2025 Volume: 01 Issue: 07 www.ijrpa.com ISSN 2456-9995 **Research Article**

International Journal Research Publication Analysis

Page: 01-34

DESIGN AND FEASIBILITY EVALUATION OF A VIRTUAL REALITY–ENABLED APPROACH FOR DEMENTIA CARE

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Article Received: 13 November 2025
Article Revised: 03 December 2025
Published on: 23 December 2025

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DOI: https://doi-doi.org/101555/ijrpa.2352

ABSTRACT

Dementia is a progressive neurological condition that significantly affects cognitive function, emotional well-being, and quality of life, creating substantial challenges for both patients and caregivers. Recent advances in immersive technologies offer new opportunities to support non-pharmacological interventions in dementia care. This study presents the **design and feasibility evaluation of a virtual reality (VR)–enabled approach for dementia care**, aimed at enhancing cognitive engagement, emotional comfort, and user experience.The proposed system integrates immersive VR environments tailored to the cognitive and sensory needs of individuals with dementia, including reminiscence-based scenarios, calming natural settings, and simple interactive tasks. A user-centered design methodology was adopted, involving clinicians, caregivers, and end users to ensure accessibility, safety, and ease of use. The feasibility study was conducted with a small cohort of participants diagnosed with mild to moderate dementia, focusing on usability, acceptance, tolerability, and preliminary therapeutic outcomes. Quantitative measures such as task completion rates and system usability scores, along with qualitative feedback from participants and caregivers, were used for evaluation. Results indicate high levels of user acceptance, minimal adverse effects, and positive trends in mood enhancement and engagement during VR sessions. Caregivers reported reduced agitation and improved emotional responses among participants. Although the sample size was limited, the findings demonstrate the practical feasibility and potential benefits of VR-enabled interventions in dementia care.This study concludes that virtual reality represents a promising, scalable, and non-invasive tool for supporting dementia care. Future work will focus on larger clinical trials, longitudinal assessments, and the integration of adaptive and personalized VR content to enhance therapeutic effectiveness.

INTRODUCTION

DVANCES IN MEDICINE AND PUBLIC HEALTH have Achieved substantial increases in life expectancy, which are likely to continue in the foreseeable fu- ture. However, this has also contributed to a con- comitant increase in the prevalence of dementia, which in developed countries is expected to double over the next 50 years.[1] Internationally, the estimated figures are striking; for example, there are an esti- mated 700,000 and 2.3 million people with demen- tia (PWD) in the United Kingdom and the United States, respectively.[2,3]

Major symptoms of dementia that may be attrib- uted to both the underlying disease process and theindividual's reaction to it include impairments of memory, language skills, attention, visual percep- tion and problem-solving skills, temporal and spa- tial disorientation, behavioral changes and losses of social function, including the capacity to undertake activities of daily living.[4] Dementia of the Alzhei- mer's type accounts for approximately 60% of de- mentia cases diagnosed, characterized by a gradual onset and insidious decline over several years.[5] Vas- cular dementia has a more stepwise progression and frequently occurs after strokes. Dementia with Lewy bodies is typically associated with more fluctuating cognitive impairments and psychotic features such as hallucinations. Other less prevalent causes of de- mentia include Korsakoff's syndrome, Pick's disease,Huntington's disease, Parkinson's disease, Creutz- feld Jakob Disease, AIDS, brain tumors, and head injury. Comorbidity can include depression, agita- tion, sleep problems, aggression, inappropriate sex- ual behavior, and incontinence.

The development of a methodology for working with PWD in virtual environments (VEs) may enable the development of virtual reality (VR)–based cog- nitive assessment techniques, cognitive rehabilita- tion strategies, and therapeutic activity for dementia. Design of both internal and external environments may also benefit considerably from a VR-based ap- proach. How VR could make important contribu- tions in these areas is considered in the next section, followed by an introduction of the issues surround- ing the use of VR by PWD.

The potential of VR in dementia care It is important that the presence of dementing illness is discovered as early as possible, along with an identification of dementia subtype and stage of disease, as this enables treatment and care to be ini- tiated that may have potential for minimizing the onset of neurodegeneration, optimizing cognitive functioning, and/or improving quality of life.[6] In order to achieve this, cognitive, neuropsychologi- cal, and functional assessment tools that are sensi- tive, specific, reliable, and valid are needed.

However, existing “pencil and paper” cognitive assessment tools have been heavily criticized for possessing inadequate reliability and ecological va- lidity, as they are confounded by a respondent’s physical capabilities, different testing environments and the quality of stimuli presented, and assess abil- ities in contexts detached from day-to-day function- ing.[7,8] VR is a possible solution to these problems because it has the potential to improve the reliabil- ity, sensitivity, specificity, and ecological validity of cognitive assessment by enabling the precise con- trol and manipulation of stimuli presented to users within ecologically valid VEs that correspond to real-life contexts.[6,8–11]

In addition, the neglected area of cognitive reha- bilitation strategies for dementia such as memory skills training may be enhanced by utilizing ecolog- ically valid VEs.[6,8,10] Cognitive rehabilitation strate- gies aimed at restricting neurodegeneration and maintaining spared abilities have been given re- newed justification as a treatment option for early stage dementia, as the new group of drugs called “acetylcholinesterase inhibitors” increase the pro- duction of acetylcholine needed for memory and learning. The same VEs that are used to assess cog- nition could also be used as media for cognitive re-habilitation, which could simulate a person’s home or other familiar environment that is relevant to the individual’s day-to-day functioning.

However, cognitive assessment and cognitive re- habilitation approaches may only be appropriate for people in the mild to moderate stages of dementia. People in the later stages of dementia may benefit more from therapeutic activities such as multi-sensory therapy (MST) that are aimed at alleviating the more distressing psychological and behavioral symptoms of dementia such as agitation. CAVE- based VEs could be used as an alternative to cur- rently available multi-sensory environments (MSEs) or Snoezelen, and this could improve the design, delivery, and outcome of MST for PWD in later stages. MSEs utilizing VR technology have advan- tages over static environments as they are quickly and easily modified, do not require the purchase of additional equipment, and have unlimited options in terms of the stimuli that may be presented to users.

Design for dementia is another area where VR could revolutionize dementia care and research. The quality of design has a direct influence upon a per- son's quality of life, and as people grow older, they become increasingly reliant upon their environment to compensate for physical and cognitive decline.[12] A substantial volume of research has investigated indoor design features associated with improvements in spatial orientation, vitality, wayfinding, and well- being.[13–15] However, a major criticism of studies in this area is that they often fail to justify why partic- ular environmental design features yield enhanced well-being compared with others.[16] This is primar- ily due to the potentially complex interactions be- tween elements in the environment and the cost associated with making real-world design changes. VR offers the possibility of elucidating these design features by enabling the selective introduction and removal of elements within the perceptual environ- ment to identify specific combinations of factors as- sociated with success in wayfinding and enhanced well-being within settings such as residential care. In the United Kingdom, an estimated 80% of PWD are living at home in the community, almost a quarter on their own, and many are still active out- doors making trips for pleasure and visiting local amenities.[17] Therefore, VR may have an important contribution to make in identifying barriers and fa- cilitators to wayfinding and well-being in outdoor environments as well as indoor care settings.[18]

VR has significant potential for improving the state-of-the-art in the above areas; however, to date only two Furthermore, these studies do not address basic feasibility issues necessary to enable the performance of PWD in VEs to be deemed safe, reliable, and eco- logically valid.

