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# Interactive Technologies for Cognitive Stimulation and Well-being of People With Dementia

MASTER DISSERTATION

**Paulo Brando Nóbrega Fernandes**
MASTERS IN CLINICAL HEALTH PSYCOLOGY AND WELLBEING

UNIVERSIDADE da MADEIRA
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**Modelo de tese escolhido: Artigo científico em inglês.**

**Artigo já submetido.**

This article was written according to APA standards – 7th edition and has been submitted to peer review by a scientific journal and is awaiting feedback.

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## Abstract

Globally, the aging population is expected to increase from 12% to 22% between 2015 and 2050. Approximately 20% of this population suffers from mental or neurological conditions, with dementia being one of the most prevalent. Dementia is characterized by progressive cognitive decline and is currently the seventh leading cause of death, posing significant social and economic challenges and requiring extensive support from healthcare and social services. Current treatments for dementia face substantial limitations, particularly pharmacological approaches, which often come with side effects and limited efficacy. Consequently, there is a growing need for innovative non-pharmacological interventions. This thesis explores innovative non-pharmacological approaches to dementia care using interactive technology and is divided into two parts. Part I depicts a randomized controlled trial of the serious game "SAUDÆDE," which integrates personalized cognitive activities based on music and reminiscence therapy for people with dementia in an augmented reality setting. This study assesses the impact of SAUDÆDE on cognition, mood, functionality, and quality of life in people with dementia (PwD), demonstrating significant benefits in overall cognitive function. Part II reviews the use of Virtual reality based interventions through the use of head-mounted displays in dementia care, highlighting their potential to enhance and promote engagement and therapeutic outcomes through exergames. These studies emphasize the importance of personalized, technology-driven interventions in dementia care, showcasing the potential of serious games and Virtual reality-based therapies to improve the well-being and cognitive health of PwD.

***Keywords***: Dementia; Serious Games; Cognitive Stimulation; Virtual Reality; Non-pharmacological interventions

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**List of Abbreviations**

PwD - People with Dementia

VR - Virtual reality

QoL- Quality of Life

HMD - Head Mounted Display

CS - Cognitive Stimulation

CG - Control Group

EG - Experimental Group

MoCA - Montreal Cognitive Assessment

WE - Work Efficiency

DI - Dispersion Index

WAIS - III - Wechsler Adult Intelligence Scale: Third edition

SS - Symbol Search

DSC - Digit Symbol Coding

BLAD - Lisbon Battery for Dementia Assessment

TeLPI - The Irregular Word Reading Test

IAFAI - Adults and Older Adults Functional Assessment Inventory

BADL - Basic Activities of Daily Living

IADL - Instrumental Activities of Daily Living

F-IADL - Familiar Instrumental Activities of Daily Living

A-IADL - Advanced Instrumental Activities of Daily Living

GDS-15 - Geriatric Depression Scale 15 items

WHOQOL-OLD - World Health Organization Quality of Life Questionnaire-Older Adults Module

RCI - Reliable Change Index

GI – Global Improvement

NC – No Change

GD – Global Decline

P – Participant

aMCI- amnestic Mild Cognitive Impairment

BPSD - Behavioral and Psychological Symptoms of Dementia

PEPE - Portable Exergame Platform for the Elderly

VDA – Virtual Desktop Application

BOG – Behavior Observation Grid

C – Case

Q - Question

**Brief presentation of the thesis**

This thesis aims to explore the role of Interactive technologies in cognitive stimulation and the well-being of people with dementia. Currently, there are significant limitations in the treatment of dementia, as medications have restricted effectiveness, are mainly indicated for Alzheimer's disease, are not suitable for all patients and are typically used only in the early stages of dementia to delay its cognitive and physical progression (Spector et al., 2008; WHO, 2023a; WHO, 2023b). Research suggests that combining pharmacological and non-pharmacological therapies can lead to a more effective treatment approach (Ferreira et al., 2021; Spector et al., 2010). Examples of Non-pharmacological approaches in the literature include cognitive stimulation therapy (Saragih et al., 2022), music-based therapy (Ferreira et al., 2019, 2021), and reminiscence therapy (Ferreira et al., 2019).

Pharmacological therapies do not cure or reverse the cause of dementia, highlighting the need for innovative approaches, such as technology-based interventions, which have the potential to impact the lives of PwD and their caregivers positively (Cahill et al., 2007). These technological intervention approaches can be utilized in populations with cognitive decline such as PwD and are divided into different levels of complexity: a) learning compensatory strategies such as making lists with paper and pencil; b) sensory-based interventions of moderate complexity (e.g., Snoezelen room); c) more advanced technologies (e.g., serious games) (Spínola et al., 2022). Serious games are an innovative approach that has been gaining attention in the literature (Zyda, 2005) can promote activity engagement (Drazich et al., 2020; Moholdt et al., 2017), reduce stress and improve mood through beta-endorphin neuron stimulation (Li et al., 2018; Sarkar & Zhang, 2013), and have demonstrated favorable outcomes on reducing depressive symptoms (Saragih, Tonapa, et al., 2022). Serious games offer an affordable treatment avenue that can be conveniently integrated into a user's home or a daycare setting. They enable individuals facing cognitive or physical challenges to engage in virtual reality (VR). VR is a form of interactive technology that functions as a tool that allows individuals to immerse themselves in spatial contexts mirroring real-life situations (Abichou et al., 2017). VR-based interventions have been explored for enhancing health in diverse domains, such as cognitive rehabilitation (Faria et al., 2020, 2024).

To explore the role and impact of interactive technologies on cognitive stimulation and well-being in PwD, this thesis will be divided into two parts, each presenting different studies. Part I study depicts a longitudinal randomized controlled trial design, consisting of a 12-session intervention of serious games in an augmented reality setting that was developed to achieve two objectives: (1) assess the impact of personalized serious games on cognition (primary outcome) and mood, functionality, and quality of life (QoL) (secondary outcomes) in a sample of PwD; (2) conceptualize guidelines for developing personalized game content based on musical preferences, biographical elements, and photos from the self, family, and friends. At the time of writing this Thesis, this study was accepted and is under publication in the IEEE Serious Games for Health 2024 Conference Proceedings.

Part II study depicts a "Systematic Review and Feasibility Study for Enhanced Clinical Practice," study comprised of two parts: a systematic review to explore the use of Head Mounted Display (HMD) in PwD and a feasibility case study consisting of a 5-session intervention of exergaming within a fully immersive VR environment using HMD.

## Part I: Harnessing music and reminiscence approaches to personalize serious games for people with dementia: a randomized controlled trial

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**Abstract**

Current dementia treatments have limitations, leading to a need for complementary approaches for people with dementia. Non-pharmaceutical approaches, like serious games using music and reminiscence-based activities, have been demonstrated to improve health-related domains such as cognition, anxious and depressive symptomatology, functionality, and quality of life. The field of serious games for people with dementia (PwD) has become a very active research area. Nevertheless, a notable portion of these endeavors lacks a robust theoretical basis. Based on the best-established guidelines for personalizing game content, using musical elements, and reminiscence therapy, we have designed a serious game for PwD – SAUDÆDE, emphasizing a person-centered care framework incorporating co-creation and customization of cognitive stimulation programs with and for PwD using personal and meaningful content. Here, we present data on a longitudinal randomized controlled trial where we assess the impact of SAUDÆDE on cognition, mood, functionality, and quality of life in a sample of PwD. Seven PwD went through an intervention of 12 sessions with SAUDÆDE and performed a pre- and post-neuropsychological assessment. Descriptive data analysis of the outcome measures revealed that the experimental group had an increase in general cognition and functionality. Comparatively, the control group had a reduction in functionality and general cognition and a discrete improvement in attention. Additionally, through lessons learned, we aim to provide guidelines for developing personalized game content based on musical preferences, biographical information, and photos from the self and family.

***Keywords***: Music; Reminiscence; Personalization; Serious Games; Dementia; Cognitive Stimulation

## Introduction

Globally, the population has been aging, with an estimated increase from 12% to 22% between 2015 and 2050 (WHO, 2023b). In this population, approximately 20% suffer from mental or neurological conditions, with dementia and depression being the most common (WHO, 2023b). Dementia primarily affects the older population and is currently the seventh leading cause of death among all diseases (Spector et al., 2008; WHO, 2023a). Up to 90% of PwD exhibit psychological and behavioral symptoms such as depression, anxiety, apathy, agitation, hallucination, sleep disturbances, wandering, and irritability (Cao et al., 2023). According to estimates from The Lancet Public Health, the absolute number of people with dementia will continue to increase significantly over time (Nichols et al., 2022). Dementia represents a challenge marked by considerable economic and social demands, posing a significant hurdle for social services, healthcare, and formal and informal caregivers. It requires an appropriate response that manifests in a continuum of long-term care for PwD (Cao et al., 2023; Gottesman & Stern, 2019; Spector et al., 2008; WHO, 2023a).

Dementia develops because of a variety of diseases, traumas, and risky behaviors that primarily affect the brain. Its underlying causes can be organic (e.g., Alzheimer's disease) or non-organic (e.g., excessive alcohol consumption) (L. Ferreira et al., 2021; WHO, 2023a). It can manifest itself in the following forms: Alzheimer's Disease, Vascular Dementia, Dementia with Lewy bodies, and Frontotemporal Dementia. Signs and symptoms can be perceived in three phases: (1) mild, (2) moderate, and (3) severe (L. Ferreira et al., 2021; WHO, 2023a). It is characterized as a chronic and progressive neurodegenerative disease that affects millions of individuals, particularly those over the age of 60. It is hard to diagnose, as symptoms are often identified decades after the onset of the disease's development (Duong et al., 2017; L. Ferreira et al., 2021; WHO, 2023b, 2023a). This disease primarily manifests through the progressive deterioration of cognitive abilities, including memory, learning, orientation, mood, language, and the capacity for judgment and decision-making (Booth et al., 2018; Duong et al., 2017; L. Ferreira et al., 2021; WHO, 2023a). These deficits negatively impact the PwD's ability to perform daily tasks, careers, and overall well-being (Duong et al., 2017; WHO, 2023a). Neuropsychiatric symptoms are also present in PwD (Gottesman & Stern, 2019). Its increasing severity is associated with the escalating severity of dementia and may further contribute to its progression over time. Although these symptoms are not cognitive, they are universally present in PwD (Gottesman & Stern, 2019).

Currently, there are limitations in the treatment of dementia. Pharmacological approaches have many constraints on their effectiveness. Only a few are approved by the Food and Drugs Administration, carry harmful side effects, and are used primarily in mild phases to mitigate cognitive and physical decline (WHO, 2023b, 2023a; Wollen, 2010). Studies indicate that combining pharmacological and non-pharmacological therapies may result in a more effective treatment approach (Saragih, Tonapa, et al., 2022; Spector et al., 2010). Pharmacological approaches do not cure or revert dementia, leading to a need for innovative approaches to mitigate the impact of the disease progression (Cahill et al., 2007). Within the literature, cognitive stimulation (CS) therapy stands out as a non-pharmacological approach to mitigate cognitive decline and improve quality of life (QoL) (McDermott et al., 2019; Nichols et al., 2022) in mild to moderate phases (Kim et al., 2017; Mapelli et al., 2013; Saragih, Tonapa, et al., 2022; Spínola et al., 2022). Although these improvements are not related to better execution of daily life activities, CS therapy preserves cognitive functions. Additionally, it protects against cognitive decline by maximizing brain plasticity and increasing cognitive reserve (Kim et al., 2017). Music and reminiscence therapy are important non-pharmacological approaches with known benefits in this clinical population. Nonetheless, their effects on PwD still lack more robust evidence (Huang et al., 2015; Van Der Steen et al., 2017; Woods et al., 2018). Reminiscence therapy is characterized as CS through personal objects, photos, or videos belonging to PwD, positively impacting cognition, mood, communication, and QoL (L. Ferreira et al., 2019). PwD also appears to maintain musical memory and capacity preserved, being able to discriminate musical notes (L. Ferreira et al., 2019, 2021). Also, music induces (pleasure), positive chemical responses (e.g., dopamine production), and other effects such as relaxation and stress relief, which contribute to improved autobiographical memory and communication (L. Ferreira et al., 2019, 2021; Spínola et al., 2022).

