Musiquence: a framework to customize music and reminiscence cognitive stimulation activities for the dementia population.

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***Abstract*— Due to the limitations of pharmaceutical related approaches for people with dementia (PwD), there has been a need to find complementary methods. Within non-pharmaceutical approaches music and reminiscence-based activities appear to bring advantages to PwD: (1) it is easy to implement, (2) does not lead to side effects, (3) PwD appear to have an intact music memory even at later stages of the disease, among other benefits. However, literature is mixed regarding the long-term benefits of music and reminiscence related approaches in PwD. Another approach that has gained much attention over the years are serious games. However, the usage of technologies and the lack of customizable content may provide an additional challenge to health professionals and family caregivers to utilize such an approach in PwD. In this article, we present a framework called "Musiquence", which is allows customization of gamified activities in terms of technology and content, with special emphasis on music and reminiscence-based activities. Here we discuss the functionalities of the platform, the activities designed for PwD and future implementations for the platform.**

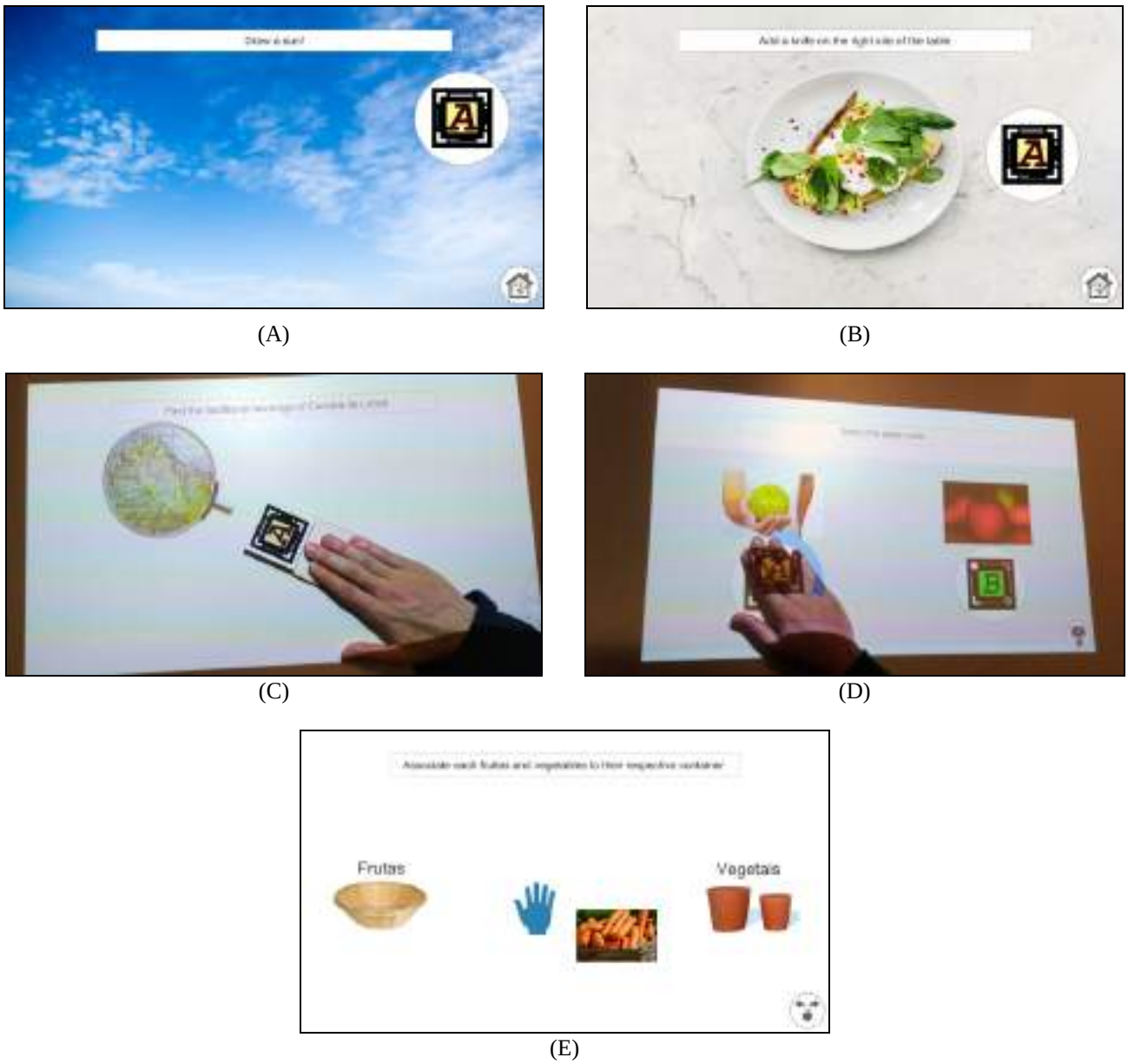
Keywords—Framework, Music, Reminiscence, Customization, Augmented Reality, Dementia, Cognitive Stimulation.