Therefore, the aim of the current study was to ad- dress several of these feasibility issues in order to inform the development of VR applications. Sim- ply stated, it is unknown if PWD can navigate through a VE with standard input devices such as joysticks or whether PWD are at risk of experiencing side effects such as simulator sickness or suffer detriments to their psychological and physical well- being when interacting with VEs. In addition, it is unknown if PWD experience presence, which is a strong indicator of ecologically valid experiences in VEs. Indeed, one of the main advantages of VEs is that they provide the opportunity to make an ecologically valid assessment of behavior necessary for day-to-day functioning.[8,10] However, to date, no study has demonstrated that PWD can perform functional tasks within the context of an ecologically valid VE.

MATERIALS AND METHODS

Research design

The research made use of VR technology available at the University of Teesside's InnovationdVirtual Reality Centre, a purpose-built resource for the creation and development of real-time virtual experiences in a wide range of application areas (http://vr.tees.ac.uk/). The project utilized the VR auditorium, where it is possible to run real-time models with a high degree of detail, powered by a silicon graphics infinite reality ONYX 1 computer. The VR Auditorium is comprised of a large 140-degree curved screen based on BARCO 1208 projectors, which provides a semi-immersive view of VEs with surround sound.

The study utilized a VE of a large park surrounded by a fence with a backdrop of local industry and geographical features (Fig. 1). The VE included models of park benches, telephone boxes, post boxes, trees, refuse bins, picnic areas, examples of locally relevant sculpture, and other perceptual opportunities.[21] To avoid the disorientation that "walking off the end of the world" may cause and to support ecological validity, view boundaries were programmed into the VE to prevent PWD from navigating beyond the main area of the park. The speed of navigation was restricted to a maximum of "normal walking speed" at an elevation of 1.65 m during the VR exercises.

PWD were seated next to their carer/keyworkers and a research assistant (RA) throughout the VR session, and postural demands were reduced by seating participants in comfortable chairs during he VR exercises. Participants were situated 2.1 m from the center of the cinema screen. A standardized level of illumination was used throughout.

FIG. 1. Screendump of the VE used for the VR exercises.

The input device used for navigation was a BG Systems Flybox© joystick situated on a table directly in front of the PWD. A directional template was placed over the joystick, which served as a memory cue for the participant while they were navigating through the VE. The joystick enabled movement with eight horizontal degrees of freedom (i.e., left, right, forward, back, and four diagonals).

Interactions between PWD, their carers/keywork- ers, the RA, and the VE during the VR session were audio and video recorded for the purposes of archiv- ing and analysis. To monitor the physical well-being of PWD, an Ohmeda 3800 pulse oximeter was used to measure their heart rate during the VR exercises. The device was attached to the forefinger of PWD, and data were recorded manually at 10-sec inter- vals during the VR exercises.

The incidence and severity of adverse effects were assessed with a modified version of the Simulator Sickness Questionnaire developed by Kennedy et al.[22] The adapted version of the simulator sickness questionnaire for PWD (SSQPWD) used the three-factor solution, which includes 12 items to assess clusters of symptoms associated with oculomotor disturbances (eyestrain, difficulty focusing, blurred vision, headache, and fatigue), disorientation (dizzi- ness with eyes open, dizziness with eyes closed, and vertigo) and nausea (nausea, stomach awareness, increased salivation, and burping).[22] The SSQPWD was administered to PWD and carers/keyworkers (who acted as controls) immediately before and after the VR session (see the Appendix for a list of 12 SSQPWD items; a complete version is available from the authors upon request). The study sought to ob- tain data directly from PWD themselves using spe- cially designed (discrete) self-rating scales. Based on previous research and the principles underpin- ning the use of “memory wallets” in dementia care, the response format used for the SSQPWD was a five-point Likert scale anchored with pictures. PWD indicated their desired response by pointing to the relevant graded category or marking their own re- sponse depending upon their preference. Figure 2 is an example of a SSQPWD item.

Recruitment of PWD and consent procedure

Following ethical approval, permission was sought from local health services and the Alzheimer’s So- ciety to approach PWD and their carers who met the following inclusion criteria: (a) a diagnosis of probable DAT in the early stages; (b) the PWD was ambulant and an active user of outdoor public spaces; (c) no evidence of susceptibility to motion sickness; and (d) no history of epilepsy (including photosensitive epilepsy) or vertigo. Experience of using computers was not a prerequisite for partici- pation. Six PWD were recruited according to the above criteria: three males and three females with an age range of 52–91 (Table 1). The procedure for obtaining informed consent from PWD was taken very seriously, as ethical con- cerns are a major issue facing VR applications re- garding neurological conditions.[8] A consent process, proposed by the Stirling Dementia Services Devel- opment Centre and elaborated by the School of Ar- chitecture at Oxford Brookes University, was used as a guide to obtain written informed consent (www.brookes.ac.uk/schools/social/dementia/ architect.html).

Stage 1: Involvement of carers and/or relatives. Carers and relatives of PWD meeting the above in- clusion criteria were given an information leaflet that detailed the rationale, aims, procedures, poten- tial for experiencing symptoms associated with simulator sickness, and contact number for the RA, including details and photographs of the research team. Potential participants and carers/relatives re- [a]Unknown.

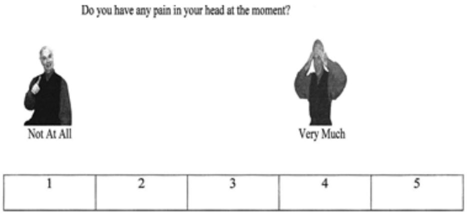

FIG. 2. Example of a SSQPWD item.

TABLE 1. PROFILE OF THE PWD

	Gender	***Age (years)***	***Age at referral***	***Living circumstances***	***Handedness***	***Medication***	***MMSE score***	***Previous occupation***	***Highest level of education***	***Previous VE experience***
Person 1	Male	60	58	Residential care	Right	a	a	Manual	School	No
Person 2	Female	74	a	With spouse	Right	a	a	a	a	No
Person 3	Female	52	50	Alone	Right	None	12	Unknown	School	No
Person 4	Male	83	a	With spouse	Right	Aricept	a	a	Degree	No
Person 5	Male	58	57	With spouse	Right	a	a	Skilled	a	Yes
Person 6	Female	91	a	Alone	Right	Aricept	a	a	a	No

MMSE, Mini-Mental State Examination.

ceived leaflets directly or via the mail system from staff belonging to health services and the Alzhei- mer's Society. The information leaflet invited inter- ested recipients to contact the RA to arrange a suitable time to visit them in their homes or other suitable venue to gain more detailed information about the study. We did not allow carers or relatives to give consent on behalf of PWD, but carers and relatives were closely involved in the consent process.

Stage 2: Explaining the study to the participant. The RA visited potential participants who expressed an interest at their homes or other suitable venue to further explain the study. At the visit, a video of the VR Auditorium that included examples of a VE was shown to PWD and their carers, followed by an opportunity to ask questions about any aspect of the study. If in the opinion of the RA the PWD un- derstood the study, he/she was asked to sign a con- sent form. Informed consent was only recognized if

PWD responded to all the items on the consent form in the affirmative. If a PWD expressed signs of unwillingness or concern about taking part in the study, this was accepted as a wish to not take part and he/she was not considered for participation any further. If carers or relatives had no concerns and were satisfied that their questions have been answered, they were asked to read and sign the “carers and relatives form” to confirm that they were aware of the research aims and requirements, and did not object to the PWD taking part in the study.