Implementing personalized interventions for PwD using personal preferences and biographical elements is time-consuming and demanding human resources. Serious games offer an affordable treatment avenue that can be conveniently integrated into a user's home or a daycare setting. They enable individuals facing cognitive or physical challenges to engage in virtual reality. Serious games are interactive applications played according to rules, utilizing specific game mechanics to enhance entertainment and enjoyment while achieving predefined goals (Zyda, 2005) within an ecologically valid approach (Faria et al., 2023). A person-centered care framework incorporating co-creation and customization of CS programs for PwD using personal and meaningful content has the potential to yield positive outcomes. This approach can improve collaboration, engagement, enjoyment, and self-acceptance in PwD (Félix et al., 2020). Through serious games, it is possible to create a personalized approach to PwD addressing their cognitive difficulties while attending to their interests (Dörner et al., 2016); serious games can stimulate beta-endorphin neurons that result in reduced stress and improved mood (Li et al., 2018; Sarkar & Zhang, 2013); promote activity engagement (Drazich et al., 2020; Moholdt et al., 2017); and have shown positive impacts on the reduction of depressive symptoms (Saragih, Everard, et al., 2022).

Musiquence is a serious game development platform that allows the creation, adaptation, and personalization of cognitive activities based on music and reminiscence according to PwD needs (L. Ferreira et al., 2019). Studies have shown that the combination of musical and reminiscence elements within the context of serious gaming delivered through the Musiquence platform appeared to impact the well-being of the participants positively. It consistently showed that all participants benefited from the intervention regarding overall cognition (Andrade  Ferreira et al., 2020; L. D. A. Ferreira et al., 2018). A previous trial with Musiquence used a pre-defined number of themes and music extracted from a participatory design study with PwD and formal caregivers (Spínola et al., 2022). The intervention was personalized for a group of people, not individually.

In this study, we developed an intervention based on literature recommendations (Dietlein & Bock, 2019), such as personalizing game content, using musical elements, and performing reminiscence therapy to design a serious game for PwD – SAUDÆDE. This serious game was implemented in the Musiquence platform. Through a longitudinal randomized controlled trial, we aimed to achieve two objectives: (1) assess the impact of SAUDÆDE on cognition (primary outcome) and mood, functionality, and QoL (secondary outcomes) in a sample of PwD; (2) conceptualize guidelines for developing personalized game content based on musical preferences, biographical elements, and photos from the self, family, and friends.

## Methods

### Software and Hardware

Musiquence works through 2 separate applications: (1) game editor, which health professionals can use to create and customize new activities; (2) game experience, where the player experiences the game through the display and execution of activities in sequential order. This platform supports different interaction technologies such as augmented reality (full-body and objects can be used as input devices), PC (mouse is used as an input device), tablets and interactive table (touch is used as input), Leap Motion and Kinect (body movement can be used as an input) (L. Ferreira et al., 2019). Given the difficulties of this population, a mechanism to assist in the correct response was conceptualized through auditory cues. When a participant selects the wrong answer, the background music distorts, signaling that the chosen response is incorrect; after this moment, the participant is given a few seconds to change their decision (L. Ferreira et al., 2019).

**Setup**

Prior research (Andrade  Ferreira et al., 2020; L. D. A. Ferreira et al., 2018) has demonstrated that PwD can positively interact with augmented reality technologies using various modalities. In this study, we have chosen an AR setup consisting of a projection and input through physical objects and limb movements, enhancing accessibility for PwD. The Musiquence platform ran on a laptop and was displayed through the Optoma DLP Projection Display (OPTOMA, New Taipei, Taiwan), held with a tripod. A PSEye webcam (Sony, California, USA) detected markers projected on the table. Musiquence detects these markers through a tracking system – AnTS (Bermúdez i Badia, 2004-2014). The activities were visually presented on the table, and the sound came from the Optoma DLP Projection Display. The hardware setup is shown in Figure 1.

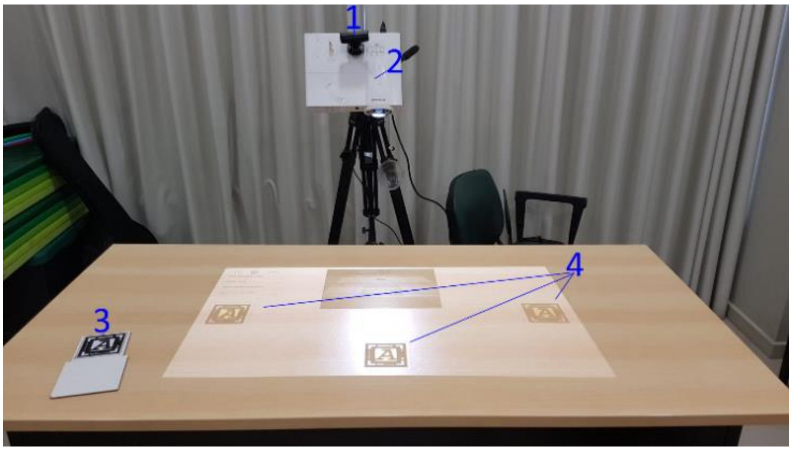


*Figure 1*. Illustration of the augmented reality setup, consisting of the following components: 1- PSEye webcam; 2- Optoma DLP Projection Display; 3- Physical object input; 4- AnTS tracking system.

**Development of personalized game content SAUDÆDE**

The Musiquence platform game editor enabled us to create and edit various activities that can be used to personalize the intervention with digital content (e.g., images and music). Figure 2 displays the different activities with examples from the SAUDÆDE. With this tool, we were able to create and customize SAUDÆDE activities, benefiting from its several functionalities: write questions and answers, upload images, upload music and voice instructions, add activity timer, change response timer, add auditory feedback, preview the activities and organize them, add and delete activities, and add musical distortion as an aid (L. Ferreira et al., 2023).

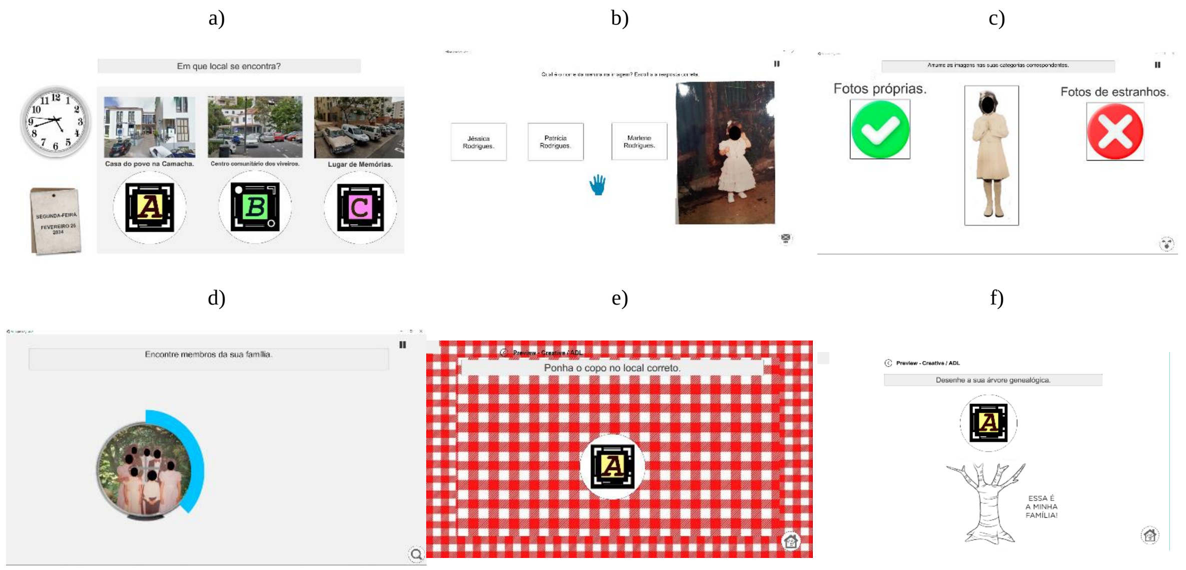


*Figure 2*. (a) Orientation-related activities can be created, and the PwD has to choose the correct answer (stimulates PwD orientation);(b) Knowledge quiz activity: The PwD selects the correct answer to the given question (stimulates memory);(c) Association activity: The PwD must associate given stimuli to their respective categories (stimulates associative memory); (d) Search Activity: The PwD in this activity has to find hidden objects that are only visible with a magnifying glass (stimulates executive functions and attention);(e) Activities of Daily Living: PwD must complete ADL activities (e.g., brushing teeth). To complete the activity, PwD has to select and place the correct object on the marker (stimulate

attention, selective attention, memory and executive functions); f) Creative Drawing: PwD must complete the activity with a drawing and place it in the marker (stimulates fine and gross motor skills and memory);

Reality orientation and reminiscence are two fundamental approaches for CS with PwD (Spector et al., 2010). SAUDÆDE activities are mainly based on reminiscence content, and a session always starts with orientation activities. The reality orientation activity includes questions about the present moment (day of the week, year, season, location). The researcher increased or decreased the difficulty level at the end of each cycle of tasks, depending on PwD feedback and performance. Based on previous Musiquence studies, the following activity themes were chosen: public figures, festivities, regional traditions, flowers, agriculture, regional recipes, and food (Spínola et al., 2022).

Participants' preferences were collected through questionnaires sent to informal caregivers or legal representatives (Annex A). Examples of outcomes from these questionnaires were: 1) Participants' favorite songs (e.g., Christmas music) used to aid in association tasks to aid in reminiscence and cheerful ambiance. 2) Participant (P) 2 liked Lasagna and regional soda "*Laranjada*," P5 liked the regional food Portuguese Stew "*Cozido à Portuguesa*," and coffee and P7 liked the regional food corn-based meal with tuna "*Milho frito com atum*," and fruits. Participant's preferences were collected and used to personalize the content of SAUDÆDE, with each task cycle (week) corresponding to different songs, a theme, and four exercises per activity. Twelve sessions were created (four activities for each type of game) to be administered thrice weekly. Compared to previous work (Spínola et al., 2022), SAUDÆDE had more weekly sessions, so the number of cycles diminished.

**Clinical Sample**

This study is an ongoing randomized controlled trial that intends to recruit at least 20 participants. This study is approved by the University of Madeira Ethical Commission

(Parecer n. 72). Participant recruitment took place at Lugar de Memórias I, a Garouta do Calhau Foundation daycare center for PwD located on Madeira Island (Portugal). Participants are being recruited in groups of eight through a convenience sample of PwD who attend the daycare center daily and were considered for participation if they met the following inclusion criteria: (1) knowing how to read and write, (2) the ability to sit and remain seated, and (3) preserved comprehension of simple instructions, as assessed by the health professionals. Participants participated voluntarily, and informed consent (Annex B) was obtained by themselves and their legal representatives. The intervention could be interrupted at any time if they refused to continue and would be interrupted if there were any signals of adverse events. A total of 10 patients (n=10) were assessed, and eight met the eligibility criteria (n=8). After recruitment and obtaining informed consent from the legal representative or caregiver, participants were sequentially assigned numbers (1-8) based on the alphabetical order of their names. The researcher randomly assigned these numbers to the experimental or control group (CG) using the Research Randomizer (Urbaniak & Plous, 2024), a web-based resource that offers random sampling and assignment. P4 withdrew mid-intervention, reducing the sample size to seven participants (n=7). The sample consists of people diagnosed with dementia with a mean age of M=74.57 ± 11.43, an education mean of M=5.57 ± 3.05 and comprises 87.5% females and 12.5% males. The premorbid intelligence was assessed with the Irregular Word Reading Test [37] for sample characterization. The experimental group (EG) averaged 85 on the IQ complete scale [IQR=70-86], 87 in verbal IQ [IQR=73-88], and 86 in realization IQ [IQR=74-88], and the CG averaged 84 on the IQ complete scale [IQR=70.75-106.75], 86 in the verbal IQ [IQR=73.5-108.25] and 85.5 in the realization IQ [IQR=74-104.5]. These scores fall below the cutoff point of normative data for this population, indicating below-average cognitive functioning for their age group (Alves et al., 2013).

**Procedure**

The intervention took place at the daycare center. Demographic information was collected through structured questionnaires with the support of formal and/or informal caregivers. To assess the impact of the SAUDÆDE intervention, participants underwent a baseline assessment of executive functioning, functional capacity, and dimensions related to mood and QoL. After baseline assessment, the experimental group underwent SAUDÆDE thrice weekly, each session lasting 30 minutes.