I. INTRODUCTION

Dementia is an uncurable and neurodegenerative disease that leads to a decrease of cognitive (i.e., memory) and psychological (i.e., depression) faculties [1]. Although pharmaceutical approaches have been used to mitigate the disease, only a few are FDA approved. Additionally, dementia-related drugs are accompanied by negative side effects [2]. Many non-pharmaceutical (NP) approaches have been used to stimulate people with dementia (PwD) such as aromatherapy, animal therapy, light therapy to name a few [3]. Among NP-related approaches, music and reminiscence therapies have been proposed [3] although the scientific literature is still not conclusive with respect to the effect that both therapies have on PwD [4], [5].

Nevertheless, some positive aspects can be enumerated such as (1) ease of implementation, (2) no secondary effects and (3) these activities can be performed in collaboration with third parties [6]–[8]. The adaptation of such activities to the patient's preferences has been proposed to enhance therapeutic outcomes in terms of communication and cognition [7], [9]. Similar recommendations have been made regarding the use of serious games [10]–[12].

Serious games can be described as "*a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives*" [13]. Such an approach has been considered to stimulate PwD physically, cognitively and even train such a population in terms of activities of daily living [14]. Nevertheless, considering that PwD progressively lose physical and cognitive abilities, there is a need to adapt the tasks to the patient's profile [15]. Health professionals have provided similar recommendations in a study on how PwD were able to complete different tasks using several human-computer interaction techniques in augmented reality [12].



(A) (B) (C) (D) (E)

Fig 1. *Activities.* (A) Creative Drawing. Participants must place a real drawing on the projected marker. (B) The activity of daily living. Participants must place real objects like cutlery. (C) Search Objects. Participants had to find objects that were only visible through a virtual magnifying glass using a physical wooden object. When colliding with the object, the response timer is triggered. (D). Knowledge Quiz. Participants must find the correct answer by occluding the markers using upper limbs. (E) Participants must associate fruits (Frutas) and vegetable (Vegetais) correctly to their correct container using a physical wooden object.

Another aspect to consider when using serious games with PwD is the usage of technology. Using novel technologies to complete tasks may hinder PwD's performance as they must learn how to use such technology before completing tasks [10], [16]. In [17], authors conclude that the use of technology is dependent on personal experience, motivation, and type of task to be performed. Moreover, the contact and the learning process in using modern technologies for the first time can lead to anxious behaviors [18] or even undesired side effects during gameplay (i.e., cybersickness) in PwD [19]. Hence, this leads to additional challenges in proposing novel technological approaches for a population with dementia.

In light of the previously identified issues, in this article we will present a framework that allows patient-centered design by customizing music and reminiscence-based cognitive stimulation games. Further, it supports deploying these games to the technology that can be more suitable, comfortable and accessible for the patient such as augmented reality, tablet, and desktop computer.

II. The Impact of Music and Reminiscence in Dementia

The aim of this framework is to capitalize the benefits of music and reminiscence therapy – but not exclusively – to be used in a virtual environment for PwD.

