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Immersive virtual reality reminiscence activities: assessment of engagement and participation, behavioral and psychological symptoms and well-being of people with dementia

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Resumo

A realidade virtual (RV) é uma tecnologia recente que pode ser utilizada para promover reminiscências junto de pessoas com demência, havendo ainda poucos estudos sobre o contributo da imersividade permitida pela RV para potenciar os resultados terapêuticos. O objetivo deste estudo foi analisar o efeito de uma sessão de reminiscências imersiva em comparação com uma sessão de reminiscências não imersiva, em termos do envolvimento e participação, sintomas psicológicos e comportamentais e bem-estar em pessoas com demência, utilizando avaliações por observação comportamental e medição de dados fisiológicos. Foi realizado um estudo experimental crossover, com um período de washout de sete dias. Foram recrutados 20 participantes com diagnóstico de demência, com uma média de idades de 80,55 anos e dos quais 18 (90%) eram mulheres. Os resultados indicaram que houve diferenças significativas no maior envolvimento comportamental (z = -2,67, *P* = 0,008), maior apatia durante a sessão, em termos de expressões faciais (z = -2,12, *P* = 0,034) e menor apatia, em termos de atividade intencional (z = -2.24, *P* =.025) na intervenção imersiva comparado com a intervenção não imersiva. Além disso, os resultados indicaram que a frequência cardíaca média na condição basal de repouso foi significativamente mais baixa do que na condição de exposição, independentemente do tipo de intervenção (F (1,235,19,765) = 4,333, *P* = 0,043). Os resultados sugerem que a imersividade promovida pela RV pode ser útil para promover o envolvimento de pessoas com demência em programas de intervenção. Tratando-se de tecnologias cada vez mais acessíveis e seguras, justifica-se a continuidade do estudo sobre o seu contributo para potenciar resultados terapêuticos.

Palavras-chave: Demência; Realidade virtual; Terapia de reminiscências; Envolvimento; Sintomas psicológicos e comportamentais;

Abstract

Virtual reality (VR) is a novel technology that can be used to promote reminiscence among people with dementia, and there are still few studies on the contribution of the immersiveness allowed by VR to enhance therapeutic results. The aim of this study was to analyze the effect of an immersive VR reminiscence session compared to a non-immersive reminiscence session, in terms of engagement and participation, behavioral and psychological symptoms and well-being in people with dementia, using behavioral observation and measurement of physiological metrics during interventions. A randomized crossover trial was carried out, with a washout duration of seven days. 20 participants with dementia were recruited, with an average age of 80.55 years and of which 18 (90%) were women. The results indicated that there were significant differences in higher behavioral engagement ($z = -2.67$, $P = .008$), higher apathy during the session, in terms of facial expressions ($z = -2.12$, $P = .034$) and lower apathy during the session, in terms of purposeful activity ($z = -2.24$, $P = .025$) in the immersive intervention compared to the non-immersive intervention. Moreover, the results indicated that the mean heart rate in the baseline rest condition was significantly lower than in the exposure condition, despite the type of intervention ($F(1.235,19.765) = 4.333$, $P = .043$). The results suggest that the immersiveness promoted by VR can be useful in promoting engagement of people with dementia in intervention programs. As these technologies are increasingly accessible and safe, it is justified to continue studying their contribution to enhancing therapeutic results.

Keywords: Dementia; Virtual Reality; Reminiscence Therapy; Engagement; Behavioral and psychological symptoms;

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1. Introduction

Dementia is a progressive neurodegenerative syndrome marked by a decline in cognitive skills and daily functioning, often accompanied by behavioral and psychological symptoms in dementia (BPSD) [1–6]. BPSD includes aggressive behaviors toward oneself and others, agitation, restlessness, irritability, depression, apathy, and lack of motivation [1,2,7–11]. This impacts the quality of life (QoL) and well-being of people with dementia as well as their family [12,13].

In 2023, it was estimated that 55 million people worldwide had dementia, with over 60% of them residing in low- or middle-income countries [11]. There are around 10 million new cases annually [11]. According to the World Health Organization (WHO), dementia is currently the seventh most common cause of mortality worldwide and a significant contributor to dependency and disability in the elderly population [11].

Non-pharmacological therapy is advised as the first line of treatment for BPSD [14–16]. Since commonly prescribed medications have well-documented adverse effects, including increased fall risk and mortality [17,18], non-pharmacological interventions are generally thought to be a better option than psychotropic medication [19].

A wide range of non-pharmacological interventions for BPSD have been developed and implemented, with only a few documented adverse effects [5,20–26]. According to recent systematic reviews, non-pharmacological interventions have positive effects on reducing BPSD, improving cognitive function, daily living activities, and social interaction ability of patients with dementia [4,27–29], which can contribute to maintain independence and increase QoL [30]. Non-pharmacological interventions for BPSD can be, for example: sensory stimulation interventions; cognitive or emotion-oriented interventions (e.g. cognitive stimulation, reminiscence therapy, validation therapy); behavioral management techniques (e.g. occupational therapy, progressive muscle relaxation, psychomotor therapy); and other interventions comprised of animal-assisted therapy, physical therapy and dementia special care units [4,10,20,27,31–40].

Non-pharmacological interventions have also been studied as beneficial to the well-being of people with dementia [13,20,33,35,41–44]. It has been studied primarily through self-report scales and observation, with some studies including the measurement of physiological metrics that translates into improvements in well-being by analyzing heart rate variability (HRV) and the autonomic nervous system (ANS) [45–56], however these metrics are less used [46,54,57]. Through the analysis of physiological metrics, a deeper understanding of the effects

of non-pharmacological interventions on brain activity and the ANS associated with emotional states, as well as the potential therapeutic benefits for patients with dementia, can be achieved [57].

Reminiscence therapy (RT) was introduced to dementia care in the late 1970s [58,59] and uses materials such as photographs, books, old newspapers, familiar items from the past, music and archive sound recordings to evoke memories and encourage people to share and cherish their past experiences, events and activities with family members or other groups of people, increasing well-being and pleasure to engage in this intervention [4,60–64]. RT has demonstrated to be beneficial for managing BPSD [35,65,66], such as depression [29,67–70], anxiety [71–73] and mood [19,60,64,74,75]. Furthermore, therapies that focus on unaltered remote autobiographical memories are especially significant since individuals with dementia typically remember more events from their early lives than recent experiences [60] and it can enhance the participation in the therapeutic process [70]. Increasing self-identity, engaging in fun activities with others, stimulating memories, increasing the individualization of care, or a combination of these could potentially be among the many possible RT's goals [60].

Moreover, digital technologies created more innovative alternatives to aid reminiscence [76–79]. Virtual reality (VR) is a novel technology used in non-pharmacological interventions, such as RT, as it can potentially improve memory and autobiographical memory, as well as to encourage reminiscence through their engaging elements of immersion and sense of presence [80–87]. VR is a term that refers to the set of hardware and software components that replicate a simulated environment, enabling users to interact with three-dimensional computer-generated environments or 360º video footage [88]. VR comes in different forms, ranging from fully immersive systems to non-immersive. Non-immersive systems frequently use a computer monitor to interact with the virtual environment [89,90]. Systems that offer completely immersive experiences include the user feeling physically present within a virtual environment using a head-mounted display (HMD) or a Cave, by reducing real-life stimuli [89–92].

According to recent studies, immersive VR is safe, well-tolerated, and able to encourage engagement and give dementia patients enjoyable experiences [80,88,91,93–100]. Also, Rose et al.'s study revealed that dementia participants frequently reminisced and spontaneously reenacted stories from their past when they watched 360º videos of places that appeared familiar and important to each person's life experience [88].