The EG participants were invited to sit in a quiet room. At the beginning of every session, the researcher informed the participants about the objectives of their participation in the intervention. Participants were also instructed to carry out the activities as needed, and assistance was provided whenever necessary. Participants were asked if they recognized the images and music played through the activities and would answer other questions regarding the activities at the end of the session. The control group received time-matched standard intervention at the daycare center (music therapy, Snoezelen room, paper-and-pencil cognitive tasks). Upon completing the 12 sessions, participants underwent a post-intervention assessment.

Following each session, participants were briefly interviewed with questions related to the activities: (1) Did you like the activities presented? (2) Do you recognize the music played? (3) Did you like or dislike the activities? (4) Which activities were more challenging and which were easier? (5) Would you change something, or is there anything you would like to see in these activities? (6) Are you interested in conducting more sessions?

**Outcome Instruments**

The following neuropsychological assessment protocol was used to perform a neuropsychological pre- and post-intervention assessment. To assess the primary outcome:

- Montreal Cognitive Assessment (MoCA) is a brief cognitive screening test designed to evaluate mild cognitive decline. This instrument serves as a tool that distinguishes between normal aging and pathological cognitive deficits, assessing six cognitive domains (executive functions, visuospatial capacity, memory, attention, focus, language and orientation). It is helpful in the early identification of individuals with mild cognitive impairment (MCI) and Alzheimer's disease (AD) (Simões et al., 2008). Different versions were used to minimize practice effects.
- The Toulouse-Piéron Cancelation Test (Toulouse & Piéron, 1904) assesses attention, specifically selective and sustained attention, processing speed, fatigue resistance, and visuo-perceptual capacity. Work efficiency (WE) indicates attentional and perceptual performance, and the Dispersion Index (DI) measures impulsivity and distraction (Simões et al., 2010).
- Wechsler Adult Intelligence Scale: Third edition (WAIS-III) has 14 subtests to evaluate intelligence. In this study, we used the Symbol Search (SS) and the Digit Symbol Coding (DSC) to evaluate attention and processing speed (Wechsler, 1997).
- Lisbon Battery for Dementia Assessment (BLAD): This battery consists of various subtests that assess memory, attention, language, executive functions, and visuospatial abilities. This study used the Words Pairs subtest to assess verbal memory and learning abilities (Guerreiro, 1998).
- The Irregular Word Reading Test (TeLPI) comprises 46 Portuguese words with decreasing familiarity and is designed to estimate premorbid intelligence in individuals aged 25 years or older. It evaluates crystallized intelligence and is specifically designed to withstand the effects of neurological dysfunction (Alves et al., 2013).

To assess secondary outcomes:

- The Adults and Older Adults Functional Assessment Inventory (IAFAI) was explicitly developed for the Portuguese population; it is a structured questionnaire applicable to adults, older people, caregivers, or other informants. This inventory assesses functional abilities ranging from basic self-care and routine activities to more complex cognitive activities (e.g., financial management). Functional abilities are divided into two general categories: basic activities of daily living (BADL) and instrumental activities of daily living (IADL). IADL abilities are further divided into two categories: familiar instrumental activities of daily living (F-IADL) (e.g., Household activities) and advanced instrumental activities of daily living (A-IADL) (e.g., managing finances). It further distinguishes functional disability attributed to physical, cognitive, and emotional factors (Sousa et al ., 2013).
- The Geriatric Depression Scale (GDS-15) was developed for screening depressive symptoms in late adulthood. The items in this scale pertain to characteristics of depression in older adults within the affective and cognitive domains (Matos et al., 2019).
- The QoL Assessment (WHOQOL-OLD) is an inventory designed to assess perceived QoL in older adults. The Portuguese adaptation evaluates seven domains (sensory functioning; autonomy; past, present, and future activities; social participation; death and dying; intimacy; and family/ family life) (Vilar & Simões, 2005).

## Results

### Adherence and Engagement

One participant, P4, withdrew mid-intervention, reducing the sample size (n=7) due to unpredictable reasons unrelated to the intervention. All participants (n=7) attended and finished all 12 sessions in four weeks (attendance and completion rate=100%), which suggests participants had a high level of engagement. P7 seemed to lack motivation to participate in sessions but would always attend.

**Primary Outcome**

Participants' outcomes are represented in Table 1. A pre-post quantitative analysis has shown that the EG showed a relevant increment (pre-post Mdn =4) in the MoCA test [Pre: Mdn= 11, IQR=9-15; Post: Mdn=15, IQR=14-19], mainly in the visuospatial-function (pre-post Mdn =2), attention, concentration, and memory domains (pre-post Mdn =2), and orientation (pre-post Mdn =2). There was a reduction in the Words Pairs subtest (a verbal learning test) (pre-post Mdn=-2) [Pre: Mdn=6.5, IQR=3.5-7; Post: Mdn=4.5, IQR=2.5-10]. The CG had no significant increase in the MoCA test [Pre: Mdn=9.5, IQR=5-22.25; Post: Mdn=10, IQR=6-20] but had a substantial rise in Attention, Concentration and Memory domains (pre-post Mdn=2).

There was a decrease in the Toulouse Piéron DI in the only CG participant that managed to complete the test (pre-post Mdn=-5%) [pre: Mdn=22%; post: Mdn=17%].

**Secondary Outcomes**

A pre-post quantitative analysis has shown that both groups had a slight increase in the GDS-15 test (meaning that more is worse), EG (pre-post Mdn=1): [Pre: Mdn=6, IQR=4-14; Post: Mdn=7, IQR=6-8], CG (pre-post Mdn=0.5): [Pre: Mdn=3.5, IQR=3-7; Post: Mdn=4, IQR=1.5-6.5].

Concerning functionality, there was a decrease (pre-post Mdn=-10%) in the IAFAI test [Pre: Mdn=62%, IQR=50%-95%; Post: Mdn=52%, IQR= 46%-94%] mainly in the F-IADLs (pre-post Mdn =-6%) in the EG. As for the CG, there was an increase (pre-post Mdn=9%) [Pre: Mdn=65%, IQR=44%-82%; Post: Mdn=74%, IQR=46%-84%], mainly in the BADL domain (pre-post Mdn=9%).

Finally, there was a decrease (pre-post Mdn=-10) in WHOQOL-OLD for EG [Pre: Mdn=113, IQR=87-114; Post: Mdn=103, IQR=86-114].

Table 1

*Pre and Post Results of the Neuropsychological Assessments. bold and underlined values represent improvement and decline*

| Assessment Instruments | | | Assessment Instruments Results | | | |
|---|---|---|---|---|---|---|
| | | | Control Group | | SAUDÆDE Group | |
| | | | Mdn | Pre-post difference | Mdn | Pre-post difference |
| MoCA | Total Result | Pre | 9.5 | 0.5 | 11 | 4 |
| | | Post | 10 | | 15 | |
| | Executive functions | Pre | 0.5 | 0.5 | 1 | 1 |
| | | Post | 1 | | 2 | |
| | Visuospatial function | Pre | 2 | 0 | 1 | 2 |
| | | Post | 2 | | 3 | |
| | Memory | Pre | 0 | 0 | 0 | 0 |
| | | Post | 0 | | 0 | |
| | Attention, Focus and Memory | Pre | 0 | 2 | 1 | 2 |
| | | Post | 2 | | 3 | |
| | Language | Pre | 3 | -0.5 | 2 | -1 |
| | | Post | 2.5 | | 1 | |
| | Orientation | Pre | 3 | -0.5 | 4 | 2 |
| | | Post | 2.5 | | 6 | |
| WAIS III | Digit Symbol Coding | Pre | 0 | 2 | 12 | 2 |
| | | Post | 2 | | 14 | |
| | Symbol Research | Pre | 1 | 0 | 5 | 0 |
| | | Post | 1 | | 5 | |
| BLAD | Pairs Of Words | Pre | 3.75 | 0 | 6.5 | 2 |
| | | Post | 3.75 | | 4.5 | |
| Toulouse Piéron | Dispersion Index | Pre | 22% | -5% | 36% | -2% |
| | | Post | 17% | | 34% | |
| | Work Efficiency | Pre | 50 | 3 | 34 | -0.5 |
| | | Post | 53 | | 33.5 | |
| IAFAI | Global Functional Disability | Pre | 65% | 9% | 62% | -10% |
| | | Post | 74% | | 52% | |
| | | Post | 16% | | 6% | |
| | F-IADL | Pre | 30% | 1.5% | 30% | -6% |
| | | Post | 31.5% | | 24% | |
| | | Post | 0% | | 0% | |
| | Cognitive Impairment | Pre | 65% | 8% | 58% | -6% |
| | | Post | 73% | | 52% | |
| | | Post | 0% | | 0% | |
| GDS-15 | | Pre | 3.5 | 0.5 | 6 | 1 |
| | | Post | 4 | | 7 | |
| WHOQOL-OLD | Total Result | Pre | 109.5 | -1.5 | 113 | -10 |
| | | Post | 108 | | 103 | |

**Reliable Change Index**

The Reliable Change Index (RCI) aims to evaluate the efficacy of a specific therapy or program. Rather than emphasizing mean score differences, it offers insights into treatment effects for each individual, enabling assessment of whether an individual demonstrates improvement or deterioration compared to their initial assessment (Brazão et al., 2015). Furthermore, we calculated the RCI to evaluate significant clinical change following the intervention using the Zahra RCI calculator . If the results exceed 1.96, we can assert with a confidence interval of 95% that significant change has been verified (Jacobson & Truax, 1991). To interpret this measure, if a participant's changes exceed 1.96, it indicates Global improvement (GI); if changes fall within the range of 1.96 to -1.96 standard deviations, it signifies No Change (NC); and if changes are below -1.96, it indicates Global Decline (GD). Results are detailed in table 2.

Table 2

*Reliable Change Index of Intervention*

| Outcome Measures | | Categories | CG (n=4) | EG (n=3) |
|---|---|---|---|---|
| MoCA | | GI | 0 | 3 |
| | | NC | 4 | 0 |
| WAIS-III | Digit Symbol Coding | NC | 4 | 3 |
| | Symbol Search | GI | 1 | 1 |
| | | NC | 3 | 2 |
| BLAD | Word Pairs | GI | 0 | 1 |
| | | NC | 4 | 1 |
| | | GD | 0 | 1 |
| IAFAI | | NC | 4 | 3 |
| GDS-15 | | NC | 4 | 2 |
| | | GD | 0 | 1 |
| WHOQOL-OLD | | NC | 4 | 3 |
| | | GD | 0 | 0 |

## Lessons Learned

During the process, a few guidelines were identified for approaching PwD in assessing and intervening with serious games through augmented reality. With these guidelines, we aim to orient game creation, customization, and intervention on PwD.

1- Assessment: It is crucial to select assessment instruments carefully when working with PwD. Our study used the Toulouse Piéron Cancellation Test; however, only one participant completed the test. After switching to a shorter version, two additional participants completed it, but most of the sample could not complete the task. Subjective self-response scales like the WHOQOL-OLD and GDS-15 may not accurately represent their QoL or symptoms of depression due to their condition. Additionally, we observed that the time of day significantly impacts performance, with mornings being preferable for assessments whenever feasible.

2- Theme Selection: It is crucial to choose all themes beforehand and to engage in discussions with both formal and informal caregivers to identify their preferences related to the themes. Some participants opted for the theme of revisiting old photographs of themselves, which proved to be a highly positive experience for them. As a result, we strongly recommend incorporating this theme into future activities.

3- Questionnaires: While family members proved valuable information sources, the responses were often too simplistic and did not align with our expectations. For example, when asked about the participant's favorite food, the response was that the participant did not show a particular interest or liked food in general. As a result, we conducted interviews with the participants and other professionals at Lugar de Memórias to get further insights into participants' preferences. If questionnaires are to be utilized for gathering information in the future, we recommend including a note on the questionnaire urging respondents to provide comprehensive answers. Additionally, it is essential to emphasize the significance of obtaining detailed information and its implications for customizing activities.

4- Music selection: It is sometimes complicated for PwD to remember which songs they like and which are their favorite. As such, asking family members or formal/informal caregivers is essential. Their insight can provide valuable guidance in choosing music that resonates with the PwD and enhances their overall experience. P2 demonstrated a keen awareness of background music, often recognizing and identifying songs and singers, while P7 occasionally engaged with her favorite music by singing along or requesting to turn it off. P5 was not vocal about the music but generally recognized it when prompted.

