Serious Games in Virtual Reality and Augmented Reality: Instrumental Activities of Daily Life using techniques of Procedural Memory

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Abstract

With the increase in Average Life Expectancy a larger percentage of the population reaches higher ages. This new societal paradigm is accompanied by an increase of age-related neurodegenerative diseases like Alzheimer Disease. Even with the effort in the last few years to understand and diminish the population affected by Alzheimer Disease, no real conclusion on the causes were reached. Pharmacological interventions that aim to control the impact and progression of this neurological condition seems to be insufficient to ensure the quality of life of these patients.

This work proposes to use the new advances on Virtual Reality technology to develop a Serious Game dedicated to the teaching of the Instrumental Activities of Daily Life to Neurodegenerative disease patients, by using Implicit memory learning techniques like Errorless Learning methods, to avoid errors and allowing for better retention of procedures.

Keywords: Virtual Reality; Alzheimer's Disease; Implicit Memory; Errorless Learning; Instrumental Activities of Daily Life;

1. Introduction

In the last decades, the Average Life Expectancy has increased, making itself accompanied by a growth on the manifestation of neurodegenerative diseases, like Alzheimer. Without a pharmacologic solution, these diseases are an ever-growing problem that many studies seek to understand and compare the causes and symptoms of Alzheimer's Disease (AD) patients who are incapable of having an independent life due to the inability of being autonomous.

The AD is known to affect the person memory capabilities. It is recognised through deficits on the Explicit Memory in the early stages, which is composed of the episodic and semantic memory. The Explicit Memory is also known as Declarative Memory. This is the ability of *"knowing how"*, which allows subjects to consciously recall events, facts and of recognizing information. The Implicit Memory also known as Non-Declarative Memory, is the ability of *"knowing that"*. It allows for the retention of processes enabling for improvements of behaviours as the subject acquires more experience. The Implicit Memory is responsible for the procedural, skeletal and emotional memories. Only when the AD patient reaches advanced stages is the Implicit Memory affected.

AD treatment can be very hard since it involves going through a large number of sessions of repetitive and meticulous evaluation from the therapist. This treatment can eventually affect the state of mind of the patient leading to frustration. To help the treatment process of the AD patients many studies looked over the Serious Game concept, in the last few years. Serious Game offer a controlled and consistent teaching, leading to a better interpretation of the sessions and a less stressful experience.

The use of Virtual Reality (VR) allows for new perspectives over the process of rehabilitation of the patient by opening opportunities for a new and improved view of the existing treatments. By using VR, actions, as well as the environment, can have a better approximation to reality, which improves Ecological Validity and reinforces the training method. This kind of method allows exercising both the procedural and motor memory capabilities while immersed in a controlled, dynamic and personalised space.

With this in mind, this study proposes a therapy for AD where the patient goes through an intervention using a VR simulator software. This software

will use Errorless Learning (EL) to ensure proper retention of the steps of the learning behaviour. It also includes some other practice methods to reinforce the knowledge and the patients' ability to transfer the learned knowledge to a new environment.

2. Background

AD is a cognitive deficit which, in the early stages, exhibits symptoms of Mild Cognitive Impairment. It results in a significant change to the memory capacities such as difficulties at remembering appointments. Studies show that overall 10% to 55% of the Mild Cognitive Impairment cases turn to dementia over 2-6 years period [1, 16], acting as a good predictor for therapists. Also, 2% to 10% of the AD cases appear before the age of 65, doubling the proportion every five years after the 65 years [16].

The learning challenge of AD come from the deficit of cognitive functions, caused by the shrinking of the hippocampus (see Fig. 1), that affects the consolidation of information [14, 18]. The Explicit Memory deficit causes the patient to treat every information as absolute truth, making them unable of recognising their own mistakes. By testing the behavioural impact of the AD by challenging the patients with specific paradigms and small exercises to study the intact capabilities [2, 9, 11, 18], it was possible to understand that these patients are unable to differentiate a mistake on is own actions, often leading to keeping capabilities without knowing *"how"*.

The studies [2, 9, 11, 18] demonstrate that Implicit Memory capabilities are intact until later stages of the disease. This opens up the possibility of maintaining and acquiring abilities to do Instrumental Activities of Daily Life, i.e. basic and necessary activities for a normal daily life, through the use of Procedural Memory. The Procedural Memory uses newly acquired information to create new behaviours. The accumulative capabilities of this memory and repetitive attempts at doing a given action strengthens the behaviour, forming experience, and allowing for the generation of habits [18].