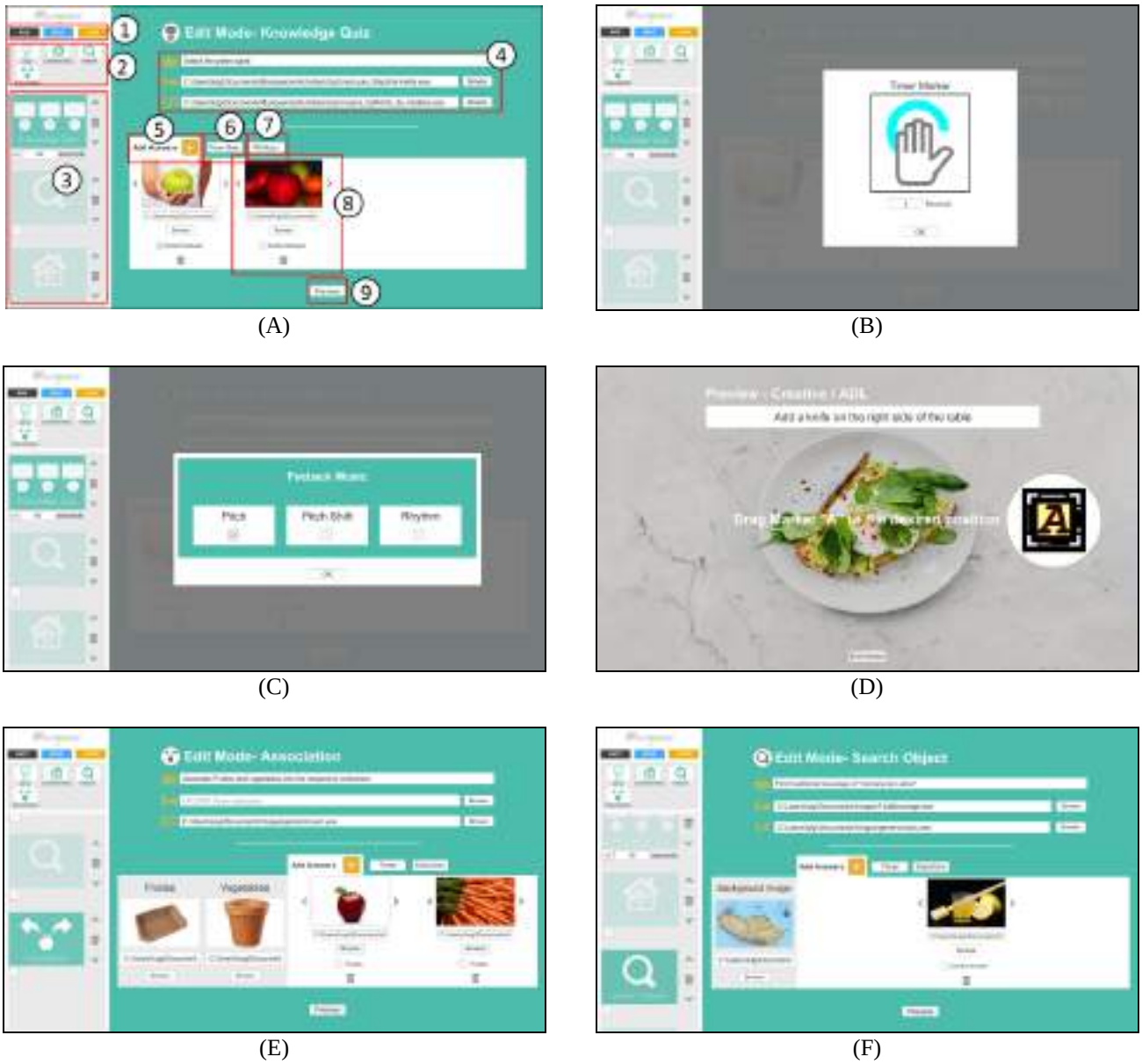


Fig 2. Game *Editor*. (A) 1. Save, Load and Exit button. 2. Available activities – Knowledge Quiz, Search Object, Association and creative/ADL. 3. The sequence of activities. The up/down arrow allows the user to change the order of execution of the activities. The trash icon allows the user to delete an activity. Under each activity, the user can add a condition to finish an activity. 4. Input fields. Participants can write questions and upload verbal instructions and music. 5. Users can add answers to an activity. 6. Users can access the marker timer responses. 7. Users can manipulate musical components. 8. Answers displayed in the activity. For each answer, the user can add an image, change the order of the answers using left/right arrows, check the answer as a correct answer and delete the answer by clicking the trash can icon. 9. Users can preview the activities. (B) Marker timer. The user can adjust the response time of an answer. By default, the markers are defined as 4 seconds. (C) Musical distortion. If the activity has background music, the latter can be manipulated in terms of pitch, pitch shift, and rhythm to provide auditory feedback on current actions. (D) In the ADL, Creative Drawing and Search Objects activities, users can preview activities and define the position of the markers within the game canvas. (E) In the association activity, the user can define additional images to define the categories, in this case for fruits and vegetables. (F) The user can define a general background image and object image for the Search Object activity.