Stage 3: Continuing consent. This applied to all PWD who initially agreed to take part and involved explaining the study and obtaining written consent for a second time immediately before the VR ses- sion. This ensured continued understanding and in- formed consent by the PWD. Again there was an opportunity to ask questions and participants were informed of their right to withdraw at any stage from the study without giving a reason.

Rose et al. stated that “side-effects do not appear to be a serious barrier to the use of VR in neurologi- cal rehabilitation; however, it is important to remain vigilant.”[9] Therefore, our safeguards to reduce the risk of distress and discomfort as a result of simula- tor sickness involved establishing the psychologi- cal well-being of the PWD before the VR sessions by asking them how comfortable they were feeling, and consulting carers. This established if PWD were having a “good” or “bad” day, and in cases where PWD and/or a carers indicated that they were not feeling “well,” then the study session was post- poned. PWD and carers were also screened for sus-ceptibility to motion sickness and a history of vertigo and epilepsy, including photo-sensitive epilepsy.

The time spent interacting with the VE at any one time was restricted to #20 min, which protected against the increased risk of simulator sickness as- sociated with lengthy exposure periods.[23] To avoid the adverse effects associated with fast navigation and passive control of VEs,[24] PWD were allowed to navigate themselves through the VE with the joy- stick and were restricted to a maximum of normal walking speed at an elevation of 1.65 m during the VR exercises. PWD and carers/keyworkers were closely monitored for signs of discomfort and dis- tress before, during, and after interacting with the VE by asking them how they were feeling.

At any time during the VR session, should PWD or carers/keyworkers display signs of simulator sickness, distress, or discomfort, the session was immediately stopped. Members of the research team present during all VR sessions were in a position to provide psychological support in the event of PWD and/or carers/keyworkers becoming distressed. In addition, the university's nurse was available if re- quired and key workers were invited to the VR ses- sions to offer additional emotional support. After the VR session, participants were escorted to a com- fortable room for refreshments, where they were further monitored for any adverse effects. Finally, to ensure the safety of the participants and their carers, a member of the research team drove the participants home.

VR exercises

Each VR session lasted for approximately 50 min and PWD were asked to undertake two exercises, which included a 15-min, break after the first one. In a sensitive manner, it was explained to carers/ keyworkers that they should refrain from answer- ing for PWD and influencing their navigation through the VE. However, they were encouraged to offer reassurance and support to PWD in the event of them experiencing difficulty or misunderstand- ing the instructions from the RA.

Exercise 1: Quality of the VE experience

The time allocated for this exercise was 20 min. The aims of this task were to determine if PWD: (a) experience presence in the VE; (b) can navigate in the VE using a joystick; (c) perceive objects in the VE as realistic; (d) perceive objects in the VE as moving in a ecologically valid fashion, and (e) feel in control of what they are doing. These aspects were assessed with items adapted from the VRuse

questionnaire.[25] The VRuse in its original form as- sessed 10 factors (10 items for each factor) associ- ated with the usability of VR systems as a function of the attitudes and perceptions of users regarding the interface and method of interaction: functional- ity, user input, system output, user guidance and help, consistency, flexibility, simulation fidelity, error correction/handling and robustness, presence, and overall system usability. As PWD can become con- fused and distressed by excessive questioning[26] and a requirement of the current study was that the in- teraction should be restricted to #20 min to avoid simulator sickness, an abridged version of the VRuse was needed, referred to as the Dementia VRuse (DVRuse). Consequently, five of the 10 usability factors were selected to construct the DVRuse: (a) presence, (b) user input (the extent they can move around in the VE using the joystick), (c) system out- put (quality of the display), (d) simulation fidelity (whether the objects in the VE move realistically and naturally) and (e) overall system usability (feel- ing in control of their actions and enjoying their interactions with the VE). Two items—rather than the full 10 from each of these five-factors—were used to reduce the time required to administer the scale. Given that PWD have impairments of short-term memory, the DVRuse was administered in real-time at standardized intervals to overcome problems as- sociated with recall and "proxy assessments."[6]

Each DVRuse item was printed on a separate A4
card for presentation during the VR exercise and the order of item presentation was identical for each PWD. Text was printed using a font size of 48 with black text on white background and with color images to compensate for the decline of visual acuity associated with ageing. The response format used for the DVRuse was based on the same princi- ples as the SSQPWD, but a three-point pictorial re- sponse format was used as follows: (a) a person smiling with thumbs up—representing "very much so," (b) an expression of puzzlement—representing "a little," and (c) frowning with thumbs down— representing "not at all."

At the beginning of exercise 2, the RA demon- strated to PWD how to navigate through the VE using the joystick. The PWD was then given the op- portunity to practise navigating with the joystick and to ask questions about the nature of the exer- cise. All PWD started the interaction at the same point in the VE (the gate at the entrance to the park), and were asked to walk through and explore the park in any direction they wished. They were also informed that they could stop to look at objects in the VE and did not have to be constantly in mo- tion. However, if a participant remained stationary for $30 sec, they were encouraged to explore the VE further with the prompt "where do you want to go you now?" Throughout the exercise, the RA and carers/relatives or keyworkers engaged participants in conversation about elements in the VE and offered continued reassurance and encouragement as to their performance.

Approximately every 90 sec during the interaction, the RA spoke aloud a DVRuse item. The RA then held the item printed on a card in the participant's field of view, minimizing information-processing demands and reductions in presence that may be caused by divided attention between the card and the VE. Participants were then asked to indicate their desired response to each item by pointing or saying aloud one of the three graded categories. They were not asked to stop interacting with the VE while responding to these items. However, if they decided to stop the interaction to respond to any of the items, their choice to do so was respected. PWD were given ample time to respond to each item and were encouraged to carefully consider their response. However, if participants experienced difficulty by taking $20 sec to respond, the RA further explained the item using appropriate frames of reference, and with assistance from a carer and/or keyworker where appropriate. In the event of participant still having difficulty with an item, they were reassured that a response was not required and the item was recorded as missing data. This was done to prevent PWD from becoming frustrated as a result of con- tinued failure and repetitive questioning. This pro- cedure was followed for each of the five-factors of the DVRuse questionnaire, but if the time spent interacting with the VE exceeded 20 min and a par- ticipant had not responded to all 10 items the inter- action was stopped. During the 10-min break after this exercise, participants were monitored for signs of simulator sickness.

Exercise 2: Functional tasks

The time allocated for this exercise was 20 min. The aim of this exercise was to determine if PWD could orientate and perform instrumental activities of daily living in the context of an ecologically valid VE. The functional tasks were making a telephone call, mailing a letter, disposing of litter, and finding an appropriate place to sit down and rest.

All participants began the interaction at the en- trance to the park. As in exercise 1, the RA initiated the exercise by demonstrating how to navigate through the VE using the joystick, and they were given the opportunity to practise using the joystick before the start of the exercise. Participants were given complete freedom to explore, and they were informed that they could stop to look at objects in the VE and did not have to be in motion constantly although, as in exercise 1, if they remained station- ary for $20 sec, they were encouraged to explore the VE further. At intervals of approximately every 90 sec, the RA spoke aloud the instructions for the real-time task and presented the participant with a memory reinforcer on an A4 card, which was held within their field of view. The memory reinforcer reduced the need for additional prompting by the RA. The functional tasks were presented in the same order for all participants and each task was recorded either as a success or a failure.