With inconsistent findings, numerous studies have also investigated the efficacy of VR for decreasing BPSD and enhancing the QoL for dementia patients [101–105]. In particular, some VR reminiscence study's observed that this intervention can be feasible [104] , safe [106], well-accepted [82] and promotes positive levels of comfort, pleasure, satisfaction with the experience [98,107], engagement to social interactions [107,108] and well-being [82,109]. Regarding BPSD, this intervention can reduce feelings of apathy [82,104,110,111], depression [102,110,111], anxiety [83,112] and improve mood [82,102,108].

Despite these promising benefits, in the context of dementia care, VR reminiscence interventions are novel and under researched [113]. Moreover, most studies that evaluate the effect of RT or RT using VR on people with dementia evaluate using questionnaires and behavioral measures, with few studies evaluating people's physiological metrics during the intervention [82,109]. With all this in mind, the aim of this study was to analyze the effect of an immersive VR reminiscence session compared to a non-immersive reminiscence session, in terms of engagement and participation, BPSD and well-being in people with dementia, using behavioral observation and measurement of physiological metrics during interventions.

Considering the objective of the present study, the following hypothesis was determined for this study:

H1: The application of a reminiscence intervention using immersive VR (HMD) contributes to a greater engagement and participation, less BSPD and to a greater well-being in session compared to a non-immersive reminiscence intervention (monitor), using 360º videos from locations relevant to the participants.

2. Methods

2.1. Recruitment

This study was a randomized crossover trial since each participant was exposed to two interventions (an immersive VR reminiscences session and a non-immersive reminiscences session) with a washout duration of seven days [114]. Which intervention each participant performed first was randomized. It is a quantitative study since the data collected was quantifiable and observable, being based on standardized questionnaires.

This study was approved by the ethics committee of the ESS – Polytechnic of Porto (CE0031E). Institutions were contacted via email to disclose the study with their clients, with the aim of obtaining participants. Authorizations were subsequently distributed to the participants' families in order to have their consent to participate in the research proposal, in accordance with the Declaration of Helsinki [115]. The consent form contained an explanation of the study objectives, the procedures to be carried out and the commitment that all data relating to the identification of participants in this study were confidential and kept anonymous. In addition, it also ensured that participants could refuse to participate or interrupt their participation in the study at any time, without any type of penalty.

The recruitment of the participants resulted from a non-probabilistic convenience sampling process, with participants recruited from institutions providing care to people with dementia, to which there was easy access by researchers. A sample of 22 participants was recruited considering as inclusion criteria having diagnosis of dementia. Considered exclusion criteria were: severe visual deficits that prevented them from experiencing the videos, severe communication deficits that do not allowed them to express their life stories, as well as describe their sensations during the intervention, score of 7 on the Global Deterioration Scale (GDS) [116] which represents an advanced stage of the dementia process, having a diagnosis of Lewy body type dementia due to the likelihood of visual hallucinations, and having severe motor limitations that prevented the active exploration of the videos. Within this sample of participants, 11 began the intervention with an immersive approach and 11 began with a non-immersive approach. However, 2 participants were excluded from the study after it was started, as shown in figure 1.

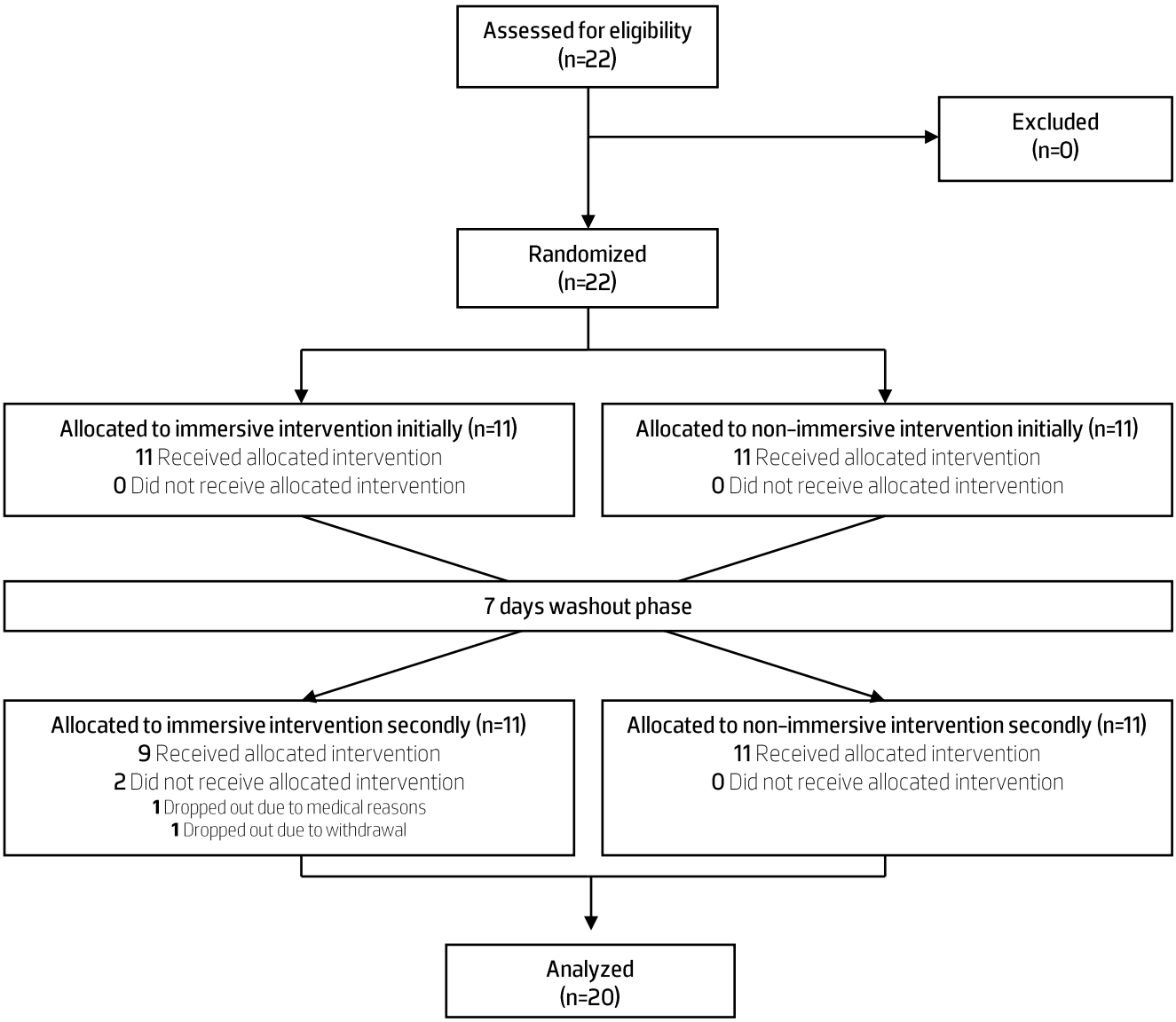

Figure 1. CONSORT flow diagram.

2.2. Measurements

The level of dementia progression was measured with the Global Deterioration Scale (GDS) [116,117]. The Engagement of a Person with Dementia Scale (EPWDS) [118] was used to assess engagement and participation during the session, the Person-Environment Apathy Rating (PEAR) [119] was used to assess apathy, a commonly BPSD, before, during and after the session, the Observed Emotion Rating Scale (OERS) [120] was used to assess BPSD during the session, such as pleasure, anger, anxiety/fear, sadness and general alertness, the Observable Well-Being in Living With Dementia Scale (OWLS) [121] was used to assess well-being during the session. Furthermore, a questionnaire was developed to characterize the participants regarding sex, birth

date, marital status and education years. After each session, to evaluate the participant's self-perception of the experience, a Likert scale from 1 to 5 was also created with the following questions: "Did you like the experience?", "How was the experience?", "How motivated are you to do this activity again?", "Interested in seeing other places?", "How well did you manage to watch the video?" and "How comfortable was the activity?". To analyze the psychophysiological metrics, Electrocardiography (ECG) [122] was used to assess engagement and well-being during the session, through the HRV and ANS activity.

The GDS [116] is a scale that identifies the stage of degenerative dementia and encompasses functional and cognitive deficits. It is a seven-level rating scale in which level 1 reflects no cognitive decline, level 2 reflects very mild cognitive decline, and levels 3 through 7 are defined, respectively, as mild, moderate, moderately severe, severe, and very severe cognitive impairment. Each level is associated with clinical stages ranging from normal (level 1) to late-onset dementia (level 7). This scale is completed with the help of professionals from the institutions.

The EPWDS [118] is a scale that assesses and measures the degree of engagement of participants during interventions. It consists of five categories of engagement: affective, visual, verbal, behavioral and social engagement. Each category is divided into two items, one of which is perceived as positive involvement and the other as negative involvement. The total score varies from ten to fifty points, and the higher the total score, the greater the positive engagement demonstrated by the person. Each item is scored according to a five-point Likert scale (from 1 to 5). In terms of internal consistency, the Cronbach's alpha is 0.94 [118].

The PEAR [119] is a scale used to assess participants' apathy before, during and after sessions. Apathy is measured by looking at six indicators: facial expressions, eye contact, physical engagement, purposeful activity, verbal tone and verbal expression, on a scale of 1 to 4, with higher scores indicating a greater level of apathy. This scale can also be an aid to assess engagement based on apathy levels. In terms of internal consistency, the Cronbach's alpha is 0.85 for the PEAR-Apathy subscale version [119].

The OERS [120] is an observational scale to assess two positive emotions (pleasure and general alertness) and three negative emotions (anger, anxiety or fear, and sadness). During a 10-minutes period, the researcher chooses one of six possible defined time intervals (e.g., 1 = never; 2 = < 16 seconds; 3 = 16–59 seconds; 4 = 1–5 min; 5 = > 5 min; and 7 = not in sight) that a target

subject demonstrates each of the five emotions. Higher scores indicate longer duration of expression of that emotion.

The OWLS [121] is an instrument used to code observed expressions of well-being in people with dementia when participating in activities. The person is observed for 30 seconds. All items are scored dichotomously as "1" if present and "0" if not present. It consists of eight categories of well-being: attention, initiative/responsiveness, relaxation, happiness, pleasure, expressions of identity, mastery and relationships. For each category, a scale of 1-10 is used to evaluate the relative frequency during the 30-seconds intervals. The higher the score, the higher the levels of well-being. In terms of internal consistency, the inter-rater reliability's Cohen's Kappa is 0.82 and the intra-rater reliability's Cohen's Kappa is 0.98 [121].

Recording HRV's data was used to access the following parameters that can be interpreted in relation to a participant's emotional activation. On the Time-Domain were used: Mean HR, since its variability is closely related to emotional activation [122,123]; SDNN, which is the standard deviation of all R-R intervals, to analyze the cyclic components responsible for HRV; RMSSD, described as the root mean square of successive differences, to analyze parasympathetic nervous system (PNS); pNN50, which is the percentage of successive normal sinus RR intervals more than 50 ms, to also analyze PNS [123–126]. In terms of Frequency Domain (FFT Welch Method) on Low frequencies (LF) (0.04Hz, 0.15Hz), to analyze the mix of sympathetic and parasympathetic activity and the baroreflex activity, and High frequencies (HF) (0.15Hz, 0.4Hz), to analyze the PNS, were used: Peak Frequencies and Absolute Powers [123–126]. Moreover, the Total Power, which is the sum of the energy in the LF and HF bands, and LF/HF Ratio, which is the ratio between sympathetic nervous system (SNS) and PNS, were also analyzed [127]. On Non-linear indices were used: SD1, which is the standard deviation – Poincaré plot Crosswise, to analyze quick and high frequent changes in HR variability; SD2, which is the standard deviation – Poincaré plot Lengthwise, to analyze long-term changes in HRV [123–126]. ECG data can be used to provide information about participant physiological and emotional arousal in many fields and environments [122].

2.3. Intervention

Prior to data collection, the evaluation protocol and data collection methods were defined among the entire research team. For all assessment scales used, authorization was previously

requested from the respective authors, if necessary. Translated versions were used to evaluate the outcomes. After preparing the protocol, the researchers were trained in executing it. Then the pilot evaluation phase began, using the protocol with relatives and after with older people, to test its effectiveness and efficiency. After making some changes, as a result from the pilot phase, the sessions began with the participants.

In the pre-intervention session, the participant and, if necessary, the caregivers were asked which location was most significant to them, from a list of locations already filmed. The participant characterization questionnaire was also completed. After obtaining all the necessary information, the researchers contacted formal or informal caregivers, so that this information could be confirmed and add to when necessary. It should also be noted that to maintain the confidentiality of all participants, an alphanumeric code was assigned to each participant, so that there was no identification of the participant. During this period, professionals from the institutions were asked to complete the GDS scale for each participant. Regarding the intervention, each participant was exposed to two sessions with a seven-day washout. On one session a significant location video was shown, using the *Oculus Quest 2* HMD. Before this session, the researchers connected the HMD to a computer to watch what the participant would be seeing during the session. Participants were explained how the HMD were used and how it works. After that, a first video was shown from a neutral and calm place (library) so that the participant could explore and understand how the video works in the HMD. The exposure to the first video was between 2 and 3 minutes. Subsequently, the HMD was placed again for the participant to explore the video of the previously chosen significant location. The exposure to this second video was between 5 and 6 minutes. In the other session, the same intervention structure was used, using a computer monitor and a mouse to explore it. It was explained how the computer mouse works and how it is used to explore the video. There was randomization of participants regarding which session they would perform first, carried out by a researcher not involved in data collection and intervention. The sessions were held in the participant's preferred space, lasting 20 to 30 minutes, in the period from May 2024 to July 2024.

During exposure to the two experimental conditions, the participant's peripheral physiological activity was recorded using the BITalino Core BT/BLE amplifier (acquisition frequency 1000 Hz). More specifically, the heart rate (HR) and HRV were collected through ECG with 3 electrodes placed on the trunk (positive electrode on the right clavicle; negative electrode on the left iliac crest; ground electrode on the clavicle left). The procedure consists of a non-

invasive, painless collection with no known side effects. To apply the electrodes, it was necessary to clean the area of the skin where the electrodes were applied with alcohol and abrasive gel, to remove any residue that could interfere with collection. The electrodes were subsequently fixed using tape (adhesive tape suitable for application to the skin). Precautions were only necessary when cleaning and preparing the skin of participants with skin problems and/or open wounds in the positions where the electrodes were to be placed. After placing the electrodes, the participant was asked to remain relaxed and silent for 5 minutes so that their physiological signals could return to a normal state. After 5 minutes, physiological signals were recorded at rest for 2 minutes. Physiological signals were also recorded throughout the period of habituation and exposure to the significant location video.

Before, during and after the sessions, various assessment instruments were applied with the aim of evaluating the variables of engagement and participation, BPSD and well-being. During the sessions, in both interventions, the researchers asked several questions, following a previously defined guide, in order to allow greater discussion and communication with the participant. With the aim of discussing the observed behaviors with the entire research team and the researchers present could focus on the parameters of the protocol and the personal stories that the participants were describing, the session was filmed, in accordance with the consent of the participant and caregivers. The camera was placed in front of the participant to capture their entire body and all their movements and reactions. It started when the participant entered the room and ended when the participant left the room. After each session, the participant's self-perception of the experience scale was applied. Data collection was carried out by two properly trained researchers who followed the same data collection protocol, in person with the participants.

2.4. Statistical Analysis

Statistical analysis was performed using the *IBM Statistical Package for the Social Science* (SPSS) version 29 software. First, descriptive statistics were used to present the characteristics of the participants and the instruments results. According to the nature of the variables, categorical variables were presented as number (n) and percentages (%) and continuous variables were presented with the mean (M), standard deviation (SD), minimum and maximum values.

Subsequently, to be able to analyze the differences between the two interventions, immersive and non-immersive, through the results of the different scales, the paired samples *t*-test was applied, whenever the normality of the variables was assumed. When this assumption was not assumed, the respective non-parametric test, the Wilcoxon signed-rank test, was applied.

The statistical assumptions for carrying out the tests were validated through the normality analysis of the *Shapiro-Wilk* test variables, with the normal distribution of variables being assumed whenever the p-value was greater than the significance level. A significance level of .05 was considered when carrying out all statistical tests.

Regarding ECG data, data preprocessing and measure extraction was conducted using the pyHRV Python Toolbox pipeline. Processing of ECG included signal filtering (3 Hz – 45 Hz), R-peak detection (Hamilton-Tompkins algorithm) and lastly feature extraction (as reported in section 2.2) [128,129]. Outliers were removed using the 3 interquartile range criteria [130] and the statistical significance threshold was set at .05. Descriptive and inferential statistics were computed using SPSS. For inferential statistics, parametric tests were used whenever data distribution was deemed approximately normal using threshold criteria for skewness and kurtosis – less than |2.0| and |9.0|, respectively [130]. Additionally, two-way repeated-measures ANOVAs were implemented for comparing the three conditions in the two types of interventions. For these models, sphericity was tested using Mauchly's test. The Huynh-Feldt correction was employed whenever this assumption was not met and the epsilon was higher than .57; otherwise, the Greenhouse-Geisser correction was used [130].

3. Results

3.1. Sample characteristics

According to table 1, the study included 20 participants, aged between 68 and 93 (M = 80.55 ± 6.69), the majority were female (n=18, 90%) and 11 participants were widows (55%). Regarding education, the average number of years spent studying by participants was 4.75 years (SD ± 2.07). The most common level of deterioration, classified by the GDS, was moderate cognitive decline (n=10, 50%), with a mean scale score of 4.15 (SD ± 0.81). For more detailed information, consult table 1.

Table 1. Sample characteristics, through sociodemographic variables and dementia stage, through the GDS scores.

	Sample n=20
	n (%)
Age (years)	
Mean ± Standard deviation	80.55 ± 6.69
Min-Max	68-93
Sex	
Feminine	18 (90)
Masculine	2 (10)
Education (years)	
Mean ± Standard deviation	4.75 ± 2.07
Min-Max	0-9
Marital status	
Married	6 (30)
Widow/er	11 (55)
Single	2 (10)
Divorced	1 (5)
GDS	
Mild cognitive decline	4 (20)
Moderate cognitive decline	10 (50)
Moderately severe cognitive decline	5 (25)
Severe cognitive decline	1 (5)
GDS score (1-7)	
Mean ± Standard deviation	4.15 ± 0.81

3.2. Comparison of engagement and participation in the different interventions

According to table 2, the results indicated that there was no significant difference between the immersive intervention and non-immersive intervention in terms of engagement in the session, t (19) = 1.058, *P* = .303. Analyzing the mean EPWDS scores, although there were no significant differences, considering the maximum EPWDS score, the mean obtained in the two interventions indicates that the engagement in both sessions was positive. According to table 3, the results indicated that the behavioral engagement in session was significantly higher on immersive intervention (M = 4.33, SD = 0.52) compared to non-immersive intervention (M = 4.05, SD = 0.58), z = -2.67, *P* = .008. Regarding all the remaining engagement indicators on the EPWDS scale, it was possible to conclude that there was no significant difference between the immersive and non-immersive intervention. For more detailed information, consult tables 2 and 3.

Table 2. Comparison of the immersive and non-immersive intervention according to the EPWDS scores.

	Mean ± Standard deviation		
	Immersive intervention	**Non-immersive intervention**	***P***
EPWDS	43.75 ± 4.36	43.05 ± 4.21	0.303[a]

a – values obtained through the T test for paired samples.

Table 3. Comparison of the immersive and non-immersive intervention according to the EPWDS categories scores.

	Mean ± Standard deviation		
	Immersive intervention	**Non-immersive intervention**	***P***
Affective engagement	4.20 ± 0.71	4.23 ± 0.67	0.816[b]
Visual engagement	4.70 ± 0.38	4.63 ± 0.39	0.499[b]
Verbal engagement	4.55 ± 0.39	4.58 ± 0.44	0.813[b]
Behavioral engagement	4.33 ± 0.52	4.05 ± 0.58	**0.008**[b]
Social engagement	4.23 ± 0.47	4.13 ± 0.53	0.356[b]

b – value obtained using the Wilcoxon signed-rank test.

3.3. Comparison of behavioral and psychological symptoms in the different interventions

According to table 4, the results indicated that apathy on facial expressions during the session was significantly higher on immersive intervention (M = 2.30, SD = 0.80) compared to non-immersive intervention (M = 2.00, SD = 0,65), z = -2.12, *P* =.034. It also indicated that apathy on purposeful activity during the session was significantly higher on non-immersive intervention (M = 1.75, SD = 0.72) compared to immersive intervention (M = 1.50, SD = 0.51), z = -2.24, *P* =.025. Regarding all the remaining apathy indicators on the PEAR scale, it was possible to conclude that there was no significant difference between the immersive and non-immersive intervention. According to table 5, the results indicated that there was no significant difference between the immersive and non-immersive intervention in terms of pleasure (z = -0.25, *P* =.803), anger (z = 0.00, *P* = 1.000), anxiety or fear (z = -1.00, *P* =.317), sadness (z = -0.38, *P* =.705) and general alertness (z = 0.00, *P* = 1.000) in the session. For more detailed information, consult tables 4 and 5.

Table 4. Comparison of the immersive and non-immersive intervention according to the PEAR scores.

		Mean ± Standard deviation		
		Immersive intervention	Non-immersive intervention	*P*
Before	Facial expressions	2.85±0.88	2.85±0.88	1.000[b]
	Eye contact	1.45±0.69	1.40±0.69	0.763[b]
	Physical engagement	2.80±0.95	2.85±0.88	0.796[b]
	Purposeful activity	2.45±1.15	2.40±1.14	0.785[b]
	Verbal tone	2.85±0.75	2.90±0.85	0.763[b]
	Verbal expression	2.40±0.75	2.15±0.88	0.059[b]
During	Facial expressions	2.30±0.80	2.00±0.65	**0.034[b]**
	Eye contact	1.35±0.49	1.20±0.41	0.180[b]
	Physical engagement	1.80±0.83	2.00±0.86	0.248[b]
	Purposeful activity	1.50±0.51	1.75±0.72	**0.025[b]**
	Verbal tone	2.25±0.55	2.20±0.52	0.655[b]
	Verbal expression	1.65±0.59	1.50±0.51	0.257[b]
After	Facial expressions	2.40±0.75	2.55±0.61	0.405[b]
	Eye contact	1.25±0.44	1.20±0.41	0.655[b]
	Physical engagement	2.35±0.88	2.35±0.88	1.000[b]
	Purposeful activity	1.95±0.63	1.85±0.67	0.595[b]
	Verbal tone	2.30±0.66	2.40±0.50	0.516[b]
	Verbal expression	1.80±0.70	1.90±0.64	0.480[b]

b – value obtained using the Wilcoxon signed-rank test.

Table 5. Comparison of the immersive and non-immersive intervention according to the OERS scores.

	Mean ± Standard deviation		
	Immersive intervention	Non-immersive intervention	*P*
Pleasure	3.80±1.06	3.75±1.02	0.803[b]
Anger	1.00±0.00	1.00±0.00	1.000[b]
Anxiety/fear	1.05±0.22	1.10±0.31	0.317[b]
Sadness	1.50±0.76	1.55±0.89	0.705[b]
General alertness	4.60±0.50	4.60±0.50	1.000[b]

b – value obtained using the Wilcoxon signed-rank test.

3.4. Comparison of well-being in the different interventions

According to table 6, the results indicated that there was no significant difference between the immersive and non-immersive intervention in terms of well-being in the session. Analyzing the mean OWLS scores, although there was no significant difference, a tendency towards a higher level of happiness and pleasure in immersive intervention compared to non-immersive intervention may emerge. It can also be observed that in both interventions all participants presented themselves attentive, responsive and relaxed during the intervention. For more detailed information, consult table 6.

Table 6. Comparison of the immersive and non-immersive intervention according to the OWLS scores.

	Mean ± Standard deviation		
	Immersive intervention	Non-immersive intervention	*P*
Attention	10.00±0.00	10.00±0.00	1.000[b]
Initiative/responsiveness	10.00±0.00	10.00±0.00	1.000[b]
Relaxation	10.00±0.00	10.00±0.00	1.000[b]
Happiness	9.10±1.65	8.70±2.13	0.382[b]
Pleasure	5.90±2.69	5.05±2.89	0.245[b]
Identity expressions	6.50±2.40	6.30±2.49	0.795[b]
Mastery	3.70±2.43	3.75±2.47	0.745[b]
Relationships	3.05±2.37	3.30±2.39	0.293[b]

b – value obtained using the Wilcoxon signed-rank test.

3.5. Comparison of physiological metrics in the different interventions

Relatively to the time domain results (Tables 7-9), for the repeated-measures ANOVA for mean HR, the sphericity assumption was not met ($P < .001$) and the epsilon was .618 for the condition effect and .589 for the condition * intervention interaction. Thus, the Huynh-Feldt correction was employed for this model. The results indicated a significant main effect for condition, $F(1.235,19.765) = 4.333$, $P = .043$, partial $\eta 2 = 0.213$. Post-hoc pairwise comparisons with a Bonferroni correction indicated that mean HR in the baseline rest condition (M = 67.55, SD

= 2.58) was significantly lower (*P* = .020) than in the exposure condition (M = 69.79, SD = 2.31). However, there was no significant main effect for intervention, F (1,16) = 0.026, *P* = .875, partial $\eta 2$ = 0.002, and non-significant intervention*condition interaction, F (1.178,18.852) = 0.279, *P* = .641, partial $\eta 2$ = 0.017.

The repeated-measures ANOVA results for SDNN indicated no significant main effect for intervention, F (1,16) = 0.069, *P* = .796, partial $\eta 2$ = 0.004, condition, F (2,32) = 2.501, *P* = .098, partial $\eta 2$ = 0.135 and intervention*condition interaction, F (2,32) = 0.256, *P* = .776, partial $\eta 2$ = 0.016.

For the repeated-measures ANOVA for RMSSD, the threshold criteria for skewness and kurtosis assumption was not met (skewness > 2), despite being very close values. The results indicated no significant main effect for intervention, F (1,16) = 0.007, *P* = .935, partial $\eta 2$ = 0.000, condition, F (2,32) = 1.729, *P* = .194, partial $\eta 2$ = 0.098 and intervention*condition interaction, F (2,32) = 0.458, *P* = .637, partial $\eta 2$ = 0.028.

The repeated-measures ANOVA results for pNN50 indicated no significant main effect for intervention, F (1,19) = 1.466, *P* = .241, partial $\eta 2$ = 0.072, condition, F (2,38) = 0.006, *P* = .994, partial $\eta 2$ = 0.000 and intervention*condition interaction, F (2,38) = 0.611, *P* = .548, partial $\eta 2$ = 0.031.

Considering the frequency domain results (Tables 7 and 10), the repeated-measures ANOVA results for Peak Frequencies on LF band indicated no significant main effect for intervention, F (1,19) = 0.112, *P* = .741, partial $\eta 2$ = 0.006, condition, F (2,38) = 0.857, *P* = .433, partial $\eta 2$ = 0.043 and intervention*condition interaction, F (2,38) = 0.076, *P* = .927, partial $\eta 2$ = 0.004. In terms of Peak Frequencies on HF band, the repeated-measures ANOVA results indicated no significant main effect for intervention, F (1,19) = 0.297, *P* = .592, partial $\eta 2$ = 0.015, condition, F (2,38) = 0.480, *P* = .623, partial $\eta 2$ = 0.025 and intervention*condition interaction, F (2,38) = 0.182, *P* = .834, partial $\eta 2$ = 0.010.

For the repeated-measures ANOVA for Absolute Powers on LF band, the threshold criteria for skewness and kurtosis assumption was not met (skewness > 2 and kurtosis > 9). The sphericity assumption was not met for the condition * intervention interaction (*P* < .001, epsilon = .576). Thus, the Huynh-Feldt correction was employed for this model. The results indicated no significant main effect for intervention, F (1,14) = 0.029, *P* = .866, partial $\eta 2$ = 0.002, condition, F (2,28) = 0.465, *P* = .633, partial $\eta 2$ = 0.032 and intervention*condition interaction, F (1.153,16.140) = 0.231, *P* = .672, partial $\eta 2$ = 0.016. For the repeated-measures ANOVA for Absolute Powers on

HF band, the threshold criteria for skewness and kurtosis assumption was not met (skewness > 2 and kurtosis > 9). The sphericity assumption was not met for the condition effect (*P* < .001, epsilon = .594) and for the condition * intervention interaction (*P* < .001, epsilon = .547). Thus, the Huynh–Feldt correction was employed for the condition effect and the Greenhouse–Geisser correction was employed for the condition * intervention interaction. The results indicated no significant main effect for intervention, F (1,14) = 1.386, *P* = .259, partial $\eta 2$ = 0.090, condition, F (1.187,16.619) = 2.493, *P* = .130, partial $\eta 2$ = 0.151 and intervention*condition interaction, F (1.094,15.321) = 0.449, *P* = .530, partial $\eta 2$ = 0.031.

For the repeated–measures ANOVA for Total Power, the threshold criteria for skewness and kurtosis assumption was not met (skewness > 2 and kurtosis > 9). The sphericity assumption was not met for the condition effect (*P* = .014, epsilon = .732). Thus, the Huynh–Feldt correction was employed for the condition effect. The results indicated no significant main effect for intervention, F (1,15) = 0.460, *P* = .508, partial $\eta 2$ = 0.030, condition, F (1.463,21.948) = 0.295, *P* = .679, partial $\eta 2$ = 0.019 and intervention*condition interaction, F (2,30) = 0.471, *P* = .629, partial $\eta 2$ = 0.030.

For the repeated–measures ANOVA for LF/HF Ratio, the threshold criteria for skewness and kurtosis assumption was not met (skewness > 2). The results indicated no significant main effect for intervention, F (1,13) = 0.272, *P* = .611, partial $\eta 2$ = 0.020, condition, F (2,26) = 0.015, *P* = .985, partial $\eta 2$ = 0.001 and intervention*condition interaction, F (2,26) = 0.739, *P* = .488, partial $\eta 2$ = 0.054.

In terms of the non–linear indices results (Tables 7 and 11), for the repeated–measures ANOVA for SD1, the threshold criteria for skewness and kurtosis assumption was not met (skewness > 2). The results indicated no significant main effect for intervention, F (1,16) = 0.007, *P* = .935, partial $\eta 2$ = 0.000, condition, F (2,32) = 1.729, *P* = .194, partial $\eta 2$ = 0.098 and intervention*condition interaction, F (2,32) = 0.458, *P* = .637, partial $\eta 2$ = 0.028. The repeated–measures ANOVA results for SD2 indicated no significant main effect for intervention, F (1,16) = 0.124, *P* = .729, partial $\eta 2$ = 0.008, condition, F (2,32) = 2.858, *P* = .072, partial $\eta 2$ = 0.152 and intervention*condition interaction, F (2,32) = 0.171, *P* = .843, partial $\eta 2$ = 0.011. In terms of SD2/SD1 Ratio, the repeated–measures ANOVA results indicated no significant main effect for intervention, F (1,18) = 0.177, *P* = .679, partial $\eta 2$ = 0.010, condition, F (2,36) = 0.970, *P* = .389, partial $\eta 2$ = 0.051 and intervention*condition interaction, F (2,36) = 0.086, *P* = .918, partial $\eta 2$ = 0.005.

Table 7. Descriptive statistics for physiological data results.

		Immersive intervention						Non-immersive intervention					
		Resting		Habituation		Exposure		Resting		Habituation		Exposure	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Time Domain	Mean HR* (bpm)	67.75	2.71	70.29	2.43	70.16	2.61	67.35	2.55	70.80	2.85	69.41	2.16
	SDNN* (ms)	54.91	11.07	64.75	12.50	56.45	8.74	47.02	8.83	62.09	9.25	58.61	12.36
	RMSSD* (ms)	68.15	14.74	74.56	16.70	68.14	14.65	57.42	11.97	77.79	13.11	72.07	16.16
	pNN50 (%)	21.95	5.79	20.34	5.78	22.56	6.73	28.12	7.78	29.47	7.64	27.60	7.12
Frequency	Peak Frequencies on LF (Hz)	0.08	0.01	0.08	0.01	0.07	0.01	0.07	0.01	0.08	0.01	0.07	0.01
Domain	Peak Frequencies on HF (Hz)	0.28	0.2	0.26	0.2	0.28	0.2	0.29	0.2	0.28	0.2	0.28	0.2
	Absolute Powers on LF** (ms^2)	439.79	191.58	936.82	440.69	643.60	239.73	686.25	562.64	709.36	337.29	766.43	458.94
	Absolute Powers on HF** (ms^2)	1312.25	709.72	2616.25	1300.45	884.48	388.28	629.62	194.71	1231.55	398.55	599.29	219.08
	Total Power*** (ms^2)	2882.99	1198.18	3073.20	1027.44	2436.12	720.09	2744.16	1017.57	4065.57	1314.27	4100.21	2076.64
	LF/HF Ratio**** (–)	0.81	0.37	0.64	0.16	0.73	0.21	0.54	0.14	0.68	0.22	0.65	0.16
Nonlinear	SD1* (ms)	48.18	10.43	52.72	11.81	48.18	10.36	40.60	8.46	55.01	9.27	50.96	11.43
methods	SD2* (ms)	57.29	12.67	72.43	13.82	61.61	7.79	49.88	9.87	66.14	10.16	63.29	13.79
	SD2/SD1***** (–)	1.42	0.21	1.67	0.22	1.53	0.18	1.41	0.19	1.55	0.21	1.46	0.19

*** n = 17 (3 outliers); ** n = 15 (5 outliers); *** n = 16 (4 outliers); **** n = 14 (6 outliers); ***** n = 19 (1 outlier).**

Table 8. Inferential statistics from the repeated-measures ANOVA on Time Domain results.

		F-value	*P* -value	partial $\eta 2$
Mean HR*	Intervention	0.026	0.875[c]	0.002
(bpm)	Condition	4.333	**0.043**[d]	0.213
	Condition*Intervention interaction	0.279	0.641[d]	0.017
SDNN* (ms)	Intervention	0.069	0.796[c]	0.004
	Condition	2.501	0.098[c]	0.135
	Condition*Intervention interaction	0.256	0.776[c]	0.016
RMSSD* (ms)	Intervention	0.007	0.935[c]	0.000
	Condition	1.729	0.194[c]	0.098
	Condition*Intervention interaction	0.458	0.637[c]	0.028
pNN50 (%)	Intervention	1.466	0.241[c]	0.072
	Condition	0.006	0.994[c]	0.000
	Condition*Intervention interaction	0.611	0.548[c]	0.031

*** n = 17 (3 outliers)**

c – value obtained through the two-way ANOVA test

d – value obtained through the two-way ANOVA test (Huynh-Feldt correction)

Table 9. Post-hoc pairwise comparisons between the conditions effect for Mean HR.

	Mean HR*	
	Mean ± Standard deviation	*P*
Habituation – Resting	3.00±1.42	0.154[e]
Exposure – Habituation	-0.76±0.91	1.000[e]
Exposure – Resting	2.24±0.72	**0.020**[e]

*** n = 17 (3 outliers)**

e – value obtained through the post-hoc pairwise Bonferroni correction

Table 10. Inferential statistics from the repeated-measures ANOVA on Frequency Domain results.

		F-value	*P*-value	partial $\eta 2$
Peak Frequencies on LF (Hz)	Intervention	0.112	0.741[c]	0.006
	Condition	0.857	0.433[d]	0.043
	Condition*Intervention interaction	0.076	0.927[d]	0.004
Peak Frequencies on HF (Hz)	Intervention	0.297	0.592[c]	0.015
	Condition	0.480	0.623[c]	0.025
	Condition*Intervention interaction	0.182	0.834[c]	0.010
Absolute Powers on LF (ms^2)**	Intervention	0.029	0.866[c]	0.002
	Condition	0.465	0.633[c]	0.032
	Condition*Intervention interaction	0.231	0.672[d]	0.016
Absolute Powers on HF (ms^2)**	Intervention	1.386	0.259[c]	0.090
	Condition	2.493	0.130[d]	0.151
	Condition*Intervention interaction	0.449	0.530[f]	0.031
Total Power* (ms^2)**	Intervention	0.460	0.508[c]	0.030
	Condition	0.295	0.679[d]	0.019
	Condition*Intervention interaction	0.471	0.629[c]	0.030
LF/HF Ratio** (-)**	Intervention	0.272	0.611[c]	0.020
	Condition	0.015	0.985[c]	0.001
	Condition*Intervention interaction	0.739	0.488[c]	0.054

** n = 15 (5 outliers); *** n = 16 (4 outliers); **** n = 14 (6 outliers).

c – value obtained through the two-way ANOVA test

d – value obtained through the two-way ANOVA test (Huynh–Feldt correction)

f – value obtained through the two-way ANOVA test (Greenhouse–Geisser correction)

Table 11. Inferential statistics from the repeated-measures ANOVA on Non-linear methods results.

		F-value	*P* -value	partial ηp2
SD1* (ms)	Intervention	0.007	0.935[c]	0.000
	Condition	1.729	0.194[d]	0.098
	Condition*Intervention interaction	0.458	0.637[d]	0.028
SD2* (ms)	Intervention	0.124	0.729[c]	0.008
	Condition	2.858	0.072[c]	0.152
	Condition*Intervention interaction	0.171	0.843[c]	0.011
SD2/SD1*** (-)**	Intervention	0.177	0.679[c]	0.010
	Condition	0.970	0.389[c]	0.051
	Condition*Intervention interaction	0.086	0.918[c]	0.005

*** n = 17 (3 outliers); ***** n = 19 (1 outlier).**

c – value obtained through the two-way ANOVA test

3.6. Comparison of the participant's self-perception of the experience in the different interventions

The participant's self-perception of the experience questionnaire results (Appendix 1) demonstrated that generically the participants enjoyed both interventions (immersive and non-immersive), with a tendency to evaluate more positively to the immersive intervention than non-immersive intervention, despite reporting slightly greater difficulties to visualize the videos in the immersive intervention.

Based on table 12, the results indicated that there was no significant difference between the immersive and non-immersive intervention in terms of the participant's self-perception of the experience in the session. Analyzing the questionnaire mean scores, although there were no significant differences, a tendency to enjoy more the immersive intervention compared to non-immersive may emerge. Also, a tendency to watch the video better on non-immersive intervention compared to immersive intervention may emerge. Considering the maximum questionnaire score on each question, the mean obtained in the two interventions indicates that the participant's self-perception of the experience in both sessions was positive. For more detailed information, consult table 12.

Table 12. Comparison of the immersive and non-immersive intervention according to the participant's self-perception of the experience questionnaire.

	Mean ± Standard deviation		
	Immersive intervention	Non-immersive intervention	*P*
"Did you like the experience?"	4,80±0,41	4,60±0,60	0,102[b]
"How was the experience?"	4,45±0,69	4,35±0,59	0,414[b]
"How motivated are you to do this activity again?"	4,05±0,83	3,90±0,85	0,439[b]
"Interested in seeing other places?"	3,95±0,69	4,05±0,89	0,627[b]
"How well did you manage to watch the video?"	4,15±0,75	4,50±0,51	0,070[b]
"How comfortable was the activity?"	4,45±0,61	4,55±0,51	0,480[b]

b – value obtained using the Wilcoxon signed-rank test.

4. Discussion

The aim of this study was to analyze the effect of an immersive VR reminiscence session compared to a non-immersive reminiscence session, in terms of engagement and participation in session, BPSD and well-being in people with dementia, using behavioral observation and measurement of physiological metrics during interventions. It was found that the behavioral engagement in session was significantly higher on immersive intervention compared to non-immersive intervention. The results also indicated that apathy on purposeful activity during the session was significantly lower on immersive intervention compared to non-immersive intervention, however apathy on facial expressions during the session was significantly higher on immersive intervention compared to non-immersive intervention. Regarding the physiological analysis, the mean HR in the baseline rest condition was significantly lower than in the exposure condition, in both interventions. As for the other measures evaluated, there were no significant differences between the immersive intervention and non-immersive intervention.

Regarding engagement in the session, the results indicated that behavioral engagement was significantly higher in the immersive intervention than in the non-immersive intervention. This

suggests that the immersive intervention would have been more engaging for the participant to watch the video, pointing to locations and attempting to touch or approach objects. This is consistent with scientific research, which indicates that participant engagement during an intervention usually increases with increased immersion in the activity [104,107,108,131,132], demonstrating good adherence to these immersive interventions [96,98], due to the greater ease in evoking past memories and offering greater opportunity for the participant to explore and interact with the environment through body movements [78,82,96,98,104,133]. This result may have been observed due to, combined with the immersiveness of VR, the fact that it was a new and different way of participating in interventions may also have provoked greater interest and engagement.

Interpreting engagement in general and the remaining engagement indicators, it was possible to conclude that there were no significant differences between the immersive and non-immersive intervention. This result is not in line with the scientific literature already cited, which refers that interventions with greater immersiveness tend to be more motivating, thus promoting greater participant engagement [82,98,104,131,132,134,135]. This result can be explained, not only by the small number of participants and number of sessions per interventions, but the fact of carrying out activities using new technologies, such as VR, can be limiting to the participant's participation, due to lack of knowledge and the fact that handling the software can be confusing [96,98,136]. Furthermore, greater immersion may also have been a distracting element to the participant's involvement [137], also decreasing their social engagement, thus influencing communication between the participant and the researcher during the immersive session [104,107].

For BPSD, it was possible to conclude that apathy on purposeful activity, was significantly lower in the immersive intervention compared to the non-immersive intervention, indicating greater engagement in the session. This result is in line with scientific evidence that tells us that immersive activities may provide greater interest in the activity, thus also increasing their motivation to engage and intentionally participate in the session [82,104,107,110,111,132,135,138–140]. Contrary to this scientific evidence, it was possible to conclude that the apathy demonstrated in facial expressions during the session was significantly higher in the immersive intervention than in the non-immersive intervention. This result can be explained by the fact that the use of HMDs in the facial area may have limited the participant's

movements in terms of facial expressions or even limited the researchers' observation of apathy's facial expressions.

When it comes to the other apathy measures evaluated, through the PEAR, it was possible to conclude that there were no significant differences between the immersive intervention and non-immersive intervention. Handling the non-immersive activity with the computer mouse or the use of VR itself, may have limited the participant's own attention to the activity, which may have influenced the results when it comes to apathy in interventions [96,98,136].

Regarding pleasure, anger, anxiety, sadness and general alertness, there were no significant differences between immersive and non-immersive intervention. According to scientific evidence, greater immersion could have a greater positive effect on mood, happiness, pleasure, agitation, depressive and anxious symptoms compared to non-immersive activities [82,83,88,98,102,104,107,108,110,111,135,138,139,141–147]. This lack of a significative difference can be explained not only by the sample size, but also by the fact that immersive activities can amplify emotions experienced by participants during the intervention, both positive and negative emotions due to the high degree of presence and realism provided by the VR [131,148]. The fact that there was only one session for each intervention may also have limited the observation of significant differences. Overall, in this study, both interventions showed positive effects on the participants, also making it difficult to conclude significant differences, combined with the possible difficulties of the assessment measures not being sensitive enough to identify differences, especially considering the range of their scores.

Regarding measures of well-being, it was possible to conclude that there were no significant differences between the immersive intervention and non-immersive intervention. Analyzing the results of the OWLS scale, it was possible to verify a tendency for higher levels of happiness and pleasure in the immersive intervention than in the non-immersive intervention, which is in line with studies that report that participants could have higher levels of well-being during activities with immersive interventions, due to the stimulation of memories of autobiographical memories, promoting their sense of identity [63,71,82,83,96,109,133,135,139,145,146,149]. The methodology of the instrument used could have been a limitation to observe significant differences, as OWLS is quoted if, in the evaluated period, the first four items are not rated, it is not possible to count the following, even if the person presents these indicators of well-being, which may have influenced these results [121]. It was also concluded that in both interventions all participants presented themselves attentive, responsive and relaxed during the intervention.

This result is in line with scientific evidence that also found that these reminiscence interventions can be an enjoyable and relaxed session, where participants are attentive and focus during the session [96,98,139].

Regarding physiological measures, it was possible to conclude that mean HR was significantly lower in the baseline rest condition compared to the exposure condition. However, no significant differences were found on the remaining physiological measures. Immersive reminiscence interventions can potentially unbalance the ANS. Due to the fact that it was a reminiscence intervention, capable of promoting the person's interest and causing relaxation and pleasure, there was the possibility of the PNS dominating over the SNS [112,150–153], based on a decrease in the mean HR and increase in SDNN, RMSSD, pNN50, HF and SD1 values [124,150,153–156]. Despite this, reminiscence interventions, being carried out with new technologies, such as VR, can promote interest and engagement in the session, thus increasing the participant's motivation to participate actively [82,104,107], presented by the dominance of the SNS over the PNS, based in the increase in the mean HR, which is in line with the results of this study, and increase in LF, LF/HF ratio values [124,150,151]. This dominance of the SNS may also be combined with fear, nervousness or anxiety when carrying out VR activities, due to lack of knowledge about the use and function of these technologies [96,98,136].

Regarding SD2 values, although there were no significant differences, there was a tendency for these values to be higher during habituation and exposure conditions compared to resting condition, which is in line with what was previously mentioned, that immersive reminiscence interventions can promote greater motivation to engage in the activity, thus increasing SNS, combined with the increase in mean HR also observed [82,104,107,157]. As this variable is speculative and more reliable over longer-term recordings, it will be necessary to further investigate this relationship with the ANS.

The inability to observe significant differences between the types of intervention may have been due to the positive effects caused by both interventions, evidenced by the participant's own self-perception of the experience.

In terms of the participant's self-perception of the experience, although the results indicated that there were no significant differences, it was possible to observe a tendency to enjoy the immersive intervention more than the non-immersive intervention. This result is in line with scientific evidence that says that immersive intervention is usually more appreciated, more satisfying and interesting for participants than non-immersive intervention, with good adherence

and participation [82,96,98,104,107,134,135,158,159]. Studies also support the safety and feasibility of using VR to promote autobiographical memory activities [82,88,91,94–99,104,106,135,159–162]. It was also possible to observe the tendency to see the video presented in the non-immersive intervention better than in the immersive one. The comfort factor of the HMD in conjunction with the participants' prescription glasses, may account for this outcome.

As strengths, this study investigates a scarcely explored area, namely the impact of RT using VR in the population with dementia on their engagement, BPSD and well-being. Including the participants' physiological data during the sessions may also have been a strong point, as it is an area that is also scarcely explored and referred to, in the literature, as essential to evaluate. The instruments focus on various aspects of each variable to be evaluated, collecting different characteristics about each intervention, managing to reach most of the different characteristics of the participants' intervention and its impact. These instruments focused on observation-based measures, something extremely relevant in dementia due to difficulties in insight and communication. Having confirmed the information about aspects of the participants' life stories, with the caregiver/family member, to choose the video that would be presented, may also have been a strong point, taking into account the presence of memory deficits by some participants. Furthermore, a strong point of this study was the fact that the intervention was focused and personalized for each participant, promoting greater impact and engagement in the sessions, making it more identifiable [64,70,77,163–165].

Despite that, this study had limitations, as already mentioned, the small sample size, which may have influenced the power and significance of the statistical tests carried out. The fact that there were only two male participants, further limiting the possible generalization of the results. It is also important to mention, as a limitation of this study, the fact that it was not possible to ignore unconscious information bias, as the researchers responsible for carrying out the intervention were aware of the hypotheses under study. Another existing limitation was the fact that, since the immersive intervention was carried out with participants sitting in a static chair, to reduce adverse effects, such as nausea or fall risk, it may have limited the exploration of the 360º video, which, ultimately, could have affected the depth of the intended immersive experience. The fact that there was only one session of each type of intervention may have influenced the results, depending on the participant's general condition on the day of each intervention and external events that day. In the non-immersive intervention, the use of the computer mouse may have

been a limitation for some participants, due to difficulties in understanding its functionality or handling, which may have influenced their engagement and the impact of the intervention itself. The habituation video may have influenced the results as the chosen video may have not been recognized by some participants, differentiating the level of participation of each participant, which may have influenced the results and comparisons with this condition. In the immersive session, it was necessary to remove the HMD between the habituation and exposure period to change the video, which could have influenced the physiological analysis, removing the potential of the habituation period.

As it was a study in which the same participants had to undergo both interventions with a washout period between them, the different stages of dementia progression may have influenced the second intervention, as there may have been a transition effect from the first intervention to the second intervention.

5. Conclusion

In this study it was concluded that the immersive intervention promoted significantly greater engagement and less activity related apathy compared to the non-immersive intervention, however there were no significant differences in well-being and the remaining BSPD, despite the results suggesting a tendency for a greater positive effect in the immersive intervention, such as happiness, pleasure and enjoyment. These results show the potential of using new technologies, such as VR and computers, for participants' adherence and engagement in intervention programs for people with dementia, as these technologies are increasingly accessible and safe.

In the future it will be important to carry out the same studies with a larger sample size and balance between the number of male and female participants, allowing for more complex statistical analyses and the results generalization. It would be pertinent to evaluate the possibility of carrying out immersive interventions with a swivel chair, so that the participant can safely view the 360º video, which could facilitate the identification of the significant location. The effectiveness of presenting the habituation and exposure video in the same video without interruptions and without having to remove the HMD, enhancing the effectiveness of the habituation period and transition to the exposure period, should also be studied. In the non-immersive session, the possibility of handling the activity in a more simplified way should be evaluated, with the video showing the 360º on the computer automatically or on a touch screen, for example. Furthermore, it would be important to carry out studies with a greater number of

sessions for each of the interventions, reducing the external influences that may occur on each participant and, if possible, always hold the sessions at the same time and place, without disrupting the participant's daily routine. The possibility of carrying out the habituation period with a video that is equally recognized by all participants should also be evaluated, such as showing a video of the room in which the session is taking place. Future studies should also continue to evaluate which washout period is most effective and indicated for this population.

It would also be important to carry out studies with the aim of evaluating the possibility of carrying out these interventions with family members or even the interventions themselves being carried out by them, in order to better explore the events and memories of the location presented in the video. Evaluating the possibility of carrying out these studies in more advanced stages of dementia or in different contexts, for example at home and hospitals, would also be something to be taken into consideration. Furthermore, the need to continue carrying out studies using observational instruments and physiological analysis, as these both enrich the data evaluated during the session and complement it in cases of participants with difficulties in expressing emotions during the session. For future studies it may also be important to analyze other physiological metrics such as the galvanic skin response, through electrodermal activity, to better understand how this results can be related to arousal and emotions responses.

In short, the continued exploration of this topic, which is scarce, is important, allowing the analysis of non-pharmacological interventions that are innovative, beneficial, effective and pleasurable for people with dementia, increasing engagement and well-being and reducing BPSD, thus being able to provide more appropriate and safe activities for the population, promoting an increase in the quality of life of the population with dementia and their caregivers and family members.

6. References

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7. Appendices

Appendix 1

		n (%)				
		1	2	3	4	5
		"I didn't like it very much"	"I didn't like it."	"I didn't like it, nor did I like it."	"I liked it"	"I liked it a lot."
"Did you like the experience?"	Immersive	0 (0)	0 (0)	0 (0)	4 (20)	16 (80)
	Non-immersive	0 (0)	0 (0)	1 (5)	6 (30)	13 (65)
		"Very bad."	"Bad."	"Neither bad nor good."	"Good."	"Very Good."
"How was the experience?"	Immersive	0 (0)	0 (0)	2 (10)	7 (35)	11 (55)
	Non-immersive	0 (0)	0 (0)	1 (5)	11 (55)	8 (40)
		"Very Unmotivated."	"Unmotivated."	"Neither unmotivated nor motivated."	"Motivated."	"Very motivated."
"How motivated are you to do this activity again?"	Immersive	0 (0)	0 (0)	6 (30)	7 (35)	7 (35)
	Non-immersive	0 (0)	2 (10)	2 (10)	12 (60)	4 (20)
		"Very disinterested."	"Disinterested."	"Neither disinterested nor interested."	"Interested."	"Very interested."
"Interested in seeing other places?"	Immersive	0 (0)	0 (0)	5 (25)	11 (55)	4 (20)
	Non-immersive	0 (0)	1 (5)	4 (20)	8 (40)	7 (35)
		"Very bad."	"Bad."	"Neither bad nor good."	"Good."	"Very Good."
"How well did you manage to watch the video?"	Immersive	0 (0)	0 (0)	4 (20)	9 (45)	7 (35)
	Non-immersive	0 (0)	0 (0)	0 (0)	10 (50)	10 (50)
		"Very uncomfortable."	"Uncomfortable."	"Neither uncomfortable nor comfortable."	"Comfortable."	"Very comfortable."
"How comfortable was the activity?"	Immersive	0 (0)	0 (0)	1 (5)	9 (45)	10 (50)
	Non-immersive	0 (0)	0 (0)	0 (0)	9 (45)	11 (55)