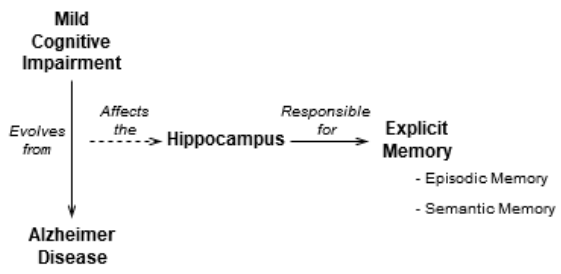

Figure 1: When Mild Cognitive Impairment evolves to AD the physical size of the brain shrinks, affecting the form of the hippocampus, creating a deficit in Explicit Memory capabilities.

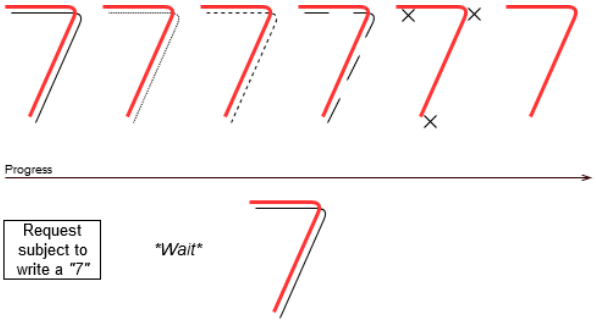

Figure 2: Above is the Vanishing Cue, the patient is asked to draw a seven overlapping (colour red) the already drawn seven (colour black) and after each try, the already drawn seven disappears a little bit. Bellow is the Spaced Retrieval, the patient is requested to draw a seven and only after a given interval of time is the answer given (colour black). However, if the patient answers (colour red) before the therapist gives the answer then the waiting time is increased until the exercise is unnecessary.

These patients won't be able to learn and perform as efficiently as a healthy adult in the same age stage but this method shows that AD patients can go from 50% performance level to 70% [11].

To mitigate the consequences of learning an error, a focus in Implicit Memory teaching techniques appeared for example like EL and sensorimotor learning, known to be useful in learning and retaining information in mild AD patients [18]. The EL methodology objective is to avoid mistakes, by providing a cue immediately after an instruction is given to ensure the person knows the action he must do, consequently avoiding mistakes. Some of the methods (see Fig. 2) used in EL [7]:

- **Vanishing Cues** - Causes the answer to progressively disappear to tested the knowledge the patient has of the step;
- **Spaced Retrieval** - The cue for the answer is given after an increasing interval of time to test the ability of the subject to anticipate exemplification;

2.1. Serious Games

The Serious Game are video games directed for serious topics like education and health, instead of a ludic game where the objective is purely to entertain the end user. These games open the possibility of a more controlled and structured treatment of patients [4]. These games have the capability of keeping the patient in the flow state, or the feeling of complete and energized focus in an activity while maintaining a high level of enjoyment and fulfilment [4, 8, 15].

The use of a Serious Game allows for a more controlled experience depending less on the therapist reactions. Also, allowing for a better adaptation of the activity to the patient cognitive capabilities. This means that Serious Game go beyond

the traditional therapy and laboratory testing since they have the capability of simulating real-life environments and activities while also enhancing the Ecological Validity of the results. This is done by analysing the decisions and reactions of the player to either save them for further analysis or to adapt the experience of the player [15].

Frédérick Imbeault et al. [8] approached the adaptability of the experience by developing a Serious Game that uses the ELO system to dynamically adjust the difficulty by comparing the performance of the player in the previous game sessions.

Teresa Paulino et al. [19] developed a game called Reh@City that let the AD patients use to practice Activities of Daily Life by simulating multiple environments of cloth store, kiosk, park and home. This simulator used a difficulty adaptation module, which adapted the experience based on MOCA [20] cognitive assessment score and performance in the simulator.

2.2. Virtual Reality

The use of the VR allows the therapist to take the AD patient to a safe environment where the patient can repeat an activity until the patient properly learns it. When the activity has reached a satisfyingly level of reliance the patient is taken to a non-safe environment to test the Ecological Validity.