5- Personalization: Despite the preliminary results, personalizing reminiscence activities for each participant was highly beneficial. It is crucial to prioritize the quality of stimuli and the familiarity of images or objects related to the themes, as this can enhance problem-solving abilities and contribute to a more fulfilling overall experience. This approach consistently evoked curiosity, reminiscence, and engagement among participants. Participants frequently acknowledged that the activities resonated with familiar themes from their past, prompting them to share comments and memories related to their personal experiences. For instance, during discussions about foods and regional recipes, P7 would express immediate interest upon seeing her favorite food, moving closer to the table and commenting enthusiastically: *"Ah! I love grapes"*, or *"Milho com atum, my mouth is watering."* Similarly, P2 eyes would light up as she exclaimed, *"I love lasagna!"* or "*Look, it is laranjada!*" Participants also shared their preferences and recipe preparation methods, with P5 remarking, "This is my way of making it. Others do it differently." In activities centered around festivities and traditions, P2 expressed affection for Christmas and its traditions, often reminiscing about the local tradition of "*Missa do Parto*" and its songs. P7 recalled memories of her marriage during the local festivity of "*Festa de St. António*." When discussing flowers and agriculture, participants recognized and admired the beauty of the flowers used. They identified which crops were typically farmed locally and the professions responsible for cultivating and selling flowers. During discussions about public figures, all participants recognized and expressed admiration for the individuals featured in the activity. For example, P2 exclaimed, *"Look, it is my dear Alberto João Jardim,"* who was the former regional president of Madeira Island. While P5 laughed and said, *"It is Fernando Mendes!"* (a famous TV host) P2 and P5 revisited old photographs of themselves and their families in their chosen theme, relishing the opportunity to reminisce about memories and identify family members captured in the images. P2 particularly enjoyed this theme, confidently remembering all the individuals in the photos and recalling the events depicted with amazement. P5 was surprised and somewhat embarrassed to see her photographs in the activity, jokingly commenting, "Beautiful lady." This reaction was especially meaningful, as P5 typically appeared more reserved and less reactive. P7 chose the theme of animals, expressing amazement upon seeing animals for the first time but also mentioning that she did not enjoy animal activities, indicating a contradiction in her preferences.

6- Communication: A platform that utilizes music and reminiscence-related activities requires effective communication with individuals with PwD and their formal/informal caregivers. Acknowledging that cognitive deficits may hinder their ability to engage with the platform is essential. Many participants may not be familiar with technological devices, underscoring the importance of providing clear instructions and ongoing support. Additionally, participants may be reluctant to seek help or instructions, highlighting the need to be attentive to verbal and non-verbal cues and offer assistance proactively. Waiting for a request for help may not be effective, as PwD may refrain from asking, feeling inadequate or burdensome. Moreover, participants may encounter moments of demotivation, highlighting the importance of reinforcing positive aspects, such as recognizing their accomplishments.

7- Activities Creation and Interaction: To ensure smooth operation within an augmented reality setting such as the one used in this intervention (AnTS; Bermúdez i Badia, 2004-2014), it is crucial to position stimuli in the central and upper sections of the screen, with a white background, except for the stimuli. Additionally, the PSEye webcam should be placed atop the projection to cover the entire display area. Ignoring these recommendations increases the risk of poor tracking, rendering tasks unachievable. Maintaining an appropriate level of difficulty is paramount, necessitating the customization of activities based on feedback from PwD. P2 frequently expressed dissatisfaction with drawing activities and eventually refused to participate. Addressing this challenge involved adjusting the difficulty level of the activities. Conversely, P7 often found activities either too easy or difficult and expressed aversion to utilizing the tracking device and the hand symbol displayed, along with a lack of motivation to persist. It is important to note that this participant dislikes any form of activity. In contrast, P5 enjoyed engaging with activities as long as they contributed to her cognitive functioning, often stating, *"I like activities that make my head move."* Consistent positive feedback following each successful activity emerged as a significant confidence and performance booster. P2 greatly appreciated receiving positive feedback from voice instructions when providing correct answers and sometimes expressed gratitude by saying to the instructor's voice, "*Thank you, miss, I like you."* Given their limitations, activities should feature simple, clear, and straightforward instructions when introducing task goals. Participants may require repeated guidance to maintain focus during activities.

**Discussion**

SAUDÆDE was individually customized for each participant. The goal was to optimize engagement and enjoyment in a serious game-like manner through personalized activities tailored to participant's preferences.

Across the general cognition assessment measure MoCA, participants in the EG demonstrated a significant improvement, according to the RCI. The EG participants improved by 4 points on the MoCA assessment, whereas the CT group only slightly improved by 0.5 points. Regarding the impact of SAUDÆDE in specific cognitive domains, participants had difficulty completing the Toulouse Pieron cancellation test. Only 1 participant from the CG and two from the EG completed it. EG participants had a high level of DI Mdn=36% that slightly decreased post-intervention (Mdn=-2%) and had a slight decrease (Mdn=-0.5) in WE post-assessment (Mdn=33.5). CT group, namely Participant 6, had a low dispersion index with DI=22% and a significant decrease post-intervention -5%, a slight increase (Mdn=3) on WE post-assessment Mdn= 53. These results indicate that in the EG, there were no significant changes in attentional or perceptual performance; however, in the CG (P6), significant changes were observed, which translates to an improvement in the ability to pay attention and a reduction in impulsivity and distraction. In the WAIS-III SS subtest, groups showed no difference post-assessment, although according to the RCI, one participant from both groups experienced a significant increase. The DSC results showed an improvement (Mdn=2) post-assessment for both groups, which indicates an increase in visual construction, processing speed and visual attention but showed no significant changes according to the RCI. Considering BLAD's Pair of Words subtest, the EG results showed a significant decline (Mdn=-2) post-assessment, which indicates a decline in verbal memory and verbal learning abilities compared to the CG, which showed score maintenance (Mdn=0), the RCI shows that for the CG there were no significant changes, but for the EG there were a global improvement, decline and no significant changes.

Since dementia is typically associated with an exponential decline in cognitive function, achieving stability is viewed as a positive outcome. Therefore, intervention administered to both groups could be beneficial in maintaining cognitive function. Previous studies reported such benefits (McDermott et al., 2019; Nichols et al., 2022), although the EG significantly improved overall cognition in the MoCA test.

Considering WHOQOL-OLD, results showed a lower score on perceived QoL post-assessment (Mdn=-10) for the EG associated with a decline (Mdn=-5) in the social participation domain and no significant change for the CG (Mdn=-1.5), both groups had no significant changes according to the RCI. These findings contradict existing literature, which suggests that CS, reminiscence, and music approaches are typically associated with an improvement in quality of life (L. Ferreira et al., 2019; McDermott et al., 2019; Nichols et al., 2022).

The EG exhibited a 10% decrease in median scores for global function disability post-assessment, indicating improved performance in familiar instrumental activities of daily living (F-IADL) and cognitive impairment domains. In contrast, the CG demonstrated a 9% increase in global function disability, indicating a decrease (mdn=8%) in both performances in basic activities of daily living (BADL) and cognitive impairment domains. However, according to the RCI, there were no significant changes. While it is assumed that cognitive improvement generalizes in ADL functioning, it is noted in the literature that enhancements in cognition are not necessarily directly linked to improvements in ADL functioning (Kim et al., 2017; Ryan & Brady, 2023). SAUDÆDE contained ADL activities, which might have resulted in an improvement in the EG or can be due to it being administered at various intervals. PwD experiences periods of decline and improvement, which may have influenced the variability in informant responses.

Incorporating co-creation and customization of the CS program for each participant using personal and meaningful content yielded positive outcomes. Participants reported liking the activities and seemed engaged and happy while performing them. P7 does not want to do any activity at the daycare center but always agrees to attend the sessions and never misses one. This approach has positively impacted collaboration, engagement, and enjoyment, as described in the literature (Félix et al., 2020). Another noteworthy discovery was that Participants could identify the researcher who conducted the SAUDÆDE program despite limited interaction outside the intervention sessions. Although they did not recall specific activities or themes, they associated the researcher with guiding them through activities in the augmented reality setting. For example, P5 remembered engaging in activities with the researcher and inquired about future sessions despite not recalling the researcher's name, schedule or activities.

Similar findings from this study are present in previous similar work with the same augmented reality settings (L. Ferreira et al., 2023). The sample in this study showed improvement in attention and had identical results in WAIS-III subtests, with an SR increase and a slight decrease in DSC, indicating improvement in visual construction, processing speed, and visual attention. Overall cognition showed cognitive function maintenance, reported subjective QoL maintenance, and showed similar behavioral changes.

**Conclusion**

In conclusion, the SAUDÆDE program demonstrated favorable outcomes, particularly in enhancing overall cognition compared to CG standard intervention. EG participants never indicated any discomfort or adverse events during intervention or when their daily routines were interrupted. Participants appreciated the personalized content, exhibited heightened engagement and curiosity upon encountering familiar material, and desired additional sessions. Nevertheless, it is crucial to recognize the limitations of this study, particularly the small sample size, which renders generalization of results difficult. Additionally, challenges were encountered in collecting reminiscence material, leading to suboptimal activities, particularly for P7. Furthermore, technical issues were experienced during the intervention, further complicating the study's intervention. Future research endeavors will focus on expanding the sample size and exploring the feasibility of allowing SAUDÆDE participants to choose from a broader range of themes suggested in the study (Spínola et al., 2022).

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## Part II: Head-Mounted Displays in Dementia Care: A Systematic Review and Feasibility Study for Enhanced Clinical Practice

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**Abstract**

Current dementia treatment has limitations, leading to a need for complementary approaches, such as serious games, which are a non-pharmaceutical alternative with known benefits in health-related domains such as cognition and mood. The field of mental health interventions through virtual reality with people with dementia (PwD) has become a very active research area, especially in cognitive and behavioral domains. However, existing interventions often need more immersive experience of head-mounted displays (HMDs) as they are typically implemented on computers, projections, and tablets.

Individuals with dementia may face barriers when engaging in physical exercises, namely, motor impairments and institutionalization-related constraints. However, physical exercise is linked with beneficial mental outcomes. To address this problem, innovative approaches such as Exergames are needed. Integrating gamification elements with cognitive stimulation in a game environment promotes physical activity and engagement by making mundane activities more enjoyable. To provide guidelines for clinical practice in such an emerging field, we systematically reviewed the use of HMDs for interventions with PwD. We ran a feasibility study, presenting exergames in an HMD to sample with PwD. Participants underwent a 5-session intervention of exergames previously validated for the Portuguese elderly in floor projection interaction format.

Results emphasize the feasibility and potential benefits of using exergames in HMD. Positive cognitive outcomes were observed for most participants. The immersion and gamification of activities resulted in high levels of engagement, which acted as a motivator for physical exercise. However, some mild adverse effects were experienced, and further research is needed to explore long-term effects and minimize HMD limitations.

***Keywords*:** Dementia; Exergames; Mental Health; Head-Mounted Display

## Introduction

Dementia currently has a significant social and economic impact on social and healthcare services, primarily affecting the elderly population and ranking as the seventh leading cause of death among all diseases (Spector et al., 2008; WHO, 2023a). Globally, the population has been aging, with an estimated increase from 12% to 22% between 2015 and

2050 (WHO, 2023b). In this population, approximately 20% suffer from mental or neurological conditions, with dementia and depression being the most common (WHO, 2023b). Dementia is characterized by chronic and progressive neurodegeneration that affects millions of individuals, especially those over the age of 60 (Duong et al., 2017; WHO, 2023a, 2023b). Its underlying causes can be organic (e.g., Alzheimer's disease (AD)) or non-organic (e.g., excessive alcohol consumption) (Ferreira et al., 2021; WHO, 2023a). This disease primarily manifests through the progressive deterioration of cognitive abilities, including memory, learning, orientation, mood, language, and capacity for judgment and/or decision-making (Duong et al., 2017; Ferreira et al., 2021; WHO, 2023a). The worsening of neuropsychiatric symptoms is linked to the progression of dementia, and its management determines its advancement over time (Gottesman & Stern, 2019). Up to 90% of PwD exhibit symptoms such as depression, anxiety, apathy, agitation, hallucination, sleep disturbances, wandering, and irritability (Cao et al., 2023).