Traditional music therapy is defined as "controlled use of Music, its elements and their influences on the human being, to aid in the physiologic, psychologic and emotional integration of the individual during the treatment of an illness or disability" [20]. Although scientific literature is somewhat mixed regarding the effects that it has in a dementia population [5], some studies claim that it can help PwD to relax. Indeed, studies suggest that listening to music releases melatonin [21], which is a hormone that leads to soothing behaviors. Besides, music appears to be a good medium for stimulating autobiographical memories and enhance communication [9]. Moreover, brain areas that are responsible for music processing appear to be intact even in more advanced stages of dementia [22]. Reports claim that participants can identify the names of musical excerpts correctly [23] and even identify melodical errors [24] (more in sub-paragraph IV.B).

Regarding reminiscence therapy, it is used to help stimulate auto-bibliographical memories through the use of physical objects and pictures, and to diminish depressive

symptomatology [4]. Although it is possible to identify additional advantages in PwD such as improved mood, cognition, communication, and life quality, scientific literature is still inconsistent about its benefits [4]. Although some positive aspects have been identified, the scientific literature is not yet clear regarding the usage of both music and reminiscence therapy. Thus, more research is needed to understand the benefits of both music and reminiscence therapy better.

III. Framework Activities

The framework at this moment includes, but is not limited to, five different activities. Implementing more activities for PwD in the future is possible thanks to its modular design. The activities used were developed and tested in a previous study [12] in different interaction paradigms. To interact with the game, participants must interact with markers using their upper limbs, full body or the usage of real objects depending on the setup. Currently, the activities of [12] went through aesthetic changes to enhance task performance in PwD. The changes were made based on observation and feedback provided by health professionals. The activities are as follows:

- Creative Drawings (Fig 1A) – In this activity, participants train skills such as memory, and fine and gross motor skills. This activity is a puzzle-like game where participants must draw to complete missing pieces of painting.

- Activities of daily living (Fg 1B) – Here, PwD train memory and divided attention. Similar to Creative Drawings, it is a puzzle-like game where PwD must complete a set of chores (i.e., setting the dinner table) by adding real physical objects (i.e., cutlery).

- Search Object activity (Fig. 1C) – This activity is designed to train the attention and memory of PwD. It is an exploration game where participants have to find hidden virtual objects that were only visible through a virtual magnifying glass

- Knowledge Quiz (Fig. 1D) – This is an activity which aims to train memory in PwD. Here, participants are required to answer a question correctly by selecting the correct answer(s) among incorrect ones.

- Association activity (Fig. 1E) – In this activity, PwD train associative memory. Participants are required, for example, to separate fruits from vegetables and place these in the correct containers.

IV. Framework Musiquence

Musiquence (music + sequence) is a framework that displays a sequence of music and reminiscence related activities previously customized by health professionals to be played by PwD. It is developed using Unity 3D (Unity Technologies, San Francisco, California) and divided into two separate applications: *Game Editor* and *Game Experience*.

Game Editor. In a previous study [12], we tested a set of augmented reality-based activities that PwD had to complete using different human-computer interactions. Health professionals participated in the study to provide feedback regarding the usage of such systems for intervention purposes. Although health professionals were interested in using such a system in their interventions, they were concerned about the content that was presented to the participants. Thus, we started developing a user interface for health professionals to customize activities for a dementia population. The *game editor* allows health professionals, relatives and caregivers to create activities and customize these according to the participant's profile.

The editor flow is inspired by the Microsoft Power Point (One Microsoft Way , USA) (see Fig.2A). Activities are presented as "slides" in sequential order. As new activities are added in the editor, users can (1) change the order of activity execution, (2) eliminate activity and (3) add a condition to finish an activity (i.e., the player must finish the activity in 1 minute before carrying on to the next activity).