Déborah A. Foloppe et al. [6] presented a VR software called Virtual Kitchen Software with the use of a Head Mounted Display and controllers. This solution was developed to compare the learning process in real-world and virtual-world. Déborah A. Foloppe et al. observed a notable difference between the result of real and virtual world training. The patient showed significant improvements in autonomous performance when in real-world training. Meanwhile, virtual-world training allowed for a reduced need for written instructions and visuospatial indications of the target objects. After six-months assessment showed that the patients maintained their autonomy in both the real and virtual world trained tasks.

Hofmann et al. [12] presented a study which compared the performance of three groups: AD patients; Major Depressive Episode patients; a control group.

From the results of the intervention, it was clear that the AD patients presented larger improvements than the other groups, displaying a distinct amount of mistakes, bigger latencies when answering, difficulties answering the multiple-choice questions and repeating the instructions more times than the other groups. However, by mid intervention the AD patients were already having a performance closer to the other groups, showing an improvement in the behaviours.

3. Solution

This study proposes a Serious Game developed in Unity game engine, version 2018.4.11f1, following game development and VR design paradigms, such as those presented by Mike Alger [13]. To create a controlled environment where patients that suffer from neurodegenerative diseases can go through exercises learning new behaviours, with emphasis on AD patients with low or moderate stages of the disease.

This solution envisions a methodology of training where the AD patient has to repeat the exercise multiple times, causing him to remember the activity by using Procedural Memory.

The learning method used in this study is EL because has been proven that it guarantees good retention of knowledge. The EL techniques used are Spaced Retrieval, to ensure the retention of the knowledge, and Vanishing Cues, to make the experience effortful.

As a method to increase the retention of the activity the game will present two types of practice [5, 17, 18]:

- **Block** - Is the aspect of practising the same behaviour, under the same conditions, over and over again.
- **Random** - Where the same behaviour is practised over and over again, while always changing the conditions forcing the patient to “Read” and “Plan” their new action before the “Do” step allowing for a more complete exercise causing better retention of the newly acquired behaviour.

Also, to ensure that the experience is properly adapted to the player. The game will adapt the activity depending on two different data sets. Initially, the game will be adapted based on Addenbrooke Cognitive Assessment score [3]. As the game progresses, the data generated from the player performance in previous game sessions will allow for adaptations, resulting in a controlled evolution of the difficulty, cueing and expected effort of the game session.

The training environment should be simple, i.e. the kitchen should not have complex features, and direct, i.e. have only the objects necessary for the exercise, to avoid distracting the user from the activity. The training environment architecture was decided by considering two different factors, the target audience and space where the Ecological Validity was planned to be tested. The real-world train environment had a balcony with ”L” physical layout, which allows for a setup where items are at hand reach avoiding ample moves.

The objective of the Serious Game is to function as a simulator to teach the patient how to cook a

simple meal (see Fig. 3). This activity can be easily divided into a set of sequential steps and allow for a clear understanding of the effects of the study on the AD patient. Also, this activity only requires upper members movement, avoiding difficult or dangerous movements, and allowing the patient to be in a stationary position while doing the exercise.

In other words, this Serious Game will contain an exercise that has the objective of teaching one activity to the player divided into multiple steps, where each of the steps will require the player to do one action.

3.1. Recipe

The environment will be a kitchen with only the equipment needed to accomplish the recipe, which is "Yoghurt cake".

The activity was chosen based on motivational factors for the patients, presenting them with the opportunity of creating something to share with their family.

The "Yoghurt Cake" recipe uses the following ingredients: 4x Eggs; 1x Yogurt; 2x Sugar measures; 3x Flour measures; 1/2x Oil measure; Margarine;

The following utensils: 1x Bowl; 1x Wooden Spoon; 1x Cake Mould; 1x Measure (Yogurt Cup); Oven;

To avoid fine movements, the recipe assumes:

- The Eggs have already been broken and put in a bowl;
- The Mould has already been greased with Margarine;
- The Oven has been preheated to 180ºC;

The steps of the recipe are:

1. Add the Yoghurt;
2. Add the 3 cups of flour;
3. Add the 2 cups of sugar;
4. Add the oil;
5. Mix the ingredients with the wooden spoon;
6. Add the mix to the cake mould;
7. Put the cake mould in the oven;
8. Wait 40 minutes;
9. Remove the cake mould from the oven;

3.2. Questionnaire

The developed solution evaluation will be through an online questionnaire where the participants will be anyone used to the use of computer and online services. This approach was chosen to take into consideration the current state of Covid-19 pandemic that prevents presential activities.