Currently, there are many limitations in treating dementia (WHO, 2023b, 2023a; Wollen, 2010). Studies indicate that combining pharmacological and non-pharmacological therapies may result in a more effective approach (Saragih et al., 2022; Spector et al., 2010). The absence of physical activity is correlated with negative health outcomes in older adults, an increase in health-related costs, higher mortality, and a decrease in quality of life (QoL) (Cunningham et al., 2020; Nocon et al., 2008; Penedo & Dahn. Physical activity is recommended for healthy aging for those in residential care and daycare settings (De Souto Barreto et al., 2016; Van Santen et al., 2018; WHO, 2022) and positively influences fitness, overall cognition, functioning, general health and well-being (Chodzko-Zajko et al., 2009; McPhee et al., 2016).

Institutionalization may be associated with developing sedentary habits, accentuating aging trends, such as decreased functional capacity and cognitive decline (Marshall & Berg, 2010; Rodrigues et al., 2022). Exergames have the potential to effectively promote physical and cognitive activity and maintain these behaviors by integrating gamification elements (e.g., point systems and medals) and transforming repetitive tasks into meaningful experiences (Klusmann et al., 2021). Additionally, exergaming relies on tracking the user' body movement or reactions, which are fed back into the game, influencing the course of the game that is shown on the screen in a personalized and adaptive manner (Van Santen et al., 2018). According to the Cognitive Enrichment hypothesis (Hertzog et al., 2008), exergaming could offer advantages to PwD by creating an enriched environment that stimulates multiple domains simultaneously, which can promote enhanced brain functioning (Ismail et al., 2022; Van San-ten et al., 2018).

Virtual reality (VR) based interventions to promote health have been explored in many fields, such as motor rehabilitation (Noveletto et al., 2020; Vourvopoulos et al., 2016), cognitive rehabilitation (Faria et al., 2020, 2024), and cybertherapy (Cameirão et al., 2023; Kandalaft et al., 2013). VR can serve as a tool that allows complete immersion of individuals in spatial contexts that imitate real-life situations (Abichou et al., 2017). In order to provide guidelines for clinical practice with PwD in such an emerging field, in this work, we performed a systematic review of the use of HMDs for interventions with PwD and ran a feasibility study, presenting exergames in an HMD to a sample of PwD.

## Literature Review

### Method

A systematic search of the existing literature was performed, following the PRISMA guidelines, using three digital databases: PubMed, IEEE, and ACM. The search focused on intervention studies published in English from 2020 to 2024 in peer-reviewed journals and conferences. This timeframe was chosen due to the Meta Quest 2 release, which offered significant advancements over the Rift S, including enhanced portability and a more attractive price. Additionally, the March 2024 Steam Hardware & Software Survey (Valve, 2024) showed the Quest 2 as the most popular HMD, preferred by 37.84% of users. The search targeted titles and abstracts using the following Keywords and Boolean logic: ‘Virtual Reality’ OR ‘VR’ AND ‘Dementia.’

Clinical trials and randomized clinical trials were included if: (1) they involved interventions with PwD; (2) the intervention involved VR environments, including 360º videos and exergames; (3) they had at least one outcome measure result related to the intervention clinical effects, (4) HMD was used as the interface. Articles were excluded if they did not provide outcome data from objective clinical measures (such as cognitive and motor assessment instruments, questionnaires, and interviews), were not peer-reviewed, or were systematic reviews or meta-analyses.

Data from the included articles were extracted by the first author. The inclusion of the articles was discussed and reviewed in two meetings (one in the screening and one in the eligibility phase) with the remaining authors. The general characteristics and results of the studies were extracted, namely the author’s name and year of publication, study design, participants, type of interaction and display, type of assessment/rehabilitation VR task, outcome measures, main conclusions, and challenges.

**Results**

The results of the different phases of the systematic review are depicted in the PRISMA flow diagram. A total of 19 papers were identified through database searching, and there were no duplicates. In the first screening based on titles and abstracts, six were removed mainly due to the type of study (review articles, theoretical articles, studies describing tools with no clinical validation, studies designing new tools). In total, 13 full-text articles were assessed for eligibility; 4 were excluded as they did not involve PwD, and four were excluded because they did not use an HMD. Accordingly, this review included five articles for analysis; 4 had an experimental design, and 1 had a mixed method design. One of these five articles included in the review (Park et al., 2020) was still included in the review despite not being destined to PwD due to the study being destined to a sample of participants with amnestic Mild Cognitive Impairment (aMCI). While this condition is not considered dementia, it is a condition that might indicate early phases of Alzheimer's disease and is considered to be in a stage between aging normally and developing dementia (Park et al., 2020). The PRISMA flow diagram (Figure 3) and the articles included (Table 3) are described in Annex C and D.

## The use of HMDs in mental health interventions for PwD

### *Cognitive training*

Integrating VR-based approaches in cognitive interventions can promote learning and training (Jonsdottir et al., 2018). Literature shows that VR training enhances diverse cognitive abilities. For example, game-based simulations reduce anxiety or discomfort and improve impaired limb functions (Esteves et al., 2019).

The study of Park et al. (2020) explored the feasibility, tolerability, and effects of a 12-week culture-based VR-based training program on the domains of cognitive functioning on a sample of aMCI (n=21, Experimental Group (EG) n=10 and Control Group (CG) n=11). The VR-based training program destined at the EG was designed as a "multicomponent restorative cognitive function training" and consisted of serious games to train specific cognitive functions: to assess and improve attention and perceptual space skills, a shooting game named "Crows and Seagulls" was used in a traditional Korean setting, in this game. Participants had to identify the crows among seagulls and shoot them. To train and assess attention, another game, "Seek a Song of Our Own," was used; this game involves hitting targets according to the rhythm and drumming of a traditional Korean instrument, "Janggu." To train and assess processing speed and improve numerical ability and perceptivity, the

"Automated Teller Machine (ATM) machine" game was used; this game consists of withdrawing money according to a specific given amount displayed on the screen. To train and assess executive function and improve the level of perceptivity and numerical and logical ability, the "Shopping in the Mart" game was used; this game involves shopping in a mart for items required by the participants' families. To assess and train memory, two games were used: "Fireworks Party," which involves decorating a night sky by launching fireworks in numerical order, and the game "Fruit Cocktail," which consists of making cocktails by answering questions. This intervention did not result in any improvement in the different domains, which, according to the authors, could be due to a short period of intervention (12 weeks). Nevertheless, the VR-based training had a good compliance rate (91.55% ± 6.41%) and was well-tolerated with reduced negative events (4.2% of participants reported dizziness and 8.3% reported fatigue).

***Reminiscence Therapy***

Reminiscence therapy is a non-pharmacological approach to cognitive stimulation, administered through the use of personal objects, photos, or videos, with known benefits on QoL, mood, cognition, and communication (Ferreira et al., 2019). This person-centered approach allows customization according to each individual and is recommended for consideration in clinical practice (Dyer et al., 2016; Westphal et al., 2017). Saredakis and colleagues (2021) performed a multisite nonrandomized controlled trial aimed at exploring whether using HMD in a VR-based context improves symptoms of apathy compared to using a laptop and physical items on a sample of older adults living in residential care with up to moderate impairment as assessed according to the Psychogeriatric Assessment Scale (Jorm et al., 1995). Participants were distributed into three groups: the EG, who did the VR-based reminiscence therapy; the active CG, who did the reminiscence therapy through laptop and physical items; and the passive CG, who received standard care. Participants from the active treatment groups underwent three sessions with a 20-minute duration within two weeks. For the EG, the reminiscence therapy involved watching 360º videos. The videos were selected based on each participant's personal background and memories. The videos were selected from YouTube VR and street view content from the Wander APP; for the active CG, the content, instead of being displayed through the HMD, was mirrored onto the laptop. This study's findings suggest that there were no conclusive significant differences between the EG and the active CG. Although results from session records indicate that there was a preference for watching content through the HMD, qualitative findings suggest that more positive emotions were observed in participants in the EG compared to the active CG. Although VR promotes immersion and realism, it might compromise the interaction between the participant and the clinician. There were minimal side effects; one participant reported having a headache, and another had a heavy-head feeling. This study demonstrates that it is possible to use immersive VR to experience reminiscence therapy in an aged care context (Saredakis et al., 2021).

***Videos to improve mood***

Three feasibility studies explored the acceptability, usability, and safety of VR-based interventions using videos were identified (Appel et al., 2023, 2024; Brimelow et al., 2022). These studies aimed to assess the effects of this form of therapy on behavioral and psychological symptoms (BPS) (Brimelow et al., 2022), to improve mood, QoL, well-being (Appel et al., 2023), behavioral and psychological symptoms of dementia (BPSD) falls, length of stay and QoL (Appel et al., 2024).

These studies directed their intervention to PwD and their caregivers (Appel et al., 2024) and a sample comprised of older people (48% with a dementia diagnosis) (Brimelow et al., 2022). The intervention consisted of watching videos from a library with 84 five-minute-long, 360º videos from a custom-developed app “VRx@Home” (Appel et al., 2023), watching videos selected from “off the shelf” applications (e.g., Expeditions, YouTube, Relax VR, Arscape, Nomads) (Brimelow et al., 2022) and another library of short 360º films intentionally chosen to be calming designed specifically for PwD (Appel et al., 2024).

These studies have shown that VR-based intervention has led to immediate improvements in mood and reductions in persistent behavioral and psychological symptoms (BPS) (Brimelow et al., 2022) and a significant reduction in aggressive behavior, although there were no significant differences for other BPSDs, in terms of falls, longer length of stay, or QoL (Appel et al., 2024) and no significant differences in levels of anxiety, sadness, or anger (Appel et al., 2023). Participants reported improved mood, pleasure, and reduced apathy during VR sessions (Appel et al., 2023; Brimelow et al., 2022), often triggered by personal connections to the video content, fostering reminiscence and engagement (Brimelow et al., 2022). VR seemed to elicit a stronger emotional response compared to a tablet, with caregiver confirmation on this matter, possibly due to a sense of immersion (Appel et al., 2023). Different tools may serve different purposes, with tables seeming better at giving a joint experience to PwD and caregivers and VR as a tool to promote a more immersive experience (Appel et al., 2023). Overall, participants tolerated fully immersive VR and enjoyed the experience, with minimal adverse effects reported (Appel et al., 2024; Brimelow et al., 2022).

## Discussion

Investigation into VR-based interventions on PwD is relatively scarce despite the potential benefits they may offer in terms of mood improvement, reduction of behavioral and psychological symptoms, and potentially enhancing QoL. The purpose of this review was to provide an overview of the use of VR-based interventions in this population, aiming to shed light on their effectiveness and potential applications in dementia care. In this review, we have explored various aspects of VR-based interventions for PwD, including cognitive training, reminiscence therapy, and the use of videos. Each intervention modality offers unique opportunities and challenges in the context of dementia care. The integration of VR into mental health holds promise for promoting learning and cognitive training among individuals with cognitive impairments. While past studies have demonstrated the potential benefits of VR training in enhancing cognitive abilities, findings from a feasibility study by Park et al. (2020) indicate mixed results regarding its effectiveness in improving cognitive functioning among individuals with aMCI. Although the VR-based training program did not lead to significant improvements in cognitive domains over 12 weeks, the high compliance rate and tolerability suggest that culture-based VR training programs could be effective tools for future interventions targeting patients with aMCI within a culturally contextualized framework.

The utilization of VR technology in delivering reminiscence therapy presents a novel avenue for enhancing engagement and emotional well-being among older adults. While findings from a study by Saredakis and colleagues (2021) did not reveal significant differences in symptoms of apathy between VR-based and traditional reminiscence therapy, qualitative observations suggest that participants in the VR group experienced more positive emotions. This highlights the potential of VR as a supplementary tool for delivering reminiscence therapy, although further research is needed to explore its efficacy and optimal implementation strategies.

Feasibility studies exploring the use of VR-based interventions through videos have shown promising results in improving mood and reducing behavioral and psychological symptoms among PwD. Appel et al. (2024) reported immediate reductions in aggressive behavior and vocalizations following VR sessions, and (Brimelow et al., 2022) showed improvements in mood. Additionally, VR has demonstrated potential as a tool for fostering reminiscence and emotional engagement, with participants often expressing personal connections to the video content. However, challenges related to usability and the need for caregiver assistance in completing assessments remain significant barriers.