Participants were allocated ample time to explore the VE to identify the target object associated with actions needed to perform each task. If a partici- pant gestured to, named, or was in close proximity to the target object in the VE, the task was recorded as a success. If after further explanation by the re- searcher and/or carer/keyworker a participant had not gestured to, or named, the target object along with the associated action, it was recorded as a fail- ure. Care was taken not to inadvertently reveal the nature of the target behavior associated with the functional task throughout this exercise. For exam- ple, for the task requiring a participant to identify and navigate towards a telephone box in order to contact their carer/keyworker, the words telephone (and telephone box) were avoided and the memory reinforcer presented a person using a telephone in a home setting. Furthermore, instructions for each task were administered at locations in the VE where the target objects were outside their field of view.

RESULTS

Simulator sickness

The symptom profiles (as a function of symptom group and individual symptoms) obtained from the SSQPWD for PWD and their carers/keyworkers in both sessions 1 and 2 (where applicable) are pre- sented in Tables 2 and 3, respectively. Mean scores for each individual symptom and symptom group (subscale) were calculated for each PWD and carer/ keyworker in both sessions 1 and 2. Items within each subscale of the SSQPWD were summed and correlated with each other. (Inferential statistics are presented in each section using non-parametric tech- niques because of the small sample size, but these must be interpreted with caution, and the reader is invited to make a personal judgement as to their significance.) Cronbach's alpha reliability coefficients for each symptom group were not calculated as several items had zero variance.

An examination of the descriptive statistics in Table 2 revealed that overall mean scores at base- line for each symptom group appeared to have in- creased after the VR exercises in session 1. Persons 2 and 3 reported an increase in oculomotor distur- bances, while persons 4 and 5 reported a decrease in levels of oculomotor disturbances. Persons 2 and 4 reported increases in disorientation and nausea, respectively. Using Kendall's tau, no significant as- sociations between symptom groups were reported. Wilcoxon signed ranks tests revealed no significant differences between overall levels of oculomotor disturbances, disorientation, and nausea assessed before and after the VR exercises for session 1.

Increases in overall mean scores for disorientation and nausea appeared to occur after the VR exercises in session 2, but oculomotor disturbances demonstrated a decrease. Similar to session 1, persons 1, 3, and 4 reported a decrease in oculomotor disturbances, whereas person 2 reported an increase. Persons 2 and 3 reported an increase in disorientation. Only person 4 reported an increase in nausea. No significant associations between symptom groups were found, there were no significant differences between overall levels of oculomotor disturbances, disorientation, and nausea assessed before and after the VR exercises, and differences between sessions 1 and 2 were not significant. The rank order of mean scores for each symptom group assessed after the VR exercises in both sessions were: oculomotor disturbances > nausea > disorientation. However, Friedman tests revealed that these differences were not significant at alpha level 0.05. However, the increase and decrease in sessions 1 and 2, respectively, for oculomotor disturbances were approaching significance ($z = 1.84$, $p = 0.07$).

An examination of the descriptive statistics in Table 3 revealed that overall mean scores at baseline for each symptom group appeared to have increased after the VR exercises in session 1. Carers/ keyworkers 2, 3, 4, and 5 reported an increase in oculomotor disturbances assessed after sessions 1 and 2. In contrast to PWD, none of the carers/keyworkers reported a decrease in levels of oculomotor disturbances (with the exception of carer/ keyworker 1 in session 2). Carers/keyworkers 2, 5, and 6 reported baseline increases in disorientation, and carers/keyworkers 2, 3, 4 (session 2 only), and 5 reported a baseline increase in nausea. Using Kendall’s tau, no significant associations between overall mean scores for each symptom group were reported in sessions 1 or 2. The overall mean scores for oculomotor disturbances increased significantly

TABLE 2. SYMPTOM PROFILES OBTAINED FROM THE SSQPWD FOR PWD

Symptom group	*Individual symptom*	*Person 1*	*Person 2*	*Person 3*	*Person 4*	*Person 5*[a]	*Person 6*[a]	*Mean*
Oculomotor	Eyestrain	1[b] (1)[c]	2 (3)	1 (3)	2 (2)	1 (1)	1 (1)	
		1 (1)[d]	1 (2)	1 (1)	2 (1)	—	—	
	Difficulty focusing	1 (1)	1 (1)	1 (1)	1 (1)	3 (2)	1 (1)	
		1 (1)	1 (1)	3 (1)	1 (1)	—	—	
	Blurred vision	2 (2)	1 (1)	1 (1)	2 (1)	2 (1)	1 (1)	

		3 (2)	1 (1)	2 (2)	1 (1)	—	—	
	Headache	1 (1)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	1 (2)	1 (1)	1 (1)	—	—	
	Fatigue	1 (1)	1 (3)	3 (2)	1 (1)	1 (1)	1 (1)	
		2 (1)	1 (1)	2 (1)	2 (1)	—	—	
	Mean	1.2 (1.2)	1.2 (2.0)	1.4 (1.6)	1.4 (1.2)	1.6 (1.2)	1.0 (1.0)	1.3 (1.4)
		1.6 (1.2)	1.0 (1.4)	1.8 (1.2)	1.4 (1.0)	—	—	1.5 (1.2)
Disorientation	Dizziness (eyes open)	1 (1)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	1 (2)	1 (2)	1 (1)	—	—	
	Dizziness (eyes closed)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	1 (1)	1 (1)	1 (1)	—	—	
	Vertigo	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	1 (2)	1 (2)	1 (1)	—	—	
	Mean	1.0 (1.0)	1.0 (1.3)	1.0 (1.0)	1.0 (1.0)	1.0 (1.0)	1.0 (1.0)	1.0 (1.1)
		1.0 (1.0)	1.0 (1.6)	1.0 (1.7)	1.0 (1.0)	—	—	1.0 (1.3)
Nausea	Nausea	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	1 (1)	1 (1)	1 (1)	—	—	
	Stomach awareness	1 (2)	1 (1)	1 (1)	1 (2)	1 (1)	1 (1)	
		1 (1)	1 (1)	1 (1)	1 (2)	—	—	
	Increased salivation	2 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	1 (1)	1 (1)	1 (1)	—	—	
	Burping	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	1 (1)	1 (1)	1 (3)	—	—	
	Mean	1.3 (1.3)	1.0 (1.0)	1.0 (1.0)	1.0 (1.3)	1.0 (1.0)	1.0 (1.0)	1.0 (1.1)
		1.0 (1.0)	1.0 (1.0)	1.0 (1.0)	1.0 (1.8)	—	—	1.0 (1.2)
[a]Attended for only one session.								
[b]Before.								
[c]After.								
[d]Session 2.								
—, missing data.								

TABLE 3. SYMPTOM PROFILES OBTAINED FROM THE SSQPWD FOR CARERS/KEYWORKERS

Symptom group	*Individual symptom*	*Carer 1*	*Carer 2*[a]	*Carer 3*[a]	*Carer 4*[b]	*Carer 5*[a]	*Carer 6*[a]	*Mean*
Oculomotor	Eyestrain	1[c] (1)[d]	1 (1)	1 (2)	1 (2)	1 (1)	1 (1)	
		1 (1)[c]	—	—	1 (4)	—	—	
	Difficulty focusing	1 (1)	1 (1)	1 (1)	—	1 (1)	1 (1)	
		2 (1)	—	—	1 (1)	—	—	
	Blurred vision	1 (1)	1 (2)	1 (1)	5 (5)	1 (1)	1 (1)	
		1 (1)	—	—	1 (1)	—	—	
	Headache	1 (1)	1 (2)	1 (1)	1 (1)	1 (2)	1 (1)	
		1 (1)	—	—	1 (3)	—	—	

	Fatigue	1 (1)	1 (1)	2 (3)	1 (1)	1 (1)	1 (1)	
		1 (1)	—	—	1 (3)	—	—	
	Mean	1.0 (1.0)	1.0 (1.4)	1.2 (1.4)	1.6 (1.8)	1.0 (1.2)	1.0 (1.0)	1.2 (1.4)
		1.2 (1.0)	—	—	1.0 (2.4)	—	—	1.1 (1.7)
Disorientation	Dizziness (eyes open)	1 (1)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	—	—	1 (1)	—	—	
Dizziness (eyes closed)		1 (1)	1 (2)	1 (1)	1 (1)	1 (2)	1 (2)	
		1 (1)	—	—	1 (1)	—	—	
	Vertigo	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	—	—	1 (1)	—	—	
	Mean	1.0 (1.0)	1.0 (1.7)	1.0 (1.0)	1.0 (1.0)	1.0 (1.3)	1.0 (1.3)	1.0 (1.2)
		1.0 (1.0)	—	—	1.0 (1.0)	—	—	1.0 (1.0)
Nausea	Nausea	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	—	—	1 (1)	—	—	
	Stomach awareness	1 (1)	1 (4)	1 (2)	1 (1)	1 (2)	1 (1)	
		1 (1)	—	—	1 (1)	—	—	
	Increased salivation	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	
		1 (1)	—	—	1 (1)	—	—	
	Burping	1 (1)	1 (1)	1 (3)	1 (1)	1 (1)	1 (1)	
		1 (1)		—	1 (2)	—	—	
	Mean	1.0 (1.0)	1.0 (1.8)	1.0 (1.8)	1.0 (1.0)	1.0 (1.3)	1.0 (1.0)	1.0 (1.3)
		1.0 (1.0)	—	—	1.0 (1.3)	—	—	1.0 (1.1)

[a] Did not attend session 2.

[b] This person (session 1 only) had seriously impaired vision.

[c] Before. [d] After. [e] Session 2.

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from baseline in session 1 ($z = 2.01$, $p < 0.05$). The rank order of mean scores for each symptom group assessed after the VR exercises in both sessions were: oculomotor disturbances > nausea > disorientation. The differences between overall mean scores were not significant at alpha level 0.05 and there were no significant differences between the changes from baseline for each symptom group in sessions 1 or 2. After the VR exercises in session 1, carers/key- workers reported a significantly higher level of nausea than PWD ($z = 2.27$, $p < 0.05$). Furthermore, the higher level of disorientation for carers/key- workers than PWD after the VR exercises in session 1 was approaching significance (*z* = 1.73, *p* = 0.08). Wilcoxon tests were conducted to examine the dif- ferences between PWD and carers/keyworkers as a function of changes from baseline for each symp- tom group. No significant changes as a function of symptom group were reported in sessions 1 or 2; however, the greater change in disorientation for carers/keyworkers than for PWD in session 1 was approaching significance (*z* = 1.73, *p* = 0.08).

Quality of the VE experience (PWD only)

Responses to the five-factors of the DVRuse in both sessions 1 and 2 are presented in Table 4. The six PWD responded differently to the DVRuse items (Table 4). However, with the exception of person 6, who experienced difficulty with several of the DVRuse items (recorded as missing data), all the PWD had an overall score of $20 (i.e., 67% of maxi- mum) on the DVRuse.

The modal response to the DVRuse items was maximal (i.e., yes, very much), accounting for 60% of the 104 responses given in sessions 1 and 2. All PWD to some extent reported feeling “present” within the VE (presence); reported being able to navigate through the VE (user input); reported that objects in the VE appeared realistic and moved in natural fashion (system output and simulation fi- delity, respectively); and were in control and enjoy- ing their experience with the VE (usability). Only person one stated a negative response to the VRuse items, stating “no” in response to both of the simu- lation fidelity subscale items in session 1. Friedman tests revealed that differences in mean scores on DVRuse subscales within sessions 1 and 2 were not significant.

Functional tasks (PWD only)

The time taken to complete each of the four func- tional tasks (telephone call, mailing a letter, dispos- ing of litter, and finding an appropriate place to rest) is presented in Table 5. In both sessions, all the PWD successfully completed all four of the func- tional tasks. The time taken to complete the tasks demonstrated substantial variability between par- ticipants, ranging from 142 to 614 sec. In terms of the rank order of mean time in seconds for each functional task, no consistent pattern emerged, al- though in both sessions, the highest mean time in seconds was reported for disposing of litter (task 3). Another finding was that, with the exception of task 2, mean times for task completion in session 2 appeared to be higher than session 1.

Psychological well-being

Data on psychological well-being of PWD and carers/keyworkers assessed before and after the VR exercises in both sessions 1 and 2, where applica- ble, are presented in Table 6. All PWD rated their well-being as maximal (i.e., very comfortable) prior to undertaking the VR exercises in session 1, with the exception of person three who reported a me- dian response. Immediately after the exercises in session 1, five of the PWD reported no baseline changes in well-being. Person 6 reported a decrease in well-being after the exercises in session 1, although the decrease was negligible.

Four PWD attended for a second session, and two reported no changes in well-being from baseline lev- els after the VR exercises; however, persons 1 and 2 reported an increase and decrease, respectively, in baseline levels of well-being. Kendall’s tau tests re- vealed that the association between well-being as- sessed before and after the exercises in session 1 was approaching significance (tau = 0.75, $p = 0.08$). No significant association between well-being assessed before and after the exercises in session 2 was found. Wilcoxon signed ranks tests revealed no significant differences in self-rated well-being assessed before and after the VR exercises in sessions 1 or 2.

Four of the six carers/keyworkers reported their well-being as maximal immediately before the VR exercises in session 1, with carers/keyworkers 1 and 2 reporting less than optimal levels of well- being. Immediately after the exercises in session 1, four carers reported no change in baseline levels of well-being; however, carers 2 and 5 reported a de- crease and increase respectively immediately after the exercises.

Only two carers/keyworkers attended for a sec- ond session, and they reported a negligible increase and decrease respectively from baseline levels of well-being. Associations between ratings of well- being assessed before and after the VR exercises in sessions 1 and 2 were not significant. Wilcoxon tests

TABLE 4. RESPONSES TO THE DVRUSE QUESTIONNAIRE USED IN EXERCISE 1 FOR EACH SUBSCALE AND INDIVIDUAL ITEM

Subscale	*Item*		*Person 1*	*Person 2*	*Person 3*	*Person 4*	*Person 5c*	*Person 6c*	*Mean*
Presence	Do you feel that you are really walking through this park?		2a	3	2	3	2	3	
			2b	3	3	3	—	—	
Do you feel as if you are actually there in the park?			1	3	2	3	2	—	
			3	3	2	3	—	—	
Total			3	6	4	6	2	3	2.5
			5	6	5	6	—	—	2.8
User input	Are you finding it easy to move around in the park?		3	2	2	3	2	—	
			3	3	3	3	—	—	
	Are you finding the joystick easy to use?		2	3	2	3	3	—	
			3	2	3	3	—	—	
		Total	5	5	4	6	5	—	2.5
			6	5	6	6	—	—	2.9
System output Do the trees in the park look realistic?			3	3	2	3	3	3	
			2	3	3	3	—	—	
Do the objects in the park look real?			3	3	3	3	2	3	
			3	2	3	3	—	—	
		Total	6	6	5	6	5	3	2.8
			5	5	6	6	—	—	2.8
Simulation fidelity Are the trees and other objects in the park moving			1	3	2	3	2	—	
in a natural way?			1	3	2	3	—	—	
Are the things in the park moving as if you were			1	3	2	3	3	3	
really walking past them?			3	3	3	3	—	—	
		Total	2	6	4	6	5	3	2.4
			4	6	5	6	—	—	2.6
Usability	Do you feel in control of what you are doing?		3	3	2	3	3	2	
			2	—	2	3	—	—	
	Are you enjoying walking through the park?		2	3	2	3	3	3	
			1	—	3	3	—	—	
		Total	5	6	4	6	6	3	2.7
			3	—	5	6	—	—	2.0
Overall Score			20	29	21	30	23	12	22.5
			23	22	27	30	—	—	25.5 2.6
									2.6

[a] Session 1.

[b] Session 2.

[c] Attended for only one session.

—, missing data.

1 = no. 2 = a little. 3 = yes very much.

Adapted from Kalawsky, R.S. (1999). VRUSE—a computerised diagnostic tool for usability evaluation of virtual/synthetic environment systems. *Applied Er- gonomics,* 30:11–25.

Table 5. Time Taken to Complete the Functional Tasks in Exercise 2

Person	*Session*	*Task 1: telephone call, time taken (sec)*	*Task 2: mailing a letter, time taken (sec)*	*Task 3: disposing of litter time taken (sec)*	*Task 4: place to rest, time taken (sec)*	*Total*		
1	1	19	12	110	4	145		
	2	121	93	251	85	550		
2	1	28	113	27	8	176		
	2	22	20	40	60	142		
3	1	140	105	109	61	415		
	2	233	63	192	126	614		
4	1	91	37	245	41	414		
	2	87	33	165	33	318		
5[a]	1	81	150	33	54	318		
	2	—	—	—	—	—		
Mean	1	72	83	105	34	49		
	2	116	52	162	76	102		
							2	94
							4	06

[a] Attended for only one session.

All PWD successfully completed all the tasks by navigating towards targets objects in both sessions. Data is not shown for person 6, who was navigated through the VE by the RA.

TABLE 6. PSYCHOLOGICAL WELL-BEING BEFORE AND AFTER VR SESSIONS (5-POINT SCALE, 1 = VERY COMFORTABLE, TO 5 VERY UNCOMFORTABLE)

	Before	*After*
Session 1		
Person 1	1	1
Carer/keyworker 1	2	2
Person 2	1	1
Carer/keyworker 2	1	3
Person 3	3	3
Carer/keyworker 3	1	1
Person 4	1	1
Carer/keyworker 4	1	1
Person 5	1	1
Carer/keyworker 5	2	1
Person 6	1	2
Carer/keyworker 6	1	1
Session 2		
Person 1	2	1
Carer/keyworker 1	2	1
Person 2[a]	1	3
Carer/keyworker 2	—	—
Person 3[a]	3	3
Carer/keyworker 3	—	—
Person 4[b]	1	1
Carer/keyworker 4	1	2
Person 5[c]	—	—
Carer/keyworker 5	—	—
Person 6[c]	—	—
Carer/keyworker 6	—	—
Overall Session 1		
Persons with Dementia	1.3	1.5
Carer/keyworkers	1.3	1.5
Overall Session 2		
Persons with Dementia	2.0	2.0
Carer/keyworkers	1.5	1.5

[a]Attended for only one session. [b]Attended with two different carers. [c]Attended session 2 alone.

revealed no significant differences in well-being as- sessed before and after the VR exercises in sessions 1 and 2.

An examination of the descriptive data in Table 6 reveals that levels of well-being assessed immedi- ately before and after the VR exercises between PWD and carers were similar. No significant differences in well-being assessed before and after the VR exercises were reported between PWD and carers/key- workers in both sessions.

Physical well-being (PWD only)

The heart rate of the PWD in beats per minute (bpm) measured at 10-sec intervals during exercises 1 and 2 are presented in Tables 7 and 8, respectively. Heart rate data were not collected for person 6, as it was felt that, due to the difficulties encountered in the first session, a further session may have been detrimental to the person's well-being. An exami- nation of the descriptive statistics in Table 7 revealed that heart rate appeared to increase and decrease from baseline levels during exercise 1, although mean heart rate for persons 1, 3, 4, and 5 did not de- viate substantially from baseline and mean levels. Indeed, the maximum increase in heart rate from baseline was 10 bpm for person 5. However, heart rate for person 2 demonstrated a substantial and rapid increase from baseline reaching more than double the minimum value within a 20-sec interval, which precipitated exercise 1 being stopped for safety reasons. Subsequent discussions with person two revealed no physical symptoms (e.g., chest pain or nausea), and she intimated that she had become frustrated by searching for objects in the VE that she had remembered from the previous session.

Heart rate data were recorded for each of the four functional tasks separately to enable compar- isons to be made between individual tasks (Table 8). Negligible changes in heart rate across tasks for each of the PWD were reported, with mean heart rate remaining relatively stable.

DISCUSSION

The findings of the current study revealed that PWD did not experience any significant increase in symptoms associated with simulator sickness or decreases in psychological and physical well-being as a result of exposure to the VE. Responses to the DVRuse indicated that to some extent PWD experi- enced presence; they perceived that objects in the VE were realistic and moved naturally; they reported little difficulty using a joystick for navigating through the VE; they reported feeling in control of the inter- action; and they enjoyed their experience with the VE. All the functional tasks were successfully per- formed by PWD, which suggested that VEs are appropriate media for assessing behavior and cognition necessary for day-to-day functioning.

Simulator sickness was assessed with the SSQPWD to obtain self-ratings of three symptom groups: ocu- lomotor disturbances, disorientation, and nausea. The SSQPWD was well-received by both PWD and [a]Initial value.

TABLE 7. PHYSICAL WELL-BEING (HEART RATE IN BEATS PER MINUTE) DURING EXERCISE 1

Person	*Baseline*[a]	*Range*	*Mean (SD)*	*s^2*	*Maximum/minimum*
1	74	72–79	75.8 (1.6)	2.5	1.1
2	80	65–140	90.7 (18.6)	344.6	2.2
3	73	69–78	73.3 (2.1)	4.3	1.1
4	60	53–69	61.8 (3.3)	10.9	1.3
5	72	66–82	70.2 (2.9)	8.6	1.2
Overall	71.8		74.4 (5.7)	74.2	1.4

Carers/keyworkers. PWD demonstrated little diffi- culty understanding the items and the response for- mat that combined words, numbers, and pictures. They were given a choice of pointing to or marking their desired response to the SSQPWD items, al- though the majority opted to point at the relevant graded category that was representative of their status, along with a verbal confirmation such as "yes that one." This is consistent with previous re- search that reported the successful use of self-rating scales with word, pictorial, and number response formats for use by older people with cognitive im- pairments.[27–29]

Responses to the SSQPWD demonstrated that PWD did not experience any significant increase in oculomotor disturbances, disorientation, or nausea after exposure to the VE. Furthermore, they reported a decrease in oculomotor disturbances between the first and second VR session that was approaching significance. In contrast to PWD, carers/keyworkers, who acted as controls, reported a significant in- crease in oculomotor disturbances after the VR ex- ercises and a greater increase in disorientation, which was approaching significance in the first VR session. These findings are consistent with previous research on simulator sickness among healthy volunteers re- porting that active navigation of VEs, in our study by PWD, decreases the likelihood of experiencing simulator sickness.[24] In addition, a decrease in sim- ulator sickness with "habituation" to the VE is also consistent with previous research using non-neuro- logical populations.[30] Higher levels of simulator sickness in carers/keyworkers than in PWD may indicate reduced presence. This is likely to have been caused by a lack of interaction with the VE, which is required for the development of a mental model of the virtual space, which forms the basis of pres- ence.[31] Thus, simulator sickness is not a significant barrier to working with PWD in VEs; PWD are af- fected by exposure to VEs in comparable ways to people without cognitive impairments.