This questionnaire will be done online, following a simple set of questions where the participants will be directed to play the game and answer about their experience.

The objective is to obtain metrics on how well the message is delivered, the user experience, necessary improvements and limitations of this teaching approach.

The questionnaire was structured to take less than 30 minutes and has three parts:

- **About You** - Demographic questions and knowledge of the activity taught by the game;
- **The Game** - The participant is requested to play the game;
- **About the Game** - Questions to evaluate the participant experience by using a Post-Study System Usability Questionnaire (PSSUQ) Version 3[10];

To make the questionnaire easily available to anyone, the VR solution was adapted to a Point-and-Click solution that could be played on any computer, without an Head Mounted Display.

The player interaction is made through the mouse, instead of LeapMotion hand tracking. However, this version will keep the design decisions done for the VR version, keeping the game experience as close as possible to the VR experience.

Some of the limitations of this version are:

- **There will be no immersion** - The player will be playing with on their personal computer and not using the Head Mounted Display;
- **The interaction will be different from the intended** - The player will interact with the environment through the mouse instead of LeapMotion:
- **Some adaptations won't be triggered** - The adaptation manager will still work in this version, however, since the screen won't move and the virtualized hands won't exist, then the game won't trigger adaptations related to those.

4. Methodology

This chapter will present the design and architectural decisions.

4.1. Design

This exercise will be divided into two phases. The first phase, i.e. the introduction phase, is intended to introduce the exercise and the second phase, i.e. the exercise phase is where the player will learn the activity.

Before the exercise starts an introduction to the exercise is given, explaining what player is supposed to do. The player will receive an audio and

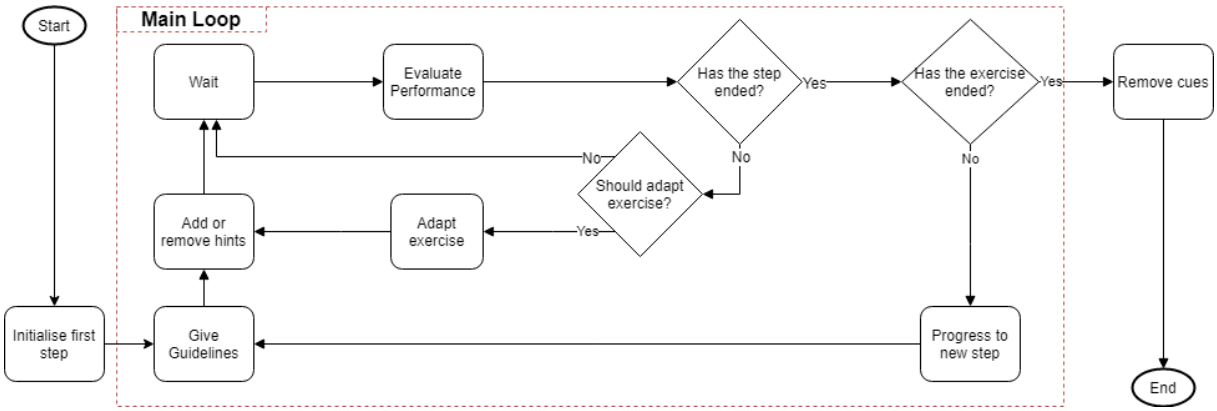

Figure 3: Core game loop shows how the player progresses through all the tasks, i.e. each step of the exercise. For each loop, the game will wait an interval of time, after which will evaluate the environment state. If the exercise step has not ended the game will check if any enforcement is necessary, i.e. any adaptation should happen so that the player can better understand the exercise step. When the player ends the current step he/she progresses to the next step if the exercise has more steps, removing the hints from the previous step and adding the hints from the new step.

visual prompt saying "Let's Bake a Cake", this first instruction is essential to create the stimulus that leads to all the consequent stimuli of the activity. This is followed by a presentation of the ingredients, utensils and appliances necessary for the exercise. The exercise environment shouldn't contain more than the strictly necessary objects. This phase is intended to create a familiarity with the exercise environment and the activity the player will be doing.