For each activity, health professionals and family caregivers can (1) write questions, (2) add verbal instructions, and (3) add background music, (4) adding answers, (5) changing the response timer and (6) manipulating the background music in terms of pitch, pitch shift and rhythm (see Fig. 2B and 2C). Manipulating music in of pitch means that musical notes are distorted in terms of both pitch shift and rhythm. Alternatively, pitch shift changes music notes only in terms of its frequency but not rhythm. Rhythm can turn the music faster or slower. As new answers are added, the user can add images and label them as "correct answers". Thus, the user can establish that one activity can have one or more than one correct answer. The user can also change the order to the answers by clicking the left / right arrows or delete an answer using the trash can icon. Also, all activities can be previewed so that health professionals can see how they will appear to the end user.

Depending on the type of activities, additional user inputs are required. For example, by previewing the Creative Drawings, Activity of daily living activities and Search Objects, users can position the markers within the limits of the game canvas (see Fig.2D). Additionally, in the Search Object and Categorization Activity, users can add additional images (see Fig. E and Fig. F). Finally, the user can export the activities as a serialized ".musiquence" file by clicking the save button (See Fig. 2A). Alternatively, the user can Load an existing file by pressing the load button and continue editing the file (see Fig. 2A).

Game Experience. In this application, users need to open a previously created ".musiquence" file to run the activities. The activities will be executed in the order as established in the *Game Editor*. In terms of software architecture, the application has a state machine (SM) implemented, which determines the sequence of events depending on the player's input (see Fig.3).

A. Musiquence and technological compatibility

Another major advantage of using this framework with a computer illiterate population, it is the versatility in terms of technological compatibility. For now, it has been deployed in augmented reality (AR) technology, but thanks to being implemented in Unity, it can be deployed in a large number

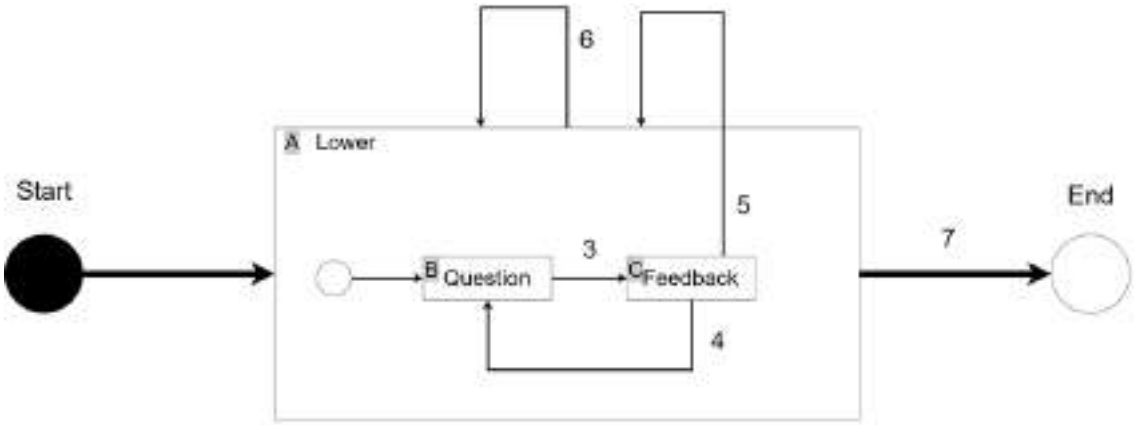


Fig.3. *State Machine*. The game's state changes according to user input. Letter **A** represents the current activity. Letter **B** represents the current question of the activity. Letter **C** represents the feedback provided to the player; If the user selects a correct answer, verbal confirmation – "Very Good!" is triggered. Otherwise, if incorrect "Oh, try again" is triggered. The arrows represent the transitions between states. These transitions only happen if certain conditions are fulfilled. Transition 3 occurs when the player selects an answer (user input). Transition 4 happens when the questions have still correct answers. Transition 5 occurs if all correct answers were selected and that more activities exist. Transition 6 is triggered if there are other activities and the time to finish the activity has ended (if applicable). Transition 7 happens if all answers to all activities have been selected and there are no more activities to be presented.

