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Development of a Video Game for Cognitive Stimulation in Early-Stage Alzheimer's Disease

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ABSTRACT

In this research, a video game was developed using Unity and WebGL as a cognitive stimulation strategy for patients with early-stage Alzheimer's disease. The process of construction of the video game began with the definition of cognitive needs and patient characteristics, obtained through literature review and interviews with experts. The interviews were focused on the following skills: memory, attention, the executive function, and problem-solving. These skills can be positively impacted with video games and are detailed according to their degree of impairment in Alzheimer's disease. Next, the story and conceptual methodology of the video game were identified: achieving a certain degree of personalization according to the patient's context, inclusion of rhythmic music that accompanies the player's experience, and adaptation of different difficulty levels based on each patient. The video game is conceptually categorized as a Serious Game and was created with a Game Design Document (GDD) specifying the dynamics and mechanisms of the game. Following, the video game was developed using Unity and WebGL framework. Finally, the patients expressed ease of use of the video game, even for those who had never used a computer, in addition to considering it entertaining, an element that the caregivers confirmed when they perceived interest in the patients at the time of the test, a factor that contributes to adherence to treatment.

Keywords: Videogame, Serious game, Patients with early-stage alzheimer's disease, Unity, Webgl, Game design document

INTRODUCTION

Alzheimer's Disease is considered the most common Major Neurocognitive Disorder today and is related to serious memory problems (Patterson, 2018). However, many diagnosed people with this disease also have neuropsychiatric symptoms in some point of their lives (Lyketsos et al., 2011); For instance, it is presumed that 90% of affected individuals with Alzheimer's dementia have this symptomatology (Volicer, 2018). Also, one or more psychological or behavioral symptoms affect nearly people with dementia in the course of their illness (Kales et al., 2015).

To optimize the effectiveness of pharmacological measures in the treatment of neuropsychiatric symptoms, while are reducing the risk of adverse events, several multimodal approaches have been designed, that mean to combine pharmacological treatment with cognitive, behavioral, psychoeducational, occupational and family interventions. The results of these combinations have led to the conclusion that the most useful approaches to maintain and maximize functioning in Alzheimer's disease, to reducing the caregiver's burden and improving quality of life, are those that mix individualized and interdisciplinary (García-Casal et al., 2017).

On the other hand, although multimodal interventions benefit both patients with this disease and their caregivers, attending programs in person is complicated for them, because some people live in rural areas, and it is difficult for them to travel. Therefore, it is necessary to have multimodal interventions that use telehealth technologies (Curioso and Galan-Rodas, 2020). One of the strategies recently included as fundamental part of several technology-mediated therapies, is based on the use of video games (Mocanu et al., 2016). The approach to this type of strategies should include the personalization of the interactive elements according to the patient's needs (Astell et al., 2014). This is why not any commercial game can be useful in the cognitive stimulation of patients with Alzheimer's disease (Chang et al., 2013).

Among the non-pharmacological measures for the treatment of Alzheimer's, it has been demonstrated that video games can have useful effects in delaying the degenerative effects of diseases such as Alzheimer's (Herranz-Gómez, 2020). These non-pharmacological treatments also have a positive impact in the accessibility and economic burden during Alzheimer's treatment in patients and caregivers (Romero Vanegas, 2022). Additionally, key aspects regarding the use of IT based solutions in people with dementia include to involve the patient in pleasurable activities that represent cognitive stimulation (Meiland et al., 2017). It is validated that the use of video games in a clinical setting produces positive effects on the cognitive area of patients, obtaining health benefits in different clinical contexts (Moscardi, 2020).

Another component that can contribute to the effectiveness of a multimodal intervention is cognitive rehabilitation, which is traditionally carried out with paper tasks and in recent decades, has been migrating to digital tools, such as computerized rehabilitation programs, virtual reality and video games. These treatment strategies have been validated to be equally or more effective than traditional tools (Kueider et al., 2012).

The Unity graphics engine has proven to be efficient for the development of 2D and 3D video games, in entertainment, academic and scientific context, such as neural training (Paszkiel et al., 2021). Also, it has been shown that the use of WebGL in HTML5-based web environments can provide similar and even superior results with respect to alternative technologies in reproduction of interactive multimedia content, such as mobile applications or desktop applications (Min et al., 2018).

For this reason, this research proposes the development of a video game using Unity as a graphics engine and the WebGL specification, for subsequent integration in a web environment developed with the Flask framework and

the jQuery library. It is intended to achieve cognitive stimulation in patients with early Alzheimer's disease.