In EL, the exercise is divided into steps, which are divided into three distinct phases:

1. **The action** - Directly state the action to be done in this step;
2. **Exemplifies the action** - Show how the step can be completed;
3. **Execution of the action** - The patient tries to repeat the action. If the patient successfully repeats the exemplified action he/she receives positive reinforcement. Otherwise, if the patient can't repeat, the intensity of the exemplification is maintained or reinforced in next session;

Each step has one action associated with it and shared with the player through a textual and audio prompt. This prompt contains a phrase explaining the action directly and explicitly, it appears in front of the player on a text box.

After this introduction to the step, the action is exemplified. The exemplification happens through hints. These are small changes to the environment and objects to enforce the action of the step.

These hints are modifications to the game objects and behaviours, which are simple, intuitive and not intrusive. Their responsibility is to guide the player through the activity. With this in mind, a group of hints have been implemented (see Fig. 4):

- **Arrow Point** - An object which points to the objective position. For example, an arrow pointing towards the oven;
- **Audio** - An audio indication that can vary from a simple sound released from an object. For example, a bell sound coming from the oven;
- **Fade** - This hint causes the object to fade out when the player tries to reach it. For example, the selected object fades if the player hands try to reach it;
- **Fixed** - A translucid replica of the object expressing a destination or position. For example, a replica of the cake mould inside the oven to express the need to move the cake mould into the oven;
- **Light** - Turn off the ceiling light except on the desired object. For example, add a light to a bowl;
- **Moving** - A translucid replica of the object expressing a movement. For example, a replica of the oven door doing the opening movement expressing the movement that the door should do to be opened;
- **Outcome** - The use of a talk balloon with an image hovering on an object, representing the expected result, action or contents. For example, a talk balloon above the flour bag with a flour icon enforcing that the flour bag contains flour;
- **Outline** - The object with this hint is highlighted to suggest that it is expected to be grabbed. For example, an outline in the yoghurt cup to signal it must be grabbed;

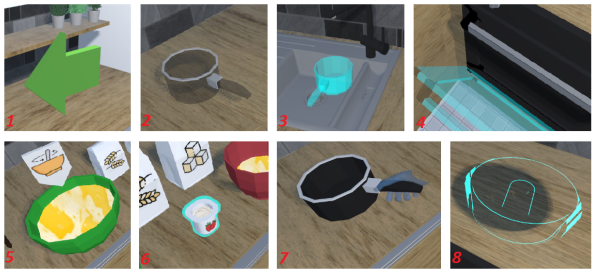

Figure 4: The visually perceptible hints, are: (1)Arrow Point Hint; (2) Fade Hint; (3) Fixed Hint; (4) Moving Hint; (5) Outcome Hint; (6) Outline Hint; (7) Shadow Hand Hint; (8) Silhouette Hint;

- **Shadow Hand** - Shadow hand which does a set of movements to teach the player what behaviour is expected. For example, a shadow hand demonstrating were and how to grab the pan;
- **Silhouette** - Same as Fixed Hint. However, it only contains the wireframe of the object. For example, the silhouette of the mould on the balcony expressing the need to move the mould outside the oven;

The EL techniques Spaced Retrieval and Vanishing Cue will change how the hints behave, affecting the exemplification of the action.

The Spaced Retrieval adds an interval of time between the first phase, i.e. "The action", and the second phase, i.e. "Exemplification of action". The use of Spaced Retrieval tests the ability of the subject to anticipate exemplification. In the game, it happens between the step introduction and the exemplification. The Spaced Retrieval will control when the hint will appear.

With Vanishing Cue, as player performance increases, the exemplifications become more faded. The game progressively hides the exemplifications. This technique affects the hints, by fading them depending on the performance of the previous session.

Positive reinforcement will happen at the end of each part of the exercise, which are:

1. **Add Ingredients** - Teaches the player to add all the ingredients with the right amounts, to the big bowl;
2. **Mix Ingredients** - This part instructs the player trough the process of mixing the ingredients;
3. **Bake** - The player is guided through the steps of putting the cake mould in the oven and see the final results;

Before starting the game session the exercise practice method can be configured to Block or Random. In Block practice, the starting position of the objects should not change between sessions. When doing Random practice, the positions of the objects are randomized, given an exercise area (see Fig. 5).

Figure 5: In Block practice the exercise objects always appear in the default positions. When doing the Random practice the exercise objects will be randomly placed on the balcony, considering the objects already placed.

4.2. Architecture

The architecture of this study solution is based on previously presented solutions in other Serious Game that are directed at the same target audience, following the structure shown in Fig. 6.