of platforms. In a previous study [12], we developed a projection-based system with a variety of tasks, which required PwD to complete these using different human-computer interaction techniques (see *IV. Framework Activities*). In general, there was a high success rate in completing the tasks. Also, participants were able to share interesting stories regarding their past. Moreover, health professionals that participated in the experiment were interested in using such a system. Nevertheless, such technology may be expensive for health professionals and family caregiver to purchase. Besides, other variables must be taken into consideration such as portability, access, and the ability for PwD to interact with novel technology. Thus, we are working to release the Musiquence framework (both *Game Editor* and *Game Experience*) for other technologies such as Tablets (using upper limb input) and computer desktop (using mouse input). At the moment, the AR setup consists of a projector projecting on a table surface, a PsEye camera and an image processing software application – AnTS [12] that detects the interaction of users with projected markers.

B. The role of music and reminiscence in the activities

Considering the benefits previously described of using music and reminiscence in PwD, one of the main advantages of this framework is that health professionals, relatives and caregivers can contextualize the activities by using patient centered and meaningful content (images, music and/or physical objects) for participants who are diagnosed with dementia. As the music is one of the most prominent features of the framework, it is played the whole time during the activity.

Further, one of the features described in *III. Musiquence Framework*, it is possible to distort certain components of the uploaded music such as pitch, pitch shift, and rhythm. The purpose for such manipulation is as a guidance system to aid PwD to avoid erroneous decision making. This feature is based on previous work [25], which aimed to test whether participants with dementia were able to avoid erroneous decision making in a virtual environment when exposed to musical distortions.

The experiment consisted of a quiz-like activity run on a tablet with ten questions; participants were required to answer the question by selecting the correct answer among three wrong answers. The experiment had two conditions: the music distortion (MD) and visual distortion (VD) condition. We hypothesized that participants would perform better in the MD condition than VD condition. To test our hypothesis, we used distortions that would stimulate different perceptional modalities. Both conditions had a well-known song playing in the background. In the MD condition, whenever participants select a wrong answer, the background music would become distorted (white noise). Regarding the VD condition, the images of the wrong answers would become distorted (shaken) without altering the background music. Results showed that participants performed better in the MD condition in terms of time and avoidance of erroneous decision making.

We further developed this mechanism in experiment [12] in which PwD had to find virtual objects based on the level of distortion of the music that is played in the background (the more distant from the target, the more distorted the music became). This mechanism is inspired by a case study [24] in which participant EN - diagnosed with advanced Alzheimer's disease - was able to identify 25 out of 26 melodies with erroneous pitch notes in the Distortion Tune Test (DTT). With the proposed framework, we intend to further explore the benefits of musical distortion feedback mechanisms in PwD.

Regarding the reminiscence related aspects of the platform, due to the ease of customizing the activities, the usage of photos or real objects (such as used during reminiscence therapy) to complete the activities can enhance therapeutic outcome. An interesting technique was used during the study by both health professional and researcher [12], in which the sequence of events during the realization of activity was presented in a storytelling narrative. For

example, in an activity of daily living, participants were told to imagine a family event in which the dinner table had to be set-up. The researcher would ask "*We need to put cutlery. Which side should we put the fork in? And the knife? The guests will be thirsty! What do we need to pour water in?*" (see Fig2.D). Thus, by presenting context, PwD may be more prone to participate and communicate during the completion of the tasks.

V. Conclusions and Future Work

In this article, we present a novel and versatile software solution that allows not only customization of cognitive music and reminiscence stimulation activities, but also adapt these to a variety of technologies to target specific needs of PwD.

Currently, we are running a usability study with health professionals using the *Game Editor* platform. We are collecting data through validated questionnaires and feedback from health professionals who have experience in interacting with PwD.

After concluding the usability study, we will work together with the same health professionals to deploy the framework in a longitudinal field study regarding the impact of music and reminiscence related activities in virtual environments in PwD. Such a study will contribute with further evidence on the impact that such therapies have in a dementia population.

Finally, we aim to make Musiquence publicly available so that health professionals and caregivers can use it as yet another tool to stimulate PwD according to their needs and technological availability. Although we have designed and developed this tool for PwD, this tool has a large potential also for other populations in need of cognitive stimulation and personalized interventions.

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