The negligible influence of simulator sickness upon PWD in the current study was arguably the result of using a semi-immersive system and adher- ing to safeguards such as restricting the speed and duration of the interaction.[23,32–34] However, despite the encouraging findings for PWD, simulator sick- ness may constitute a barrier to the involvement of carers/keyworkers in VR-based approaches to de- mentia care and research. This has important impli- cations for working with PWD in VEs, in particular as involvement of carers will invariably be a strong predictor of participation by PWD. As observed in the current study, the involvement of carers pro- vided an invaluable source of social support that served to reduce anxiety and enhance motivation of PWD during the VR exercises. The problems are that carers who experience simulator sickness may become distracted by feelings of discomfort that will impact negatively upon their ability to offer social support, and secondly, they are likely to avoid at- tending VR sessions and consenting to their depen- dents being exposed to VEs. Involvement of carers in non-VR treatments is reported to enhance psy- chosocial interventions such as memory retraining,[4] and it is likely that these benefits would be trans- ferred to VR-based psychosocial interventions for PWD. Therefore, as a precautionary measure, we recommend that both PWD and carers/keyworkers should be monitored for signs of simulator sickness before, during, and after interactions with VEs.

Quality of the VE experience

The subjective views of PWD regarding the inter- face and method of interaction were assessed in real-time with the DVRuse. With the exception of person 6, the DVRuse was also well-received, with items and response format presenting no difficul- ties in terms of understanding. However, several par- ticipants stopped navigating in the VE in order to respond to many of the items, which demonstrated

[a]Initial value.

TABLE 8. PHYSICAL WELL-BEING (HEART RATE IN BEATS PER MINUTE) DURING EXERCISE 2

Task 1: telephone call	***Task 2: mailing a letter***		***Task 3: disposing of litter***			***Task 4: place to rest***		
Baseline^a	S^2		S^2 *Baseline*^{a} *Mean*		S^2	*Baseline*^{a}	*Mean*	S^2
Person (range)	*(max/min) (range)*		*(max/min) (range)*		*(max/ min)*	*(range)*	*(SD)*	*(max/ min)*
1 71 (69–73) 70.8 (1.3)	1.8 (1.1)	73 (71–75) 73.3 (1.3)	1.8 (1.1)	73 (72–76) 74.1 (1.2)	1.5 (1.1) 7 4 (72–75)		73.9 (1.2)	1.6 (1.0)
2 60 (60–61) 60.5 (0.7)	0.5 (1.0)	66 (66–67) 66.5 (0.7)	0.5 (1.0)	65 (65–68) 67.0 (1.4)	2.0 (1.1) 6 6 (63–69)		66.5 (2.3)	5.5 (1.1)
3 72 (67–75) 71.3 (2.5)	6.5 (1.1)	74 (71–74) 72.3 (1.0)	1.1 (1.0)	74 (70–76) 72.8 (1.4)	2.0 (1.1) 7 5 (70–75)		71.8 (1.4)	2.0 (1.1)
4 58 (56–60) 58.5 (1.4)	2.0 (1.1)	58 (57–58) 57.7 (0.6)	0.3 (1.0)	60 (54–61) 58.0 (2.3)	5.4 (1.1) 5 8 (57–59)		58.0 (1.0)	1.0 (1.0)
5 66 (66–70) 67.9 (1.2)	1.6 (1.1)	70 (69–72) 70.7 (1.3)	1.6 (1.0)	70 (70) 7 0.0 (0.0)	0.0 (1.0) 6 9 (69–73)		71.6 (1.9)	3.8 (1.1)
Overall 65.4	2.5 (1.1)	68.2 6 8.1 (1.0)	1.1 (1.0)	68.4 68.4 (1.3)	2.18 (1.1) 68.4		68.4 (1.6)	2.78 (1.1)

That presenting items during the interaction caused divided attention between the VE and DVRuse items. Reponses given by PWD to the DVRuse revealed that the VE interface was of a sufficient quality to create a sense of involvement or “being there” in the park (presence) and a perception of realism (system output and simulation fidelity). This is important as a sense of presence is an important predictor for ecological validity of user experiences within VEs.[35] Although presence is not an essential criterion for producing ecologically valid user experiences within VEs, arguably a user’s perception of realism is important for ecological validity.[36] In addition, a natural method of interaction that is under the user's control is also important for ecological validity and, with the exception of person 6, participants reported they were in control of the interaction with the VE and that it was an enjoyable experience. None of the participants used the template marked with di- rectional arrows as a memory cue to facilitate the use of the joystick, even though they had no previ- ous experience of joysticks, with exception of per- son 5, who had limited experience playing video games. The high usability of the joystick is an im- portant result as without appropriate methods of navigation in VEs, PWD will not be able to experience direct interaction, a core characteristic of VR that enables users to undertake a self-directed jour- ney or activity in a VE.[37] Without appropriate meth- ods of interaction, only the development of VR-based therapeutic immersion for people is likely to have potential.

With the exception of person 6, who did not take part in exercise 2, all PWD successfully completed all of the functional tasks. This provided objective evidence that, with an appropriate interface and method of interaction, it is possible for PWD to suc- cessfully wayfind in the context of an ecologically valid VE. However, given that the VE was medium- scale, it is possible that success at wayfinding was due to exhaustive searching of the VE until an ob- ject was found, which may occur in VEs that are unfamiliar to users.[38]

Psychological and physical well-being

No significant decreases in self-reported psycho- logical well-being occurred after exposure to the VE. Physical well-being, assessed objectively by re- cording heart rate during the VR exercises, revealed that PWD experienced no decline in physical well-being. The pulse oximeter did not cause discomfort or intrude on the VE experience. Physiological mea- sures such as heart rate have been reported to be positively correlated with feelings of presence and perceived realism.[39] Overall, the heart rate of PWD in the current study increased slightly during the VR exercises, but it was unclear if this was associ- ated with a sense of presence or a perception of re- alism. It is possible that these negligible increases may have been due to the effects of situational anx- iety and/or the physical exertion required to oper- ate the joystick rather than exposure to the VE. Person 2 experienced a dramatic increase in heart rate during the first exercise in the second session, although this was an emotional reaction to her in- ability to find objects recalled from the previous session. Despite person 2 reporting no physical in- dications of discomfort, this incident clearly demonstrated the value of physiological monitoring of PWD in VEs. Physiological monitoring can serve as an early warning system for the detection of psy- chological and physical discomfort or distress of PWD in VEs.