The solution will be divided into four domains (see Fig. 7). The **Simulator**, responsible for the game experience. This simulates the kitchen and the cooking activity. The **System** which is responsible for evaluating the player and generating adaptations to ensure the training experience is adapted to the player capabilities. The **Session**, responsible for managing the sessions and the Player Model data. Finally, the **UI**, responsible for managing the therapist interface.

The **Simulator** is composed of two components: Exercise Manager and the Hint Manager. They work together to offer a simple and direct gaming experience.

The **System** is composed of two components: Evaluator Managers and Adaptation Manager. These components work together to ensure that the player has an experience adapted to the level of his capabilities.

The **Session** domain contains 2 Managers such as the Session Manager and the Repository Man-

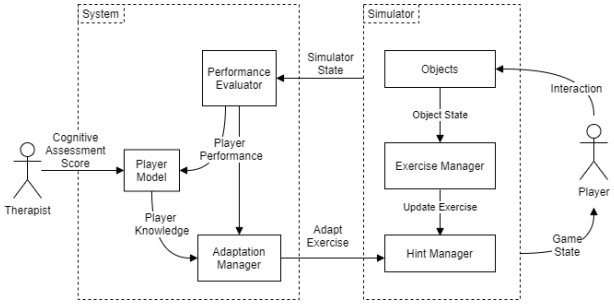

Figure 6: Architecture interaction and expected behaviours. The player interacts with the objects in the simulator causing the exercise to progress. Independently of the simulator, the system evaluates the state of the simulator environment and adapts the game, affecting how the player perceives the simulator environment.

ager. This domain is responsible for managing the sessions and the Player Model.

The **UI** Domain only contains one manager called UI Manager, which is responsible for managing the interfaces the therapist can interact with.

5. Implementation

The Adaptation Manager is responsible to ensure that the experience of the game is adapted to the player. These adaptations are done by using multiple metrics, such as previous player performance and current performance.

To do so two different types of adaptations were implemented: Active and Step.

Active adaptation happens by requesting new hints to Hint Manager to ensure the player can finish the exercise. To know when to request these hints the Adaptation Manager will use the metrics at the Error Evaluator Manager and Attention Evaluator Manager. These adaptations are tested every cycle and happen when, for a given category, the Evaluator Manager has a *CurrentWeight* greater or equal to *TriggerWeight*. When the Adaptation Manager notices this threshold has been reached one or more hints are requested to the Hint Manager. This Manager will also request the Hint Manager to remove the hint when the Evaluator Manager marks the hint to be removed and the *CurrentWeight* is less than *TriggerWeight* (see Fig. 8).

For Errors the Active adaptations happen when the player:

- Releases the current step exercise object - **Grab Hint** requested on the exercise object;
- Is still holding an exercise object from a different step - **Outline Hint** requested on the exercise objects of the current step;
- Has exceeded the duration of the step - **Light Hint** requested on the exercise objects of the current step;

For Attentional mistakes the Active adaptations considers are:

- The player is not grabbing the current step exercise object - **Grab Hint** requested on the exercise object;
- The exercise objects of the current step are not in the line of sight - **Audio Hint** and **Point Hint** requested on the exercise object;
- The player is trying to reach an exercise object from a different step - **Fade Hint** requested on every exercise object that is not used in the current step. This hint is only removed when the step ends;

Step Adaptation sets the cueing level of the Hint Manager for the current step of the exercise causing all the created hints to be set at the decided cueing level.

After three completions of a specific step, the Adaptation Manager tests if the cue level can be increased. The level increases, until a maximum of three, if the player has completed the step three times in a row without causing any adaptation. However, if the player causes at least one adaptation the level decreases, until a minimum of zero (see Fig. 9).

These adaptations are discriminated by step, meaning that a player must complete a given step at least three times, before the Adaptation Manager validates it. Consequently, the player might be on different levels at different steps. The expected result is to have more explicit hints at steps with lower levels and less explicit as the player increases level.

The Evaluator Managers are responsible to evaluate the environment to understand the player behaviours that represent mistakes. Their objective is to translate their observations into measurements, which are the *CurrentWeight* and *TriggerWeight*, that allow the Adaptation Manager to make decisions.

