Learning outcome: The system analyses the achievement of the students' learning outcome during the tutoring process.
2) Personalization
- Adaptive interface: It includes adaptive presentation and adaptive navigation. Adaptive presentation is to display certain information based on user's characteristics. For instance, the system will provide more detailed information and capabilities to a user with advanced knowledge level. Adaptive navigator intends to assist users in achieving their learning goals through the presentation of the appropriate options, such as enabling/disabling topics' links.
- Advice generator: It is a component that responds to user when an error is occurred, about the cause of the error, in order to help him or her.
- Error diagnosis: It is a module that can identify the category of assessment's mistakes based on associated misconceptions with the use of algorithmic approaches.
3) Usability
- User interface friendliness: The system is easy to be learned and used

4. CONCLUSION

This work presented guidelines for the design of serious games for deaf and blind people. The process of building digital games, which is based on a diverse set of tasks, requires the structuring of a multidisciplinary team capable of developing pedagogical, linguistic and techniques. We hope that the guidelines provided alongside with system architectures designed for specific accessibility needs, help game designers and game developers to achieve successful implementation in inclusive games, so that players can have an enjoyable learning experience.

In this way, we conclude that the references of multimedia learning combined with the guiding principles of the education of the deaf and blind create a line of development possible, with innovation and interdisciplinary methods, to a deepening of knowledge capable of contributing to the qualitative expansion in the production of inclusive serious games.

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