## From the literature to the Clinical Practice

Considering the scarce literature about the use of HMDs for mental health interventions with PwD, the authors conducted a pilot study using exergames designed by a multidisciplinary team (experts in sports science, design, psychology, and engineering) and validated for the elderly (Gonçalves et al., 2017, 2021). These exergames encompass motor skills, cognitive functions, and engagement and were tailored to suit the cultural context of Portugal. Their integration into real-world scenarios was made possible by utilizing the Portable Exergame Platform for the Elderly (PEPE) system (Simão & Bernardino, 2017; Sousa et al., 2019). PEPE is a standalone unit that comprises a computer, a depth sensor (Microsoft Kinect V2), a touch display, and a projector (LG PF1000U). Despite the mobility of PEPE, replicating it is costly as it needs metal structures and dedicated system resources. An attractive alternative involved utilizing HMDs, which offer reduced costs and higher immersion. This study explores the feasibility of employing these exergames with PwD via HMDs, thereby addressing our systematic review gaps. The study was approved by the Ethical Commission of the University of Madeira (*Parecer* n. 72).

### The Exergames

1. ExerFado: Located in the historic Fado houses of Lisbon, this game is designed to enhance lower limb strength, attention and processing speed. Players interact by stepping on piano keys aligned with descending musical notes and executing arm swipes to capture special notes. The game offers customization features such as music choice, note frequency adjustments, and speed settings (Figure 4).
2. Rabelos VR: Players navigate traditional wine transport boats (Rabelos) along historic river routes, collecting wine barrels while dodging obstacles. The gameplay focuses

on enhancing upper limb strength through rowing actions, lateral maneuvers, trunk rotations, and executive functioning. Customization options allow players to adjust rowing intensity and obstacle proximity to tailor the experience to their preferences (Figure 4).

3. Grape Stomping: This game replicates the wine-making process in Portugal's Douro region, tasking players with stomping grapes in wooden vats. Through a combination of arm and leg movements, players pull grapes and stomp them, while training divides attention, executive functions and processing speed. Additionally, players can compete against or cooperate with another player for added variety (Figure 4).

As for the setup, a desktop was connected to two monitors: one mirrored the Oculus Quest 2 using the Virtual Desktop Application (VDA), and the other was used for the VDA feature of mirroring the participant view from the HMD. Participants' movements were tracked using a Microsoft Kinect V2. Full details about setup hardware, software, and calibration are available at (Branco et al., under submission).


Figure 4. Participant using the Exergames via HMD: (a) Grape Stomping; (b) Rabelos VR (c); ExerFado.

**Procedure**

Participants were recruited from the daycare center *Lugar de Memórias I* of the *Garouta do Calhau* Foundation, a daycare center for PwD located on Madeira Island (Portugal). After obtaining informed consent, demographic information was collected through structured questionnaires with the support of formal and/or informal caregivers.

Participants underwent a baseline cognitive assessment with the Montreal Cognitive Assessment (MoCA), a brief cognitive screening test that aims to distinguish between normal aging and pathological cognitive deficits, assessing six cognitive domains (executive functions, visuospatial capacity, memory, attention, focus, language, and orientation) (Nasreddine, 2008).

Participants underwent a structured intervention consisting of five sessions over two weeks. Each session lasted 30 to 45 minutes and included culturally adapted exergames activities. At the beginning of every game activity, the researcher would instruct and demonstrate how to carry out the activities as needed, and assistance was provided whenever necessary. Participants were informed about the possibility of quitting the intervention if desired. Rabelos VR and Grape Stomping were meant to be played for 10 minutes, and ExerFado until the song's end (3:00 to 6:00 minutes).

Throughout the intervention, participants were regularly checked for their well-being, including inquiries about any feelings of dizziness, discomfort, or pain. The activity would be halted immediately if any participant reported experiencing these symptoms. Participants would then be given a break and asked if they wished to resume or discontinue the intervention.

At the end of each session, participants were briefly interviewed with questions about the activities. Additionally, the Behavior Observation Grid (BOG) enabled us to record individual behaviors throughout an intervention. The BOG seeks to objectively record behaviors observed at a specific moment, standardize target behaviors for inter-observer attention, and compare behavior evolution at the intervention's beginning, middle, and end. This grid comprises five domains: somatic aspect, presentation, behavior and performance in task execution, relationship, and psychomotor aspects (Castro, 2012).

**Clinical Sample**

Sample recruitment occurred at the daycare center *Lugar de Memórias I*. The institution psychologist provided a list of PwD who would be physically able to participate to the psychologist intern who performed the intervention. PwD were invited to participate if they fulfilled the following inclusion criteria: (1) the capability to stand and move physically, (2) knowing how to read and write, (3) preserved comprehension of simple instructions, as evaluated by the psychologist, and (4) no visual impairments. From the list provided (n=5), one participant did not fulfill the inclusion criteria. Participants took part in the intervention voluntarily. Informed written consent was obtained by an informal caregiver or legal representative, and informed verbal consent was obtained from each of the four participants:

C1 is a 72-year-old widow who has four years of schooling, used to be a seamstress/stay-at-home caregiver, has relatively good eyesight and hearing, and has no difficulties regarding reading and writing. The MoCA test shows evidence of mild cognitive decline (24 points), mainly in the memory domain.

C2 is a 56-year-old woman who is divorced, has six years of schooling, used to work as a museum operations assistant, has good eyesight and hearing and has no difficulties regarding reading and writing. The MoCA test shows evidence of moderate cognitive decline (20 points) in the general domains of cognitive functioning, particularly in memory.

C3 is an 80-year-old widow who has four years of schooling and used to work as a seamstress. She has some difficulties regarding vision and hearing but has no difficulties regarding reading and writing abilities. The MoCA test shows evidence of moderate cognitive decline (15 points) in the general domains of cognitive functioning, particularly memory, attention, concentration and working memory.

C4 is a 64-year-old woman who is married and has 12 years of schooling. She has some difficulties with vision and hearing but has no difficulties with reading and writing abilities. The MoCA test shows evidence of moderate cognitive decline (15 points), mainly observed in the general domains of cognitive functioning.

## Outcomes

### *Adherence and Engagement*

All case studies attended and finished all five sessions in 2 weeks (attendance and completion rate=100%), which suggests the participants had a high level of engagement. However, C2 appeared to show a lack of motivation to continue participating in sessions utilizing VR-based intervention.

### *Cognitive Functioning*

Results from the cognitive outcomes are presented in Table 4.

Table 4

*MoCA subdomains and total score.*

| Sample | | | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|---|
| Executive Functioning (Max 4) | | Pre | 4 | 2 | 0 | 1 |
| | | Post | 4 | 2 | 1 | 1 |
| Visual-spatial (Max 4) | | Pre | 3 | 3 | 2 | 2 |
| | | Post | 4 | 4 | 3 | 4 |
| Memory (Max 5) | | Pre | 0 | 1 | 0 | 0 |
| | | Post | 1 | 0 | 0 | 0 |
| Attention, Concentration, and working memory (Max 6) | | Pre | 5 | 3 | 6 | 3 |
| | | Post | 5 | 2 | 5 | 2 |
| Language (Max 6) | | Pre | 6 | 4 | 2 | 3 |
| | | Post | 6 | 3 | 1 | 4 |
| Orientation (Max 6) | Temporal (Max 4) | Pre | 4 | 4 | 2 | 3 |
| | | Post | 4 | 4 | 2 | 4 |
| | Spatial (Max 2) | Pre | 2 | 2 | 2 | 2 |
| | | Post | 2 | 2 | 2 | 2 |
| Total (Max 30) | | Pre | 24 | 20 | 15 | 15 |
| | | Post | 26 | 18 | 15 | 18 |

C1 was assessed with 24 at baseline and improved two points in the post-intervention, with a slight improvement, particularly in the domains of memory and visual-spatial abilities, where the cognitive impact was most noticeable.

C2 was assessed with 20 on the MoCA but then scored 18 points post-intervention, which might have led to a slight decrease, particularly in the domains of attention, concentration, working memory, and language.

C3 was assessed with 15 on the MoCA both pre and post-intervention. The intervention led to cognitive functioning maintenance.

C4 was assessed with 15 on the MoCA and surprisingly scored 18 points post-intervention. The intervention led to better cognitive functioning, namely in the language, orientation, and visual-spatial domains.

***Behavior and Task Performance during Intervention***

In terms of presentation and posture towards the task, C1 appeared active, motivated, and cooperative, completing all activities and remaining attentive for more than 15 minutes during each session. C1 showed no impulsivity and consistently persisted in all activities. As such, task participation was > 75% of the session's total time. Despite their enthusiasm for exploring the games, sometimes she had difficulty remembering how to play and required some assistance. Despite this, consistently respected the rules and session duration and was able to differentiate between the virtual and real spaces. When failing at the task, she would become slightly frustrated. C1 communicated effectively and could understand complex instructions without assistance. In terms of non-verbal communication, she had no issues maintaining eye contact with the researcher, smiled appropriately, and exhibited no repetitive or unusual behaviors. In summary, there was no change in behavior and performance in task execution.

In terms of presentation and posture toward the task, C2 initially appeared active, motivated, and cooperative. However, over subsequent sessions, motivation waned, although it still cooperated. Regarding task participation, C2 initially participated voluntarily, completed all activities and remained attentive for more than 15 minutes. However, by sessions 4 and 5, she needed external motivation to participate as she did not perform activity planning. As the sessions progressed, C2 started to lose motivation and gave up on completing tasks, usually asking if she could keep playing without the HMD. The duration of task participation was initially more than 75% of the session duration, but this value decreased over subsequent sessions. In terms of non-verbal communication, she had no issues maintaining eye contact with the researcher, smiled appropriately, and exhibited no repetitive or unusual behaviors. She was able to recall sessions and activities, although she often struggled to remember how to play. Finally, she displayed good tolerance towards frustration.

C3 voluntarily participated, completed all activities, and remained attentive for more than 15 minutes during each session. She showed no impulsivity and persisted in all activities, completing them without giving up, usually taking long breaks, and regaining strength before resuming tasks. The duration of task participation was more than 75% of the duration of the total session. In terms of attitude towards the task, she was motivated, didn’t usually choose activity order, and achieved task goals, but she was apprehensive about exploring the games. She communicated effectively, understood complex instructions with assistance, and had no speech-related difficulties. In terms of non-verbal communication, they had no issues maintaining eye contact with the researcher, smiled appropriately, and exhibited no repetitive or unusual behaviors. There was no change in behavior and performance in task execution. Initially struggled to recall sessions, activities, and using the HMD but recalled going to a specific room with the researcher to perform activities. Didn’t remember how to play and required some assistance. Despite this, consistently respected the rules and session duration and was able to differentiate between the virtual and real spaces. Additionally, didn't like failing the tasks and would become increasingly frustrated and apologetic.

In terms of presentation and posture towards the task, C4 was active, motivated, and cooperative. This participant voluntarily completed all activities and remained attentive for more than 15 minutes during each session. Showed some impulsivity and did not plan task execution. C4 persisted in all activities, completing them without giving up without taking breaks. Task participation was more than 75% of the duration of the sessions, and she frequently showed initiative and provided suggestions. C4 appeared motivated, achieved task goals, and had a positive attitude toward exploring the games. She communicated effectively, had a hard time understanding complex instructions with assistance, and had no speech-related difficulties. The participant had no issues maintaining eye contact with the researcher, smiled appropriately, and started to exhibit unusual behaviors in session 2 (blending various forms of interaction in the games rowing and stomping on the ExerFado game). She was able to recall sessions and activities if given some hints. Despite forgetting how to play and mix and match the different mechanics of the games, she consistently respected the rules and session duration and was able to differentiate between the virtual and real spaces.

***Sessions questionnaire outcomes***

C1- Question (Q) 1: Reported liking the activities, though they were fun and different from the usual activities done in the daycare center; Q2: Reported liking all activities equally, and sometimes reported like Grape Stomping the most or ExerFado; Q3: Didn't feel like there was anything hard on the intervention; Q4: Generally reported liking using HMD, and that it doesn't feel heavy, but commented in one session that it was heavy; Q5: Reported feeling somewhat dizzy at the end of sessions 2 and 5; Q6: Interested in conducting more sessions.

C2- Q1: Reported liking the activities, though they were fun and challenging; Q2: would frequently alternate between Rabelos VR and Grape Stomping, changing which one was their favorite and least favorite in each session; Q3: The hardest part of the intervention was using the HMD; Q4: Using the HMD was heavy; Q5: Would feel a headache or dizziness using HMD for too long; Q6: Interested in conducting more sessions, but would be more interested if using HMD wasn't a requirement.