CHARACTERIZATION OF THE COGNITIVE NEEDS OF PATIENTS WITH EARLY-STAGE ALZHEIMER'S DISEASE AND DETERMINATION OF THE FOUNDATIONS OF THE VIDEO GAME

Based on the identified needs from professionals in healthcare, psychology, neuropsychiatric and nursing, there was a requirement for an ICT (Information and Communication Technologies) based tool to impact cognitive stimulation in patients.

Identification of Cognitive Skills to Impact and Impact Patients

Based on the literature review, the following four specific cognitive skills have been identified that can be positively impacted with video games: memory, attention, executive function, and problem-solving ability. These skills are detailed below, according to their degree of impairment in Alzheimer's disease (Oliveira et al., 2021). To the qualitative characterization of patients who may benefit from cognitive stimulation through the video game, it was identified through literature review and information collected in co-creation workshops that this kind of intervention is only useful for patients in early stages of Alzheimer's disease, with the aim of delaying the cognitive decline, considering that in a moderate and severe state of the disease, improvement is not possible. Based on the presented conclusions, the selection and inclusion criteria outlined in this research are reviewed and adopted, which involve the following patient characteristics: over 18 years old, Major Neurocognitive Disorder (MND) diagnosis due to mild Alzheimer's disease, on Clinical Dementia Rating (CDR) with levels 0.5 and 1, ability to read and write, accompaniment of a caregiver and access to a computer with internet connection.

Narrative and Conceptual Definition of the Video Game

For the definition of the narrative and conceptual methodology of the video game, several key aspects were identified from the literature review: achieving a certain degree of personalization according to the patient's context, inclusion of rhythmic music that accompanies the player's experience, and adaptation of different difficulty levels based on each patient's cognitive abilities. Additionally, Serious Games are found to consider important factors that entertainment-focused video games lack. Therefore, the video game is conceptually categorized as a Serious Game.

Furthermore, Yepes (2022) proposes a series of specific characteristics that could be included in the development of video games, with a proper focus on the cognitive needs of patients with Alzheimer's disease. The conceptual and narrative characteristics presented in Table 1 are defined as part of the methodology for the development of the video game.

Table 1. Conceptual and narrative characteristics of the video game.

Conceptual Characteristics	Narrative Characteristics	Cognitive Skills
• Activities for stimulation of different cognitive skills. • Customization of the experience according to the patient's context and ability. • Setting in a 3D fictional world that is simple to avoid confusing the patient. • Simplicity in both gameplay and learning. • Feedback for the patient and the caregiver.	• Feedback in case of mistakes and failures. • Limited number of lives at the beginning of the game. • Various questions and educational activities to generate different stimuli. • Different ways adapted to the patient's ability. • Exploration of a world with an avatar representing the patient. • Bonuses for overcoming activities.	Memory Attention Executive Function Problem-Solving

DESIGN OF THE PLANNING AND PRODUCTION MODEL OF THE VIDEO GAME THROUGH THE GAME DESIGN DOCUMENT (GDD)

According to the definitions and conclusions from the previous chapter, the initial planning concepts that are part of the initial information in the Game Design Document (GDD) are established. Figure 1 presents an overview of the content developed in the GDD through the so-called One-Page GDD. This scheme provides a brief presentation of the GDD content, summarizing the concept, dynamics, and mechanics.

Additionally, 12 mini-games were defined, according to each one of the cognitive abilities to be impacted and adopting the recommendations concluded from the literature review and issued by experts in the area. These minigames were divided into 5 game routes: a first diagnostic route and four specific routes for each one of the cognitive abilities.

IMPLEMENTATION OF THE VIDEO GAME USING THE UNITY GAME ENGINE AND WEBGL

According to the resources characterized from literature review and the development of the steps, the project was development in Unity as a 3D project, using version 2021.3.23f1, which is the latest available version with Long Term Support (LTS) and includes the necessary updates and implementations to web platform development support, incorporating the WebGL specification as the rendering standard for browsers.

To graphical resources of the development, representative objects of a real environment are sought, based on a Low poly approach, to ensure performance on devices with limited graphical resources. Low poly is defined as a characteristic of 3D models, consisting of constructing objects using

geometric elements with few vertices (Lightbox, 2020). To this end, the "POLYGON - Sampler Pack" package from Synty Studios is incorporated into the project resources, which contains multiple low poly resources used in the construction of the environments.