AREAS FOR IMPROVEMENT AND FURTHER RESEARCH

The small sample size seriously restricted the sta- tistical power of the inferential tests and we ac- knowledge that the results in this paper have a high likelihood of Type II error. We also accept that the current study has a degree of sampling error as, firstly, our sample of PWD was self-selected and highly motivated and, secondly, PWD in the current study may have lacked homogeneity in terms of symptom presentation and dementia sub-type as cognitive impairments between PWD are not uni- form and a definite diagnosis of sub-type is possi- ble only after a post-mortem examination.

A major barrier to the recruitment of sufficient numbers of PWD in the early stages with heteroge- neous symptomology to achieve an acceptable level of statistical power is that despite the prevalence of dementia in the population, and established proto- cols for identifying the presence of dementing ill- ness, it is frequently overlooked or misdiagnosed in its early stages.[40] Furthermore, PWD and carers may avoid seeking help until symptoms seriously inhibit quality of life or a crisis point is reached. Consequently, the majority of individuals entering the health and social care system are in the later stages of the disease. Commonly used cognitive as- sessment tools such as the Mini-Mental State Exam- ination lack sensitivity,[41] or in many cases may have not been conducted at all, resulting in many people failing to receive a formal diagnosis of dementia. Indeed, even if cognitive assessments have been undertaken they may have been conducted some time ago and no longer be representative of current cognitive functioning. These difficulties were en- countered in the current study, with only six PWD and their carers/keyworkers agreeing to take part after a considerable recruitment effort. This involved contacting primary and secondary care profession- als, local health and social care services relevant to dementia care and voluntary agencies such as the Alzheimer’s Society. Using the example of correla- tions between subscales on the DVRuse, a prospec- tive power analysis revealed that in order to achieve a statistical power of 0.80 to detect a medium effect size ($r = 0.3$) a total of 85 participants would need to be recruited to establish the relationship (using a two-tailed test) between usability factors; for a large effect size (*r* = 0.5) 29 participants would be required. Given the likely difficulties recruiting this number of PWD, researchers in this area must be prepared to devote considerable time and effort, including fi- nancial resources, to recruitment.

Carers and keyworkers were asked to refrain from helping PWD to navigate and to offer encourage- ment and reassurance during the VR sessions. How- ever, a specific issue arose with person 6. This person experienced significantly difficulty when using the joystick and her carer was very critical of her per- formance during the latter part of first VR exercise that, in the opinion of the research team, impacted negatively upon her well-being and seriously di- minished her performance in the VE. However, the carer's motivation for doing this was not malicious and was probably due to a desire for person 6 to "do well." This incident clearly demonstrated that more time should be spent with carers/keyworkers during the consent process to ensure they are ab- solutely clear about their role during the VR sessions. It was evident that reverse movements caused confusion for several PWD, in particular for person 6, as they were not associated with a change in view- point (i.e., walking backwards without turning around). Clearly, this movement is not ecologically valid, especially for extended periods. Therefore, navigation devices used by PWD should be cali- brated to enable 180 degree turns in an ecologically valid fashion. It was also observed that using the joystick for extended periods may have caused mus- cle fatigue in the arm and shoulder muscles. This was due to participants having to reach forward to grasp the joystick as they were unable to place their legs underneath the table used to support it. This may have been distracting and caused reductions in presence and perceptions of realism. Therefore, fu- ture work with PWD in VEs should develop strate- gies for minimising reaching demands associated with the use of an input device by ensuring an er- gonomically sound arrangement of furniture and input device.

Despite only one PWD experiencing significant difficulty using the joystick to navigate through the VE, its relative utility compared to other navigation devices, including other models of joysticks, is un- known. It is plausible that alternative navigation devices such as spaceballs, mice and voice recogni- tion may have yielded a more natural method of navigation in the VE for some PWD, especially for people who have limited dexterity or muscle strength as a result of arthritis or other physical impairments. Therefore, different navigation devices should be evaluated for their relative usability by PWD.

Future research should be conducted to deter- mine the psychometric properties of these measures. In particular, factor analyses are needed to confirm the three- and five-factor structures of the SSQPWD and DVRuse, respectively. In addition, other psychometric properties such as repeatability (test re-test reliability) and responsiveness should be examined. In the current study, we utilized a real-time mea- sure, the DVRuse, to investigate the views of PWD regarding the VE. However, it would have been preferable to have incorporated this measure into the VE interface itself to maintain presence, guar- antee standardization of delivery, and remove the confounding influence of divided attention between items and the VE. Using an appropriate typeface and font size for older people would also compen- sate for the decline in vision and hearing associated with ageing. PWD could then respond to items dis- played on the projection screen using an appropri- ate navigation device to select a graded category representative of their status without having to at- tend to stimuli in the real-world. This approach could also be used for administering instructions to PWD and to support error-free navigation.

Interactions with VEs should be compared with corresponding abilities assessed in the real-world to determine the ecological validity of behavior ex- hibited in VEs and to capitalize on the precise con- trol of stimuli afforded by VR-based approaches.[11] In the current study, it is unclear if PWD would have behaved the same way in real-world environ- ments. Therefore, future research should undertake a series of “validation exercises” in real-world envi- ronments that share the same environmental char- acteristics as the VEs. If performance in VEs and the corresponding real-world environments are cor- related, then it can be assumed with confidence that VEs are appropriate media for assessing be- havior that is relevant to daily functioning.

A multitude of factors (and complex interactions between factors) may impact negatively upon eco- logical validity of users’ experiences in VEs either by weakening presence or perceived realism. Several of these factors were missing from the VE used in the current study, such as commonly experienced auditory and visual stimuli in park environments (e.g., bird song, meteorological features, and chil- dren playing).

Furthermore, the VE interface al- lowed participants to walk through solid objects that occasionally created confusion.

Factors external to the VE such as optimal seat- ing position and design, distance from projection screen, field of view, and luminescence need to be clarified as they have the potential to impact upon presence and perceived realism.[33] Furthermore, person-related factors may also impact upon per- ceptions of the VE interface and method of interaction such as gender, dementia sub-type and symptoms, medication, and level of education.

Dementia presents significant challenges for in- terface design, and given that it is most prevalent in people aged over 65, the effects of the ageing pro- cess should be taken into account when designing the VEs. Unfortunately, there is a dearth of research on VR interface design for older people,[8] and research on ageing indicates that VE design should address declines in vision, hearing, and psychomotor skills.

CONCLUSION

This study investigated the design and feasibility of a virtual reality–enabled approach for dementia care, with the objective of supporting cognitive engagement, emotional well-being, and user comfort through immersive, non-pharmacological intervention. The findings demonstrate that the proposed VR system is both **feasible and acceptable** for individuals with mild to moderate dementia, with high usability, minimal adverse effects, and positive responses from both participants and caregivers.

The user-centered design methodology proved effective in addressing the unique cognitive, sensory, and safety needs of people with dementia. Participants showed improved engagement and emotional responsiveness during VR sessions, while caregivers reported reductions in agitation and enhanced mood states. These outcomes highlight the potential of VR as a supportive tool that complements traditional dementia care practices rather than replacing them.Although the study was limited by a small sample size and short intervention duration, the results provide valuable preliminary evidence supporting the integration of VR technologies in dementia care settings. The feasibility outcomes justify further investigation through larger-scale, longitudinal studies to assess sustained cognitive, emotional, and behavioral impacts.In conclusion, virtual reality offers a promising, scalable, and non-invasive solution for enhancing dementia care. With continued refinement, personalization, and clinical validation, VR-enabled interventions may play a significant role in improving quality of life for individuals living with dementia and in reducing caregiver burden in future care models.

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