C3- Q1: Reported liking the activities, usually saying "they make her brain work"; Q2: Likes every activity in general; Q3: Didn't feel like anything was hard; Q4: Reported every session that the HMD felt fine and that there was no problem, although at session one that the HMD felt heavy; Q5: Reported usually feeling dizzy but unrelated to the intervention; Q6: Was interested in conducting more sessions since C3 likes to work on herself, physically and mentally.

C4- Q1: Reported liking the activities; Q2: Favorite activity was ExerFado and least favorite Rabelos VR; Q3: Doesn't feel like anything about the intervention is hard; Q4: Reported that she liked using HMD, that it makes a "bigger screen" and that it doesn't feel heavy; Q5: Reported feeling fine every session, no adverse effects; Q6: Interested in conducting more sessions.

Table 5

*Semi-structured Interview conducted at the end of every session*

| Semi-structured Interview | |
|---|---|
| Question 1: | Did you like the activities/ games? |
| Question 2: | Which game did you like and dislike the most? Why? |
| Question 3: | What was the hardest part of the intervention? |
| Question 4: | How did using the HMD feel? |
| Question 5: | Did you feel any pain, discomfort, dizziness, or other symptoms? |
| Question 6: | Are you interested in conducting more sessions? |

**Discussion and Conclusion**

This study explored the feasibility of using a VR-based intervention through an HMD, assessing its impact through a cognitive screening tool and behavior and task performance observation.

PwD experience physical and psychological barriers that limit exercise (Franco et al., 2015; Van Santen et al., 2018). While our VR-based intervention may add an additional physical barrier, as it did for C2, it may also help with psychological barriers, improving the attitude towards physical exercise and motivation. While all participants attended and completed the sessions, their levels of engagement differed. Participants C1, C3, and C4 demonstrated high levels of engagement, actively participating in the activities and showing enthusiasm for exploring the games. However, participant C2 showed a decline in motivation over the sessions and expressed a lack of interest in continuing with the intervention related to some adverse effects caused by the HMD.

On the other hand, the immersiveness achieved through the use of the HMD led most participants to focus on the task to achieve a good performance and a high score, disregarding the physical effort. These game mechanics played an important role as a motivator for physical and cognitive activity. All participants felt especially motivated if they were rewarded with medals for having good performance and would ask at the end of the game if they did better than in the previous sessions. These findings are corroborated by existing literature, which indicates that exergaming can encourage physical and cognitive activity by incorporating gamification elements to transform routine tasks into more engaging experiences (Klusmann et al., 2021).

Regarding cognitive impact, the intervention had positive results for C1, C3 and C4. Participants C1 and C4 showed a slight improvement in cognitive functioning, particularly in memory and visual-spatial abilities. Participant C3 maintained cognitive functioning, while C2 slightly decreased, especially in attention, concentration, and working memory. It's important to mention that C2 felt ill on the day of the post-assessment, which might have contributed to a lower MoCA score. These findings suggest that exergames in VR-based interventions may positively impact cognitive functioning depending on individual characteristics and the targeted domains. These results are positive since dementia is generally associated with an exponential decline in cognitive functioning. Therefore, stability is desired and can be seen as a beneficial outcome (Dumas, 2017). A five-session intervention over two weeks may not be sufficient to fully evaluate the long-term cognitive benefits of VR-based interventions for PwD, as cognitive improvements often require sustained engagement in cognitive activities over an extended period (Carrion et al., 2018).

Participants experienced mild adverse effects, with C2 and occasionally C1 reporting feelings of dizziness. Additionally, C2 mentioned experiencing headaches if she didn't take breaks. These findings are presented in previous studies (Appel et al., 2024; Brimelow et al., 2022; Park et al., 2020; Saredakis et al., 2021).

Results from this study indicate that it is feasible to use exergames in a VR-based mental health intervention through HMD. Feedback from the participants indicated a generally positive attitude towards the exergames and the use of HMD. Most participants reported enjoying the activities and expressed interest in conducting more sessions. While the study provided valuable insights into the immediate effects and feasibility of VR-based interventions, there are many limitations. Longer-term studies focusing on sustained engagement and personalized interventions are needed to fully evaluate the benefits of fully immersive VR-based interventions for PwD. The sample size was small; as such, it lacked the power to determine significant correlations and generalize findings. Finally, since there were no CG, other variables that might have influenced results, such as the standard care that participants have at the daycare center, were not controlled.

Future research should focus on longer-term interventions, assessing QoL, mood, BPSD, and cognitive benefits. Longitudinal studies with follow-up assessments conducted over several months or even years would provide a more comprehensive understanding of the potential cognitive impact of VR-based mental health interventions through HMD. Additionally, incorporating booster sessions could help maintain and potentially enhance cognitive benefits over time.

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**ANNEX**

**Annex A –** participant preference and demographic questionnaire sent to informal caregivers.

**Impacto de Tecnologias interativas baseadas em música e reminiscência para estimulação cognitiva e promoção da qualidade de vida em pessoas portadoras de demência.** O presente questionário encontra-se inserido no âmbito da Dissertação de Mestrado em Psicologia Clínica, da Saúde e Bem-estar do departamento de Psicologia da Universidade da Madeira, tem como objetivo principal compreender o impacto de um programa de estimulação cognitiva baseado em reminiscência e na música personalizado através de uma plataforma de jogos sérios Musiquence em pessoas portadoras de demência. As informações recolhidas e respetivo tratamento de dados serão confidenciais, anónimos e restritos apenas aos fins académicos. Agradecemos o tempo disponibilizado no preenchimento do questionário que nos ajudará a personalizar a intervenção da pessoa com demência a seu cuidado. Qualquer dúvida ou esclarecimento adicional poderá ser dirigido à orientadora do projeto: Prof. Doutora Ana Lúcia Faria através do e-mail: anafaria@staff.uma.pt ou ao mestrando Paulo Fernandes através do e-mail: 2067418@student.uma.pt.

**Consente e disponibiliza fotos, álbuns familiares e/ou objetos pessoais significativos para utilizarmos na personalização da intervenção?**

**Preencher com uma cruz.**

**Sim** ☐

**Não** ☐

**Assinatura do próprio ou representante legal:** ____________________________________

## Dados Demográficos

1. **Género (**Preencher com uma cruz):

Masculino: ☐

Feminino ☐

2. **Idade:** ________________

3. **Profissão/Ocupação:** ____________________________________

4. **Habilitações Literárias (**Preencher com uma cruz):

1.º Ciclo do ensino básico (4 anos de escolaridade): ☐

2.º Ciclo do ensino básico (6 anos de escolaridade): ☐

3º Ciclo do ensino básico (9.º ano): ☐

Ensino Secundário (12.º ano) Outro: ☐

## Dados Clínicos

1. **Como se encontra a sua capacidade visual? (**Preencher com uma cruz):

| Sem capacidade visual | ☐ | ☐ | ☐ | ☐ | ☐ | Boa capacidade visual |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |

**2. Como se encontra a sua capacidade auditiva?** (Preencher com uma cruz):

| Sem capacidade auditiva | ☐ | ☐ | ☐ | ☐ | ☐ | Boa capacidade auditiva |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |

**3. Tem dificuldade em ler? (**Preencher com uma cruz):

Sim ☐

Não ☐

**4. Tem dificuldade em escrever? (**Preencher com uma cruz):

Sim ☐

Não ☐

**Questionário de Preferências do Participante**

**1. Quais são as suas músicas favoritas?**

______________________________________________

______________________________________________

**2. Quais são os seus objetos favoritos?**

______________________________________________

______________________________________________

**3. Quais as suas comidas e bebidas preferidas?**

______________________________________________

______________________________________________

**4. Quais são/foram os seus passatempos?**

______________________________________________

______________________________________________

**5. Que locais costumava frequentar (ex. restaurante, igreja, parque...)?**

______________________________________________

______________________________________________

**6. Quais os seus filmes ou programas televisivos preferidos?**

______________________________________________

______________________________________________

**7. Quais foram, de uma forma geral, os acontecimentos mais importantes na vida do utente?**

______________________________________________________________________

______________________________________________________________________

**8. Em que Concelho Cresceu?**

______________________________________________________________________

______________________________________________________________________

**9. Em que Concelho Cresceu?**

______________________________________________________________________

______________________________________________________________________

**10. Quais são as Figuras Públicas Favoritas (ex. Alberto João Jardim, Amália Rodrigues?**

______________________________________________________________________

______________________________________________________________________

**11. Quais são as Festividades Favoritas (ex. Festa S. João, Natal, Fim do Ano)?**

______________________________________________________________________

______________________________________________________________________

**12. Que tradições costumava festejar (ex. Balamento na páscoa, ler as sortes na festa de S. João)?**

______________________________________________________________________

______________________________________________________________________

**13. Quais são as suas flores favoritas?**

______________________________________________________________________

______________________________________________________________________

**14. Tem alguma preferência relacionada a agricultura ou produtos agrícolas?**

______________________________________________________________________

______________________________________________________________________

**15. Quais os nomes dos familiares e amigos mais próximos?**

______________________________________________________________________

______________________________________________________________________

**16. Tem alguma coisa a acrescentar?**

______________________________________________________________________

______________________________________________________________________

## Annex B – Informed Consent sent to informal caregivers

**Consentimento Informado, Esclarecido e Livre para Participação em estudos de Investigação**

**Identificação do Investigador**: Paulo Brando Nóbrega Fernandes

**Título do estudo**: Tecnologias interativas baseadas em música e reminiscência para estimulação cognitiva e promoção da qualidade de vida em pessoas portadoras de demência

**Enquadramento: Tese de Mestrado em Psicologia Clínica, da Saúde e do Bem-Estar**

**Explicação do estudo**: O objetivo do presente estudo é avaliar o impacto de um programa de estimulação cognitiva baseado na reminiscência e na música através de uma plataforma de jogos sérios Musiquence em pessoas portadoras de demência, para tal, serão recolhidos dados demográficos e de desempenho em avaliação neuropsicológica, para avaliação do impacto do programa de estimulação cognitiva. Os participantes serão selecionados de acordo com os critérios de inclusão e exclusão do estudo. Depois da equipa de investigação obter o consentimento informado do representante legal e/ou cuidador, os participantes serão alocados ao grupo de controlo ou experimental. Os participantes serão então submetidos à pré-avaliação, que visa a obtenção de dados relativamente ao funcionamento executivo, capacidade funcional e dimensões relacionadas com o humor e a qualidade de vida, preenchidas pelo próprio com apoio dos cuidadores formais e/ou informais. O grupo experimental será submetido a um programa de estimulação cognitiva de 12 sessões, três vezes por semana e com a duração de 45 minutos. O grupo de controlo fará apenas a intervenção *standard*, equivalente em termos de duração, oferecida no Centro de Dia Lugar de Memórias. Após terminar o programa, os participantes serão submetidos à pós-avaliação, constituída pelos mesmos testes de avaliação neuropsicológica. Os dados recolhidos serão conservados durante 5 anos e depois serão destruídos.

**Condições e financiamento**: A participação no estudo não trará qualquer custo ou risco, o participante poderá optar por abandonar ou recusar a participação a qualquer momento sem qualquer consequência. Destaca-se que não estão incluídos quaisquer ganhos monetários.

Os recursos informáticos a serem utilizados neste estudo são financiados pelo projeto MACBIOIDI (INTERREG program MAC/1.1.b/098).

**Anonimato e confidencialidade**: este projeto estará em conformidade com os seguintes procedimentos no que diz respeito ao tratamento de dados pessoais:

- Os dados não serão recolhidos sem autorização. Antes do recrutamento, todos os participantes e cuidadores serão informados verbalmente e por escrito sobre os detalhes do estudo a ser realizado, incluindo qualquer risco envolvido.
- Todos os participantes assinarão um Consentimento Informado (em anexo) antes da participação no estudo;
- Nomes, datas de nascimento e outros dados sensíveis e passíveis de identificação serão encriptados para proteger a privacidade dos participantes e dos dados recolhidos;

- A informação recolhida será utilizada apenas para o propósito do projeto e não será retida para outros fins;
- Nenhuma informação pessoal será tornada pública ou cedida a terceiros;
- Serão aplicados controlos técnicos estritos para garantir que a informação não seja disponibilizada inadvertidamente a organizações de marketing direto ou outras terceiras entidades.