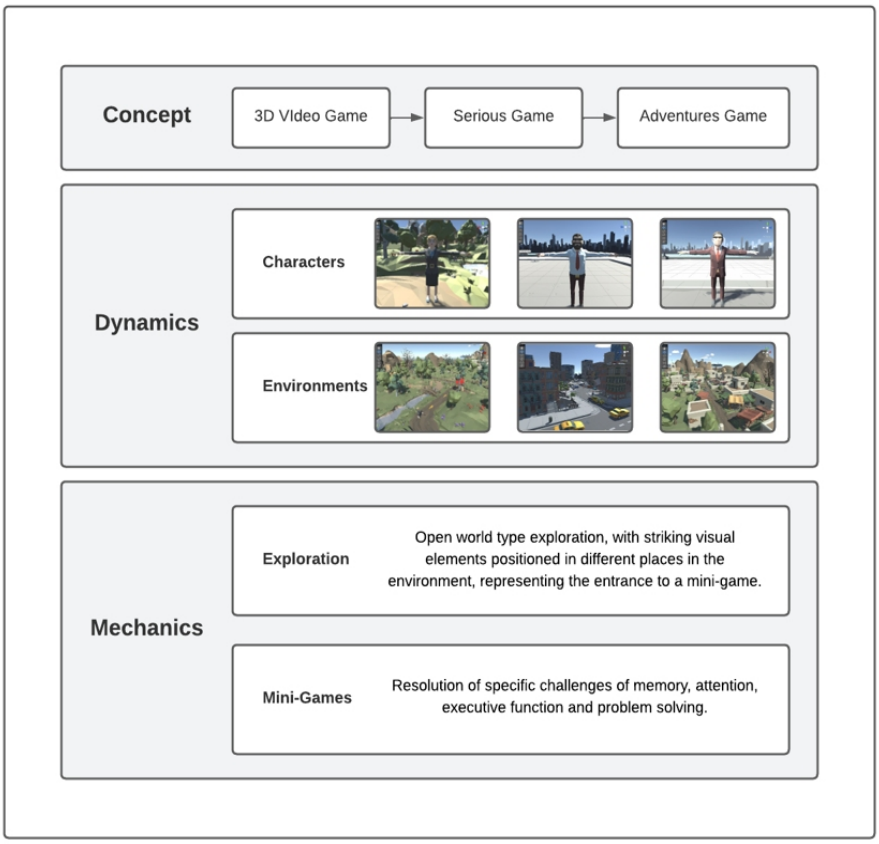

Figure 1: One-page GDD (overview).

Graphic Scenarios

Once the packages and libraries are imported, the construction and design of the base graphical environment begins, using the 3D models included in the POLYGON package and making use of customized textures according to the graphic needs of the scenes, generating two general scenarios.

Two complete and robust scenarios are constructed in terms of size and number of objects, separated into two different scenes within the project. These scenarios serve as a foundation for the other dependent scenes related to each specific interaction in the video game. The first general scenario recreates a mountain setting with sections of a village, a camp, a field, and snowy areas. The second general scenario recreates a city setting, including many objects and sections such as parks, streets, and buildings that will be useful for setting up challenges. Figure 2 presents the two constructed general scenarios.

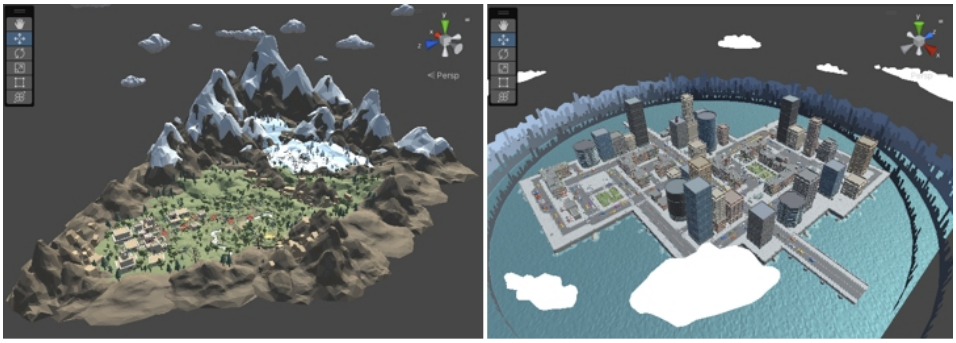

Figure 2: General graphic scenarios (mountain and city).

Development of Interactions and Mechanics

Counting on the built graphical environment, we proceed to the implementation of the interactions and mechanics defined at a general level for the video game and at a specific level for each one of the mini-games, through the coding of scripts in C#, as the standard language in Unity that includes all the necessary libraries for the management of scenes, objects, components and properties.

The general mechanics refer to the interaction features that are part of the entire video game in its different scenarios and do not vary between them. Also, for each pre-defined mini-game, specific scripts are required to ensure its proper functioning and define all the mechanics and interactions between the player and the game (scenes, objects, components, and properties). For each of the 12 mini-games that are part of the video game, the necessary scripts are coded to control the mechanics and the required interfaces. Figure 3 presents two runtime scenes of one of the implemented mini-games. The first scene showcases direct interaction with the mini-game within the 3D environment, while the second scene presents a 2D menu at the end of the challenge.

Figure 3: Mini-game scenes.

Finally, to measure the results of the patients' interaction with the video game, a score is calculated for each challenge based on the time required and the number of attempts needed to complete the challenge. The selection of

routes is done through the scenes created for each level of each challenge and using user information obtained through interaction with the backend. By crossing this information, checkpoints are generated that call the challenges defined for the specific route and at the determined difficulty level for the user.

The strategy defined in the conceptualization and characterization of the serious game requires a reward system for overcoming the mini-games through a variable that represents a quantity of coins possessed by the user. To make the use of coins more dynamic, a personal space called "My Garden" is created, where the player uses the coins earned to place decorative objects.

VALIDATION OF THE VIDEO GAME IMPLEMENTATION WITH PATIENTS TO VERIFY THE OBTAINED RESULTS

Four patients diagnosed with Major Neurocognitive Disorder due to Alzheimer's disease and their respective caregivers were selected. The participating patients in the study are in the age range of 50 to 80 years old and have low or no affinity for computer use. The participating caregivers are in the age range of 40 to 70 years old and have low to moderate affinity for computer use.

Based on the previous experience of the members of the master project regarding the validation of previous tools, the recommendation to conduct individualized sessions for each patient and their caregiver was followed. This decision was made to ensure that conducting a joint session with all patients would not hinder the execution of the test and the collection of necessary data. Each session with the patient and their caregiver lasted for one hour. During this time, they interacted with the video game while being recorded through voice and video. The *Thinking Aloud* methodology was applied, where participants verbalized their thoughts and reactions during the interactions. The sessions with each patient and their caregivers were divided into three stages: caregiver's interaction with the web platform, patient's interaction with the video game and survey about the interaction experience.

Upon consolidating the responses from the participating patients and caregivers, along with the extraction of information stored by the video game during the tests and the review of recorded sessions, positive results were obtained regarding the interaction of the target users with the development. The patients uniformly expressed that they found the video game easy to use, even for those who had never used a computer before. They also considered it entertaining, which was confirmed by the caregivers who observed the patients' interest during the test. This factor contributes to treatment adherence.

The gradual adaptation of patients to the controls and mechanics of the video game as they progressed through the challenges, as well as the generated times and attempts used to overcome the mini-games reflected in the scores, demonstrate positive cognitive stimulation. It starts with the attention given when taking control of the video game and extends to the cognitive skills stimulated through its use. From the solution developed in this work, it is

possible to measure the evolution related to the scores obtained for each cognitive ability during the different interactions a patient has with the video game over time. This measurement serves as a reference for the evolution of the skills involved in the video game.

CONCLUSION

Video games are an Information and Communication Technology tool that proves to be useful as therapy environments in areas such as rehabilitation and cognitive stimulation, allowing for positive effects on cognitive disorders in patients with early-stage Alzheimer's disease. The solution developed in this research consists of a 3D video game as a playful and therapeutic environment focused on cognitive stimulation for patients with Alzheimer's disease.

Through a literature review prior to development and the analysis of information derived from co-creation workshops conducted within the framework of the master project with patients and caregivers, four basic cognitive skills were identified as susceptible to stimulation through therapy environments such as video games, with the aim of reducing the progression of the disease: memory, attention, executive function, and problem-solving. The developed video game offers specific challenges focused on stimulating these cognitive skills. The previous research allowed for the identification of the specific characterization of patients and at which stage of the disease they are most likely to reduce the progression of cognitive symptoms.

The use of the Unity graphics engine, along with the WebGL specification, enabled the creation of a final prototype of the video game that requires minimal hardware specifications to be run on web browsers of computers or mobile devices. This factor directly impacts the loading and accessibility of the treatment for patients and caregivers, addressing a problem identified in previous research.

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