The Attention Evaluator Manager will consider a player attentive on the exercise when:

- Looking exercise objects;
- Grabbing the exercise objects;
- Reaching only to objects of the current step;
- Finishing the exercise under the determined duration;

The Error Evaluator Manager will observe an error when the player:

- Grabs and/or interacts with non-exercise objects;
- Releases an exercise object;
- Reaches for objects of different steps of the exercise;

The Exercise Manager is responsible for managing the game loop. It is responsible to check if the player has finished the step and advance to the new one, iterating the steps until there are no more steps to be done.

When initialising the exercise environment, the manager will put on the balcony the needed exercise objects for the exercise based on the practise method.

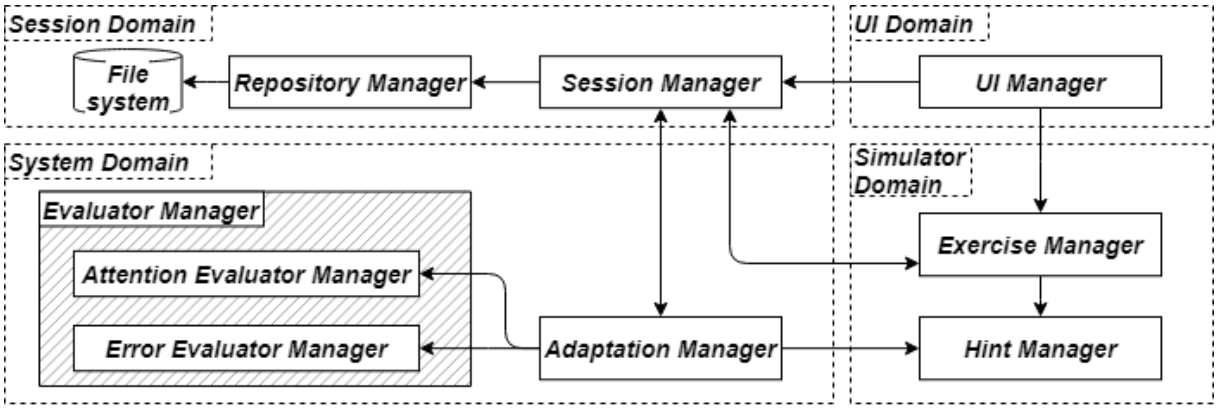

Figure 7: Decomposition and Uses architecture model. Defining the four architectural domains of the solution. Additionally, defines the main components of the solution and their allowed interaction.

The Hint Manager is responsible to attribute to a specified object a specified hint.

When requested a hint on an object, the manager will try to add the hint. The Hint Manager will only add a hint if the maximum number of hints have not been reached. This is to ensure the exercise environment is not full of hints triggering the attention of the player. Additionally the therapist can disable hints.

The Repository Manager creates a layer of abstraction for communications with the file system. It is responsible for saving/loading/deleting the game data in the JSON data files.

The Session Manager is responsible for managing the game data as well as the execution of the session, making available to every other manager the following data: Exercise; Practice Type; Language of the guidelines; The Player data, which includes the current session and current step data;

The UI Manager allows the therapist to interact with the system of the solution giving him an interface to manage the player and the sessions.

6. Results & discussion

This questionnaire was completed by 50 different participants, ranging from the ages of 17 to 33.

To understand their cooking skills the participants were questioned about their cooking habits, which showed that 62% of them cook daily. Even though some 14% of the participants don't cook very often, every participant was able to complete the exercise.

In general the scores of the PSSUQ questionnaire were positive but demonstrate that more work is still necessary to create an experience that is intuitive and simple. The achieved scores were:

- **Overall** - Average is 1.90 out of 7;
- **SYSUSE** - Average is 1.64 out of 7;
- **INFOQUAL** - Average is 1.94 out of 7;
- **INTERQUAL** - Average is 2.33 out of 7;

The SYSUSE score is 1.64 out of 7, meaning that healthy population finds the system useful.

In the case of the sixth question,the participants are asked if they could be productive with this solution. The participants were divided resulting in an average score of 2.08 out of 7. This result might be due to the participants' age and cognitive health which might feel the game develops slowly due to having to wait for the guidelines every step.

The INFOQUAL score demonstrates that the solution has some problems delivering the information to the player.

On the seventh question, the participants are asked if the system gave them an error stating how to properly fix it. This score, 3.34 out of 7, can have multiple reasons, such as the interpretation of the question was not explicit in the context or the adaptation wasn't explicit enough for the player to know how to fix the action. Having 18 participants answer NA is positive since it is not intended for the game to explicitly point any error. Making the errors explicit can make the experience stressful for the target audience and make them give up or feel demotivated to continue the exercise. However, since the obtained score in this category is so high it means this subject requires further investigation.