Qualquer dúvida ou esclarecimento adicional poderá ser dirigido ao investigador Paulo Fernandes através do e-mail: 2067418@student.uma.pt ou à orientadora da dissertação de mestrado: Prof. Doutora Ana Lúcia Faria através do e-mail: anafaria@staff.uma.pt.

**Por favor, leia com atenção esta informação. Se achar que algo está incorreto ou que não está claro, não hesite em solicitar mais informações. Se concorda com a proposta apresentada, assine este documento.**

Assinatura de quem pede consentimento: ____________________________________________

**Declaração de Consentimento do Participante**

Eu, ____________________________________________________ declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pela pessoa que acima assina. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequências. Desta forma, aceito participar neste estudo e permito a utilização dos dados, que de forma voluntária forneço, confiando em que apenas serão utilizados para fins científicos e publicações que delas decorram e com as garantias de confidencialidade e anonimato que me são dadas pelo investigador.

Assinatura legível e manuscrita do(a) cuidador(a) ou representante legal:

________________________________________

Data: ___ / ___ / ______

**Annex C** – Figure 3

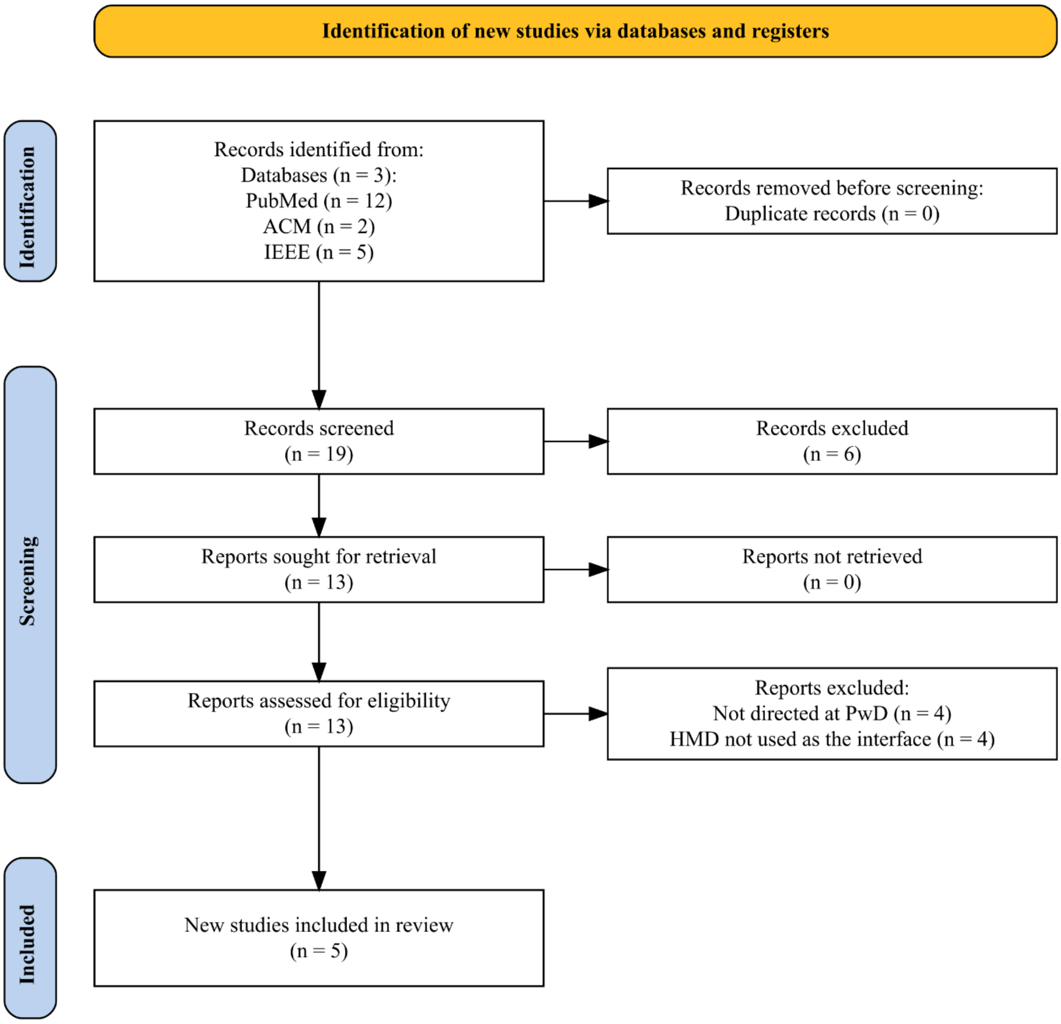


*Figure 4*. Prism flow diagram.

Annex D **- Table 3**

*Semi-structured Interview conducted at the end of every session*

| | Study Design | Participants | Interaction, display, and level of immersion | Intervention/ Rehabilitation | Outcome Measures | Conclusions | Challenges |
|---|---|---|---|---|---|---|---|
| (Park et al., 2020) | Experimental-RCT pilot study. | N=21, age ≥ 50 and ≤ 80 years; EG (n=10); CG (n=11). | Active interaction: Fully immersive VR using an HMD equipped with two controllers and two infrared laser emitter units (HTC Vive, New Taipei City, Taiwan). | Twenty-four sessions of 30 minutes, two days a week for three months of VR-based training aimed at stimulating cognitive functions through two selected games according to their level of ability; Games include shooting targets, hitting targets according to the music rhythm, decorating, making cocktails, and ADL. | Quantitative instruments: SGDS-K; K-MMSE; WCST; SNSB-D; The digit span test; Korean color-word Stroop test; Word fluency tests (category and letter fluency). | The VR training program did not lead to significant improvements across various cognitive domains during interaction; Participants tolerated the VR-based training well and exhibited high compliance throughout the program. Findings may suggest to health professionals that culture-based VR training programs might be a promising tool for future interventions with this population. | Intervention observations: Good compliance rate (91.55%) Intervention well tolerated although there were negative events were observed in the EGs, namely dizziness (4.2%) and fatigue (8.3%). |

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|---|---|---|---|---|---|---|---|
| (Saredakis et al., 2021) | Experimental-Multisite nonrandomized controlled trial. | N=43, age ≥ 65. EG (n=15); Active group (n=15); CG (n=14). | Passive interaction: EG: Fully immersive VR using HMD (Oculus Quest) to view personalized videos in VR through YouTube VR (developed by Google LLC). Active group: Laptop | Three sessions of reminiscence therapy were completed within 2 weeks. EG: Reminiscence therapy intervention using VR in the form of HMDs; Active Group: Reminiscence therapy utilizing a laptop computer supplemented by physical items if required; CG: usual care. | Quantitative instruments: AES; ACE-III; GDS-15; QoL-AD; Three-Item Loneliness Scale; SSQ; Staff Questionnaires; Qualitative instruments: Interviews and session records. | This study did not yield significant results in outcome measures; Participants actively engaged in the research and enjoyed the reminiscing process using both forms of technology; Findings suggest that VR can be effectively implemented in aged care settings with appropriate protocols. | Intervention observations: 40% of Participants (6 out of 15) reported symptoms related to pre-existing conditions before intervention. Possible after-effects: One participant reported feeling a headache, and another reported a heavy-head feeling. Symptoms were not long-lasting and did not cause significant discomfort. |
| (Brimelow et al., 2022) | Experimental-Feasibility study | N=25. Distributed in five groups (n=5). | Passive interaction: Fully immersive VR using Samsung Galaxy S7 preloaded with an aged care VR library, in tandem with a Samsung Gear VR headset. | Group sessions lasting 60 minutes were conducted twice weekly for 3 weeks for a total of 6 sessions. Each group viewed 360-degree videos on a wireless head-mounted display to provide fully immersive VR experiences. These videos were from free “off-the-shelf” applications to reduce ongoing costs for residential aged care facilities (Arscape, | Quantitative Instruments: CSDD; GAD-7; CMAI-Short; Qualitative Instruments: OERS; PEAR. | This study's results showed a decrease in depressive symptoms and apathy, eliciting a positive emotional response in the majority of residents; There were minimal adverse effects observed; Findings indicate the feasibility of group-based VR technological | Intervention observations: To minimize VR side effects, lightweight and wireless VR headsets were used. Participants tolerated the VR-based intervention. Two Participants reported mild adverse effects. Three Participants reported discomfort due to the device and fit. |

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|---|---|---|---|---|---|---|---|
| | | | | Nomads, Expeditions, Relax VR, and YouTube) | | innovation within residential aged care. | |
| (Appel et al., 2023) | Mixed methods Pilot study. | N=14; (Seven dyads of PwD and their caregivers). | Passive interaction: Fully immersive VR using the “VRx@Home” application loaded onto a Samsung Galaxy S7 Tablet and HMD (Quest 2) with hand controllers. | The intervention involved a weekly session with the researcher via Zoom, comprising 20 minutes of pre-selected videos evenly distributed by theme throughout the week and conditions. Additionally, Participants were encouraged to engage in "on-own" sessions independently, with a suggested frequency of every other day for 20 minutes, allowing free choice of videos. | Quantitative Instruments: SUS; QoL-AD; WHO-5. Qualitative Instruments: Observational data; semi-structured Interviews. Quantitative in-app metrics (e.g., time spent watching). | Findings indicate that both immersive VR and tablet-based technologies are safe and feasible for delivery at home by family caregivers; Both conditions (fully immersive and non-immersive) appeared to positively affect the mood and quality of life of PwD and their caregivers during the moment of the interventions; Improvements to VR content will increase the likelihood of VR therapy being adopted in the home setting. | Usability was a challenge. For a technology to be readily adopted, it must align with caregivers' capabilities in terms of technology and training support; The greatest challenge was using hand controllers to navigate the VR-HMD environment; PwD wasn’t able to use any of the devices without support. |

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|---|---|---|---|---|---|---|---|
| (Appel et al., 2024) | Experimental-RCT trial. | N=69 ≥65 years. EG (n=34.49%); CG (n=35.51%). | Passive interaction: Fully immersive VR Oculus Go HMD, this device doesn't require external hardware (e.g., sensors to track head movement) and has built-in headphones. | Participants in the EG engaged in VR sessions facilitated by a researcher, during which they watched 360° VR films using a head-mounted display for approximately 20 minutes every 1 to 3 days.<br>In contrast, the CG received standard care. | Quantitative Instruments: Hospital EMR, NPI-10; In-Hospital Quality of Life Observations-al Scale-adapted from the QUALID; Qualitative Instruments: Interviews and observations (EG only). | VR therapy had a significant effect on reducing aggressiveness and loud vocalizations;<br>No substantial impact comparing the EG to the CG for other BPSDS;<br>The intervention was an acceptable and enjoyable experience for Participants, and no adverse events occurred;<br>Results were promising, considering acceptability, safety, and patient experience. | HMD fit (difficulty adjusting straps and fitting glasses onto the HMD);<br>Hardware or Software technical difficulties (e.g., headset and controller out of sync);<br>Few challenges were related to apprehension, anxiety, or mild side effects or discomfort;<br>Most Participants opted to stop therapy early (Participant's choice);<br>Average length of exposure was approximately 7 minutes;<br>Most Participants reported satisfaction, fun, and being able to relax in the VR therapy; |

EG: EG; CG: CG; SGDS-K: Korean version of the Geriatric Depression Scale-Short form; K-MMSE: Korean version of Mini-Mental State Examination; SNSB-D: Seoul Neuropsychological Screening Battery, Dementia version; AES: Apathy Evaluation Scale Clinician Version;

ACE-III: Addenbrooke Cognitive Examination III; GDS-15: Geriatric Depression Scale short form; QoL-AD: the Quality of Life in Alzheimer Disease; SQQ: Simulator Sickness Questionnaire; CSDD: Cornell Scale for Depression in Dementia; GAD-7: Generalized Anxiety Disorder 7-item; CMAI-Short: The Cohen Mansfield Agitation Inventory; OERS: Observed Emotions Rating; PEAR: Person-Environment Apathy Rating Subscale Scale; SUS: System Usability Scale; WHO-5: Five Well-Being Index; NPI-10: Neuropsychiatric Inventory 10-item version; EMR: Electronic Medical Record; QUALID: Quality of Life in Late-Stage Dementia; BPSDS: Behavioral and Psychological Symptoms of Dementia.