A Scoping Review Exploring the Feasibility of Virtual Reality Technology Use with Individuals Living with Dementia

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Abstract
The existing evidence base in relation to the feasibility of using Virtual Reality technology systems with individuals living with a dementia appeared limited and was therefore explored. The research was collected and reviewed in terms of the different types of Virtual Reality systems (equipment and levels of immersion) and feasibility of the technology within different stages of dementia as well as the methodological limitations. A systematic search of the literature was conducted using the healthcare databases advanced search (Medline, PsychINFO, and EMBASE) and snowballing methods. The participants had a dementia diagnosis and the feasibility of Virtual Reality in terms of its acceptability and practicality was discussed. Only five articles met the eligibility criteria. Four included semi-immersive Virtual Reality with participants in the early stages of dementia. One included fully-immersive Virtual Reality where dementia stage ranged from 'mild' to 'severe'. Based on available demographic information, study participants resided in residential care homes, alone in the community or with their spouse. The existing literature suggests that both semi and fully-immersive Virtual Reality technology use can be feasible amongst individuals living within the earlier stages of dementia outside of a hospital environment, with it being viewed as a welcomed distraction that increased alertness and pleasure. However, Virtual Reality was also found to increase fear and anxiety in one study, raising important ethical implications around the safety of the user. The current evidence-base leaves a predominant gap in Virtual Reality technology system use for people within the moderate to later stages of dementia and those living in a hospital environment.

CCS Concepts

• ***Human-centered computing*** → Interaction paradigms → Virtual reality; • ***Social and professional topics*** → Medical information policy → Medical technologies;

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1. Introduction

Dementia is an umbrella term describing a set of symptoms linked to disorders of the brain that progress over time. The cognitive and behavioral profile varies according to the type of dementia, as well as progression of the pathology and individual patient differences [Alz17]. However, symptoms can include: agitation; aggression; a significant decline in social functions and difficulty undertaking activities of daily living [LST*00; KG00]. Apathy is also a common symptom in dementia, affecting over a quarter of the sample population (27%) in some instances [LST*00]. In addition, symptoms can include sexual disinhibition, problems with eating, abnormal vocalization and depression [DJB04] [KH09]. It is proposed that depression is a potential risk factor for the development of dementia, as well as a potential early symptom of dementia [MV10]. Cognitive ability may decline as a reaction to co-existing symptoms of depression, including social withdrawal, lack of motivation and loss of interest in oneself and others [Kit15]. Physical symptoms of dementia including weight loss, and muscle weaknesses may also be evident in the later stages of dementia [Alz17].

1.1 The National Context

The Alzheimer Society's research explored the social and economic impact of dementia in the UK. An estimated 850,000 people living with dementia in 2015 was indicated, totaling £26 billion per year in costs to healthcare. The prevalence of dementia in the UK is projected to increase by 40 percent by 2025 and 157 percent by 2051 [PKG*14]. In the US, 5.7 million people are living with Alzheimer's disease, which is predicted to increase with population growth of those aged 65 and older from 53 million in 2018 to 88 million by 2050 [Alz18]. Worldwide, dementia is estimated to affect 35 million people [Dep14].

The National Dementia Strategy set out to improve the quality of life of individuals living with dementia. One objective included providing a higher quality of care [Dep09]. Three years later, Cameron's Challenge on Dementia [Dep12] emphasised the drive for improvements in healthcare as well as better research. The use of pharmacological interventions have been found to be both overprescribed for the treatment of behavioral disturbances [Ban09], and, ineffective in treating depression [BHD*11]. As a result, and in line with the national strategy, it was recommended that best practice should reflect the use of pharmacological interventions as a last resort only, to treat complex cases where non-pharmacological interventions have proven unsuccessful. The goal therefore remains to deliver non-pharmacological innovations that support and enhance the quality of life and wellbeing of people living with dementia, with the aim of reducing distress and behavioral disturbance.

1.2 Interventions in Dementia

There is a growing evidence base demonstrating positive outcomes in non-pharmacological interventions. It is well established that good practice in the field of dementia care is underpinned by the principles of a person centred philosophy. Low intensity intervention examples include engagement in meaningful activity and social interaction [Lev08]. For example, a reduction in behaviour that challenges [KG00] and an improvement in cognition and mood have been found following reminiscence therapy, including life story review [WSJ*09]. High intensity protocol-led interventions tailored to specific presentations and needs such as music therapy [VBS03] have been shown to reduce agitation [LKL*14]. Similarly, cognitive stimulation therapy has proven to improve cognition [LMT07;

WAS*12; MRN*13] and quality of life [STW*03; AHS*13]. Such approaches can be supported by specialist individualised formulation-led interventions [BMJ*13].

1.3 Introduction to Virtual Reality Technology

Technology is increasingly influencing the way we relate to the world around us, and, unsurprisingly, technological developments in the healthcare sector are following the same course. Virtual Reality (VR), a technology first introduced in the 1950s, is now becoming a massive success in the gaming industry, largely due to miniaturisation of electronics and declining hardware costs. VR is a technology that gives the user a Virtual Environment (VE) they can interact with. There are three types of virtual reality categorised by Ma and Zheng [11]: (1) a non-immersive VR experience creates a 3D environment wherein the user can navigate using a desktop, keyboard and mouse; (2) a semi-immersive VR system uses higher performance graphics and is displayed on a large screen, which provides an increased sense of engagement with the VE compared to the non-immersive VE; (3) a fully-immersive system offers a head set which is worn by the user. The user receives both visual and auditory information via the headset. The fully-immersive VR experience can also be supported with additional equipment, for instance a mouse, a joystick or a rumble pad, which enables the user to interact within the VE [LMC11].

1.4 Virtual Reality in Healthcare

The use of VR in healthcare related applications has increased over time [SMT*08], introducing innovative non-pharmacological ways of delivering treatment and care. There are different types of VR rehabilitation strategies available including: 'video-game like' approaches with clear goