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Investigating the impact of immersive virtual reality meditation on coherence achievement score, anxiety, and depression among people living with dementia

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Abstract

Introduction: Non-immersive technology-based mindfulness meditation programs have been shown to effectively reduce stress and improve users' mental health. Still, little research has been conducted to assess the health benefits of an immersive virtual reality meditation (IVRM) program among people living with dementia (PLWD).

Methods: This pilot study is based on a single-arm, longitudinal design. PLWD residing in long-term care (LTC) facility (N=8) received six sessions (three times a week for two weeks) of an IVRM program lasting 30-40 minutes each. The IVRM program is used as an individualized, customized meditation tool in VR that provides more than 300 audio tracks, meditation process monitoring, and a selection of meditation environments. We used electrocardiography to measure coherence achievement score (CAS), the Rating Anxiety in Dementia (RAID) scale to measure anxiety, and the Cornell Scale for Depression in Dementia Short Form to measure depression. The Generalized Estimated Equation (GEE) was used in this study.

Results: The descriptive baseline data for study variables anxiety and depression were (M = 12.83, SD = 3.51) and (M = 7.88, SD = 1.95), respectively, and the CAS gap between before and after six sessions of IVRM (M = 81.68, SD = 24.21). The participants showed lower levels of anxiety and depression by achieving a large CAS gap after the use of IVRM. Age was a significant factor in depression (B = 0.01, 95% CI, 1.00 – 1.04), indicating that participant depression levels were age-dependent.

Discussion: The findings of this study provide suggestive evidence that the use of an IVRM program led to an improvement in CAS, which is indicative of a reduction in depression and anxiety. This study suggests that the use of an IVRM program can be instrumental in reducing depression and anxiety among PLWD.

Take-home message: This study investigated the impact of the use of an IVRM program on emotional health, with a focus on depression and anxiety among PLWD. We investigated the longitudinal relationship between the coherence achievement score (CAS), anxiety, and depression after the use of an IVRM.

Keywords: Alzheimer's disease and related dementias; heartMath; longitudinal design; pilot study; virtual reality meditation.

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INTRODUCTION

Over 90% of persons living with dementia (PLWD) exhibit the behavioral and psychological symptoms of dementia (BPSD) which include depression, anxiety, aggression, and agitation [1-3]. The presence of BPSD has negative implications for hospitalization, institutionalization, and overall mortality among PLWD in care facilities and their caregivers [4-6]. BPSD is further associated with decreased functional ability, psychological distress, lack of social interaction, premature nursing home placement, long-term hospitalization (resulting in substantial health care costs), and accelerated cognitive decline [7-9]. Current research underscores the importance of the use of intervention programs designed to reduce the incidence of the BPSD and improve the quality of life of PLWD.

One intervention that has been reported to be effective in reducing the BPSD among PLWD is the application of meditation programs for PLWD. There is substantial evidence that meditation practices reduce perceived stress, anxiety, and depressive symptoms and enhance the quality of life among older adults [10-13]. Research has stressed the importance of a wide variety of meditative techniques in reducing psychological challenges and increasing the quality of life of older adults. Studies that have investigated the effects of meditation programs among people with mild cognitive impairment or subjective cognitive decline have demonstrated that participants in the meditation group showed larger decreases in depressive symptoms and improvement in quality of life and well-being compared to the control group [14-16].

In spite of the reported health benefits that can be derived from participation in meditation programs, PLWD residing in care facilities may encounter challenges to participating in them including accessibility, lack of individualization, and a shortage of instructors. The application of virtual reality (VR) programs has emerged as a therapeutic, rehabilitative tool that provides accessibility, individualization, and usability [17-19]. Previous studies have demonstrated that mindfulness meditation programs using accessible technology (e.g., mobile devices) are effective in reducing stress and improving the mental health of users [20-22]. Beyond the reported health benefits of two-dimensional device technologies, research suggests that immersive VR programs may lead to more substantial improvements in human-technology integration processes like embodiment and performance than do two-dimensional experiences using technologies such as computer monitors [23]. Unfortunately, little research has focused on the potential benefits of these VR-based meditation programs among PLWD who exhibit BSDP. In addition, the majority of dementia studies have focused on proxy measurements of psychological health outcomes, therefore the incorporation of an objective assessment to understand emotional states has the potential to increase the rigor of this research [24,25].

An IVRM program can overcome practical limitations to participation by: (a) accommodating individualization by allowing users to explore preferred natural scenery such as a green meadow, waterfall, savannah, or seashore and choose a variety of natural sounds (e.g., birds chirping) while

engaging in a meditation program designed to ease stress, improve sleep patterns, and reduce depression, (b) minimizing programmatic barriers (e.g., the current instructor shortage and communication challenges between older adult users and instructors by enabling participants to practice a variety of meditation techniques at a convenient time and place, and (c) addressing the individual challenges associated with physical distance, time efficiency for participation, and financial constraints

Thus, this pilot study investigated the impact of an INVR program on emotional health (depression and anxiety) among PLWD. To investigate the relationship between exposure to the IVRM program, depression, and anxiety, our study used HeartMath [26-32], which uses electrocardiography to measures heart rhythm changes and calculates a coherence level between sympathetic and parasympathetic activities in the autonomic nervous system (ANS). This biofeedback technology provides data that increases the reliability and validity of proxy measurements of health outcomes among PLWD. Importantly, this technology allows researchers to objectively measure a coherence achievement score (CAS) that has been associated with levels of anxiety and depression [26-29] in which an improved coherence achievement score is indicative of decreased depression and anxiety [30-32].

Despite the importance of objective measurements of emotional health among PLWD, few studies have investigated the impact of a novel VR technology program (IVRM) between CAS and depression and anxiety. Thus, this study was designed to investigate the preliminary health outcomes of the INVR on depression and anxiety based on CAS measurement. We hypothesized that the IVRM users would report lower depression and anxiety levels by achieving a large CAS gap after their participation. This pilot study addresses a critically important need to improve the mental health and quality of life of PLwD. The findings of this research will provide preliminary outcomes that will form the basis for a precise estimation of effect sizes for a larger randomized controlled trial.

METHODS

Study design and sample

This pilot study was based on a single-arm, longitudinal design. PLWD residing in memory care facilities (N=8) received six sessions (three times a week for 2 weeks) of an IVRM program lasting 30-40 minutes each. Participant's age ranged from 80 to 92 (M = 83.75, SD = 5.00). All study participants are widowed females. This study conducted a G*Power analysis and obtained a value of 0.53. The criteria for inclusion were: (a) clinical diagnosis of dementia, (b) no prior experience with any VR program, (c) residing in a memory care facility, and (d) no active participation in meditation programs. The exclusion criteria included: (a) clinical diagnosis of psychiatric disorders (e.g., schizophrenia, delusion and bipolar disorders), (b) severe visual impairments, and (c) inability to verbally communicate (determined by the care facility staff or caregivers). Prior to their participation in this study, the research team obtained informed consent from the legal representatives of all participants. A participation incentive was awarded to the study participants in the form of a $20 gift card at the last intervention session. Ethics approval of the study protocol was granted by the Indiana University Institutional Review Board (IRB: IU #13607).

Intervention

This study utilized the Guided Meditation VR app (Meta Oculus Quest 2, Cubicle Ninjas, USA) as an intervention program for PLWD. Our trained research coordinator facilitated the use of the IVRM program for participants. The app is primarily designed to offer a variety of contexts such as rivers, meadows, forests, and deserts with the purpose of promoting relaxation, calmness, and inner peace for users (Figure 1). The app is used as an individualized, customized meditation tool within the context of VR that provides more than 300 audio tracks, meditation process monitoring, and a selection of meditation environments. Each user can select the place and sound for meditation and receive specific meditation guidance.

Figure 1.1. Guided meditation VR.

River Meadows Space Waterfall

Study measures

Coherence Achievement Score (CAS). CAS is a measure of the degree of coherence in the heart rhythm pattern. The scoring algorithm updates the coherence score every five seconds during an active session and sums these scores throughout the session. The more stable and regular the heart rhythm, the higher the coherence score. CAS was measured in every session (total six times), and the gap in CAS was calculated by subtracting the CAS baseline from the CAS exit measure. Increases in the CAS gap indicate an increase in coherence in the heart rhythm pattern, which indicates a higher level of emotional stability.

Rating Anxiety in Dementia (RAID).

RAID Shankar et al [33] was used to measure anxiety in individuals with dementia over the course of the study. RAID is comprised of 18 items, each of which is rated on a four-point scale in which a score of 11 or higher indicates significant clinical anxiety. For example, study participants were asked to answer a question 'Worry about physical health' on a four-point scale (0 = absent, 3 = severe). The trained research coordinator used the RAID on two occasions to assess the anxiety of participants (e.g., pre and post intervention), with a higher score indicating higher levels of anxiety. The 18 items of the RAID satisfied the internal consistency assumption (Cronbach's alpha = 0.94).

Cornell Scale for Depression in Dementia Short Form (CSDD-SF).

The CSDD Alexopoulos et al [34] is based on a clinician-administered and/or a facility staff interview of the patient to rate symptoms of depression in persons living with dementia. The CSDD-SF measures mood using four items, each of which is scored on a three-point scale ranging from 0 to 2. For instance, study participants were asked to evaluate their 'Anxious expression, ruminations, worrying' on a three-points scale (0 = absent, 2 = severe). Depression was assessed by a facility staff member on two occasions (e.g., pre and post intervention), with a higher score indicating higher levels of depression. The four items of the CSDD-SF had a 0.89 Cronbach's alpha value.

Study analysis

All statistical analyses were conducted using SPSS version 26.0. The Generalized Estimated Equation (GEE) was used to analyze the longitudinal relationship between the CAS gap (i.e., parameter), anxiety, and depression during the six sessions of the IVRM intervention in which age was considered as a covariate. Using GEE, the relationships between the parameter, anxiety and depression were tested, and a 95% Confidence Interval (CI) was calculated. The parameter indicated a gap in coherence achievement scores (CAS) during the six sessions of the IVRM intervention. The highest parameter was 126 in anxiety and 120 in depression, and the lowest parameter was 31 in both anxiety and depression. Thus, the GEE model calculated the coefficient of the parameter and predicted a change in the outcome variable for a parameter increase in the predictor.

$$Outcome\ Variable = Constant + Age + CAS\ \text{gap}$$

$$Anxiety, Depression = \beta_0 + \{(Age * \beta_1) + CAS\ gap * \beta_2\}$$

RESULTS

The descriptive baseline data (Table 1) for study variables include anxiety (M = 12.83, SD = 3.51), depression (M = 7.88, SD = 1.95), and CAS gap between before and after six sessions of IVRM

(*M* = 81.68, *SD* = 24.21). Table 2 describes the result of the GEE CAS gaps and anxiety regression analysis. The largest parameter (126) presented a - 9.00 coefficient (95% CI, 0.13 – 0.13). The lowest coefficient was - 0.88 when the participants had the parameter 31 (95% CI, 0.05 – 7.81). While parameter 70 presented a 0.50 coefficient (95% CI, 0.82 - 3.29), it was not significant. The coefficient of the parameter was likely to decrease except for outliners between 31 and 126. Thus, the participants showed lower anxiety levels by achieving a large CAS gap after the use of IVRM. Age was found to be a significant predictor, but the parameter of age was B = 0.00 (95 CI, 1.00 – 1.04), indicating that age marginally affected anxiety change.

Table 3 displays the relationship between the CAS gaps and depression. The parameter of 120 shows a – 7.50 coefficient (95% CI, 0.60 – 0.61). The smallest coefficient of depression was - 0.30 when the participants had a parameter of 31 (95% CI, 0.28 – 1.01), and while parameter 70 presented a 0.50 coefficient (95% CI, 0.82 - 3.29), it was not significant. The coefficient of anxiety decreased with an increase in the CAS gap with some exceptions from 31 to 120. Thus, the participants achieved lower levels of depression by achieving a large CAS gap after the use of IVRM. Age was a significant parameter of depression (B = 0.01, 95% CI, 1.00 – 1.04), indicating that participant depression levels were age-dependent.

Table 1. Descriptive statistics.

Variables	**Mean**	**SD**	**Cronbach's α**
Independent variable			
CAS gap	81.68	24.21	
Dependent variable			
Anxiety	12.83	3.51	0.90
Depression	7.88	1.95	0.83

Total n = 8

Table 2. Parameter estimates for anxiety,

Parameter	**B**	**SD**	**Sig.**	**95% CI for Exp (B)**	
				Lower	**Upper**
Intercept	16.00	2.06	0.00*	886.10	886.11
CAS gap = 126	-9.00	1.36	0.00*	0.13	0.13
CAS gap = 122	-8.00	2.20	0.00*	0.05	0.05
CAS gap = 120	-5.89	1.95	1.00	1.00	1.00
CAS gap = 110	-2.50	1.06	0.00*	0.10	0.65
CAS gap = 106	-5.00	2.27	0.00*	0.00	0.00
CAS gap = 105	-5.89	1.97	0.00*	1.00	1.00
CAS gap = 102	-8.00	1.40	0.00*	0.00	0.00
CAS gap = 101	-4.00	1.50	0.00*	0.01	0.01
CAS gap = 100	-1.00	1.50	0.00*	0.36	0.36
CAS gap = 99	-3.50	2.47	0.16	0.00	3.86
CAS gap = 94	-5.83	1.06	0.00*	0.00	0.02
CAS gap = 85	-9.50	3.88	0.19	7.47	19.22
CAS gap = 84	-1.75	1.23	0.15	0.01	1.96
CAS gap = 83	-4.25	0.53	0.00*	0.00	0.04
CAS gap = 79	-2.50	1.06	0.00*	0.01	0.65
CAS gap = 70	0.50	0.35	0.16	0.82	3.29
CAS gap = 65	-2.00	0.99	0.00*	0.90	1.19
CAS gap = 47	-4.59	1.09	0.00*	1.28	1.85
CAS gap = 44	-1.11	2.22	0.00*	0.09	1.09

CAS gap = 33	-1.01	1.41	0.00*	0.06	15.98
CAS gap = 31	-0.88	1.19	0.00*	0.05	7.81
Age	.00	.00	.01*	1.00	1.04
Scale					

Note: Dependent Variable: Anxiety. Redundant parameters were removed * $p < .05$

Table 3. Parameter estimates for depression.

Parameter	B	SD	Sig.	95% CI for Exp (B) Lower	Upper
Intercept	10.00	1.40	0.00*	2202.02	2202.99
CAS gap = 120	-7.50	1.81	0.00*	0.60	0.61
CAS gap = 110	-3.50	1.06	0.00*	0.00	0.24
CAS gap = 106	-4.00	0.00	0.00*	0.01	0.02
CAS gap = 99	-3.25	0.17	0.00*	0.02	0.05
CAS gap = 94	-2.13	0.48	0.00*	0.04	0.30
CAS gap = 91	-2.00	1.06	0.59	0.00	1.08
CAS gap = 85	-1.75	1.59	0.27	0.00	3.92
CAS gap = 84	-2.95	0.39	0.00*	0.02	0.11
CAS gap = 83	-3.20	0.56	0.00*	0.01	0.12
CAS gap = 79	-0.07	0.88	0.39	0.08	2.67
CAS gap = 70	0.50	0.35	0.15	0.82	3.29
CAS gap = 65	-3.00	0.34	0.00*	0.79	0.96
CAS gap = 47	-2.99	1.02	0.00*	1.00	1.31
CAS gap = 44	-1.91	0.89	0.00*	0.99	1.04
CAS gap = 33	-0.50	0.35	0.15	0.30	1.21
CAS gap = 31	-0.30	0.31	0.22	0.28	1.01
Age	.01	.00	0.00*	1.00	1.01
Scale					

Note: Dependent Variable: Depression. Redundant parameters were removed * $p < .05$

DISCUSSION

This pilot study investigated the impact of the use of an INVR program on depression and anxiety based on CAS among PLWD. The findings of this research study show that participants who participated in the INVR program reported lower anxiety and depression levels, as indicated by an increase in the CAS gap. This finding provides suggestive evidence that the use of an IVRM program leads to improvements in CAS and, subsequently, reductions in both depression and anxiety in PLWD. This study suggests that the use of an INVR program can be effective in reducing depression and anxiety among PLWD.

Prior studies have reported evidence that mobile device-based meditation programs reduce stress, depression, and anxiety among adult users with sleep disturbance and in the general population [35-39]. While these studies largely focused on the effects of the use of two-dimensional technologies on depression and anxiety among app users, our study provides suggestive evidence of the effects of the use of an INVR program on depression and anxiety confirmed by CAS data among PLWD. The findings of this study extend the body of knowledge by demonstrating the positive effects on depression and anxiety related to participation by PLWD in an IVRM program on depression and anxiety. The findings of this study make an important contribution to dementia studies by providing suggestive evidence that an IVRM program can play an important role in reducing the depression and anxiety that are the main factors in the presentation of BPSD among PLWD.

A small number of pilot studies that have tested the efficacy of VR-based programs on emotional health and depression among persons living with dementia have provided suggestive evidence that VR programs are effective in reducing depression and improving emotional health [39-41]. These studies largely focused on health outcome assessments of emotional health and depression using proxy measures. Kroenke et al [20] reported that there has been controversy regarding the reliability and validity of assessments based on proxy measures and stressed the importance of objective assessments. Thus, from a methodological standpoint, this study has combined objective assessments with proxy measurements to assess the relationship between CAS as measured by HeartMath, depression, and anxiety related to the use of an IVRM program. This study adopted electrographic measurement to objectively assess psychophysiological changes and strengthen methodological rigor by reducing research gaps related to the lack of objective assessments in previous studies.

There are, however, limitations inherent to this study that must be addressed. First, our study had a small sample size without a control group and was not double-blinded. We recommend that a randomized clinical trial be conducted with a larger sample size to achieve a deeper understanding of the efficacy of using an IVRM program with PLWD. Second, we implemented six sessions of the IVRM program without a longer follow-up assessment (e.g., three or six weeks). It would benefit future researchers to measure outcomes over a longer period. In addition, other factors may affect the experience of participants, such as the level of technology acceptance, different levels of physical functioning and dementia progression (stages of dementia), stress levels, and demographic factors. Future studies are needed to investigate how these variables influence the benefits derived from VR participation. Last, gender or ethnic diversity were not considered in the study, as all participants were female and White. A broader representation of racial and ethnic diversity in dementia studies is needed in future research.

CONCLUSIONS

Reducing depression and anxiety continues to be a major public health challenge among PLWD. The present study provides suggestive evidence that the use of an IVRM program can reduce depression and anxiety as measured by the improvement of CAS among PLWD. This overall finding suggests practical implications for healthcare professionals, caregivers, and therapists who work with dementia patients. Considering the potential health effects of using an INVR program, healthcare professionals who work with PLWD need to design and develop educational programs that teach how to access and engage with VR programs with minimal instruction to facilitate the active participation of PLWD in this VR program. In addition, healthcare professionals need to become more aware of the impact of the use of individualized VR-based meditation programs on the mental health of PLWD and learn how they might be integrated into their services to improve their clients' emotional health and well-being [42-47]. Thus, the overall finding of this study suggests that the use of individualized VR-based meditation programs has the potential to contribute to improvements in CAS assessments, which have been associated with a reduction in depression and anxiety.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of the Institutional Ethics Review Board of the Department. The datasets generated and analyzed during the current study are secured in encrypted data storage. Researchers desiring access to this data should contact the corresponding author.

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