Looking at the eighth question, where the score was 1.87 out of 7, the participants were asked if when they made a mistake they could recover quickly. The majority of the cases felt they could recover with ease except for some few participants. Also, 12 of the 50 participants voted NA meaning that they didn't do or perceive any mistake.

The obtained INTERQUAL score means that the solution interface should suffer improvements. However, this score is comprehensible since the game was adapted from VR to computer-based while the mechanics were kept as close as possible to the original. This resulted in mechanics that are not very intuitive for a computer game.

Even though the three scores of the INTERQUAL category were positive and close to the minimum, it is notable that the number of participants that voted higher scores increased. Since it is expected that the target audience has a lower technology literacy, then they will have more difficulties understanding the interface of the game. However, the intended VR solution uses LeapMotion to virtualise the hands and offer a more natural interaction. Also, the use of the Head Mounted Display impacts the perspective the player has of the environment.

Lastly, when asked their overall satisfaction with the solution the participants gave a positive score of 2 out of 7.

7. Conclusions

The Serious Game implemented present a proof of concept of a literal implementation of the EL methodology, during which the player will be guided through every step of the exercise, in this case baking a cake. One of the major changes, relative to the conventional therapy, is that the phases of exemplification and execution of the action overlap since the patient is no longer physically obstructed by the therapist. This can be used to better understand the ability of the patient to anticipate the exemplification.

As the player increases in Cue Level, the use of Spaced Retrieval will push the exemplification phase further from the moment the execution phase starts, while the Vanishing Cue will test the ability of the player to recall the action connected with the guide. This means that the patient will start from an effortless exercise and eventually end in an effortful exercise.

By using adaptation through the cognitive assessment and performance we are creating an experience that will ensure that the player can always finish the exercise. At the same time, we are saving data and metrics that can be analised by the therapist and lead to a better evaluation of the cognitive state of the patient.

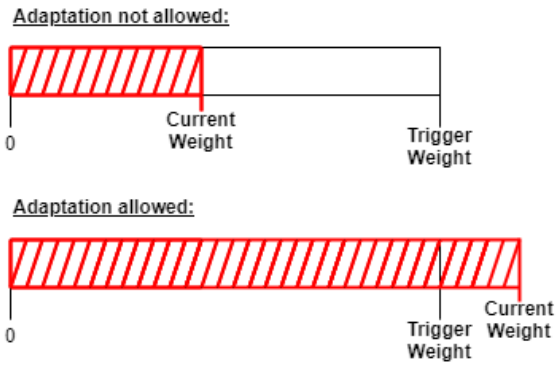

Figure 8: Active Adaptation. When *CurrentWeight* is bigger than *TriggerWeight* then the Adaptation Manager requests a new hint to the Hint Manager.

Level	Intensity	Vanishing Cue	Spaced Retrieval
0	4/4		0 sec
1	3/4		5 sec
2	2/4		10 sec
3	1/4		30 sec

Figure 9: At the level zero the hint intensity is maxed, meaning that Vanishing Cue and Spaced Retrieval will not happen. As the player progresses, the intensity of the hints will decrease until a minimum of one fourth, at level 3.

Unfortunately, it was not possible to test the solution with the target group due to Covid-19 but the questionnaire done with healthy population demonstrates a positive acceptance of the solution, an overall score of 1.90 out of 7. The solution still requires further investigation and review of the methods applied. From the participants' evaluation, some topics that require further study, are:

- The ability to be productive with the solution;
- How to solve the errors they make following the steps;
- The interface. This topic is relative to the interface of the solution used by the questionnaire participants;

The population that tested the solution does not serve as the ideal model to represent the target population, implying other topics not tested in this questionnaire might need review.

More direct work with this population with the AD patients is necessary. This will present the limitations of the study and show if the implementation can present real benefits for AD patients.

With this in mind, an intervention was prepared, even if not executed. However, from these preparations, a single session was done with the older population which resulted in optimizations, such as the position of the objects, the depth and height of the balcony and others.

The use of a proper intervention with multiple sessions might allow us to understand the retention of the knowledge of the exercise as well as more implementation requirements necessary to deliver the message, while contributing to understanding the impact of the use of VR in the population that suffers from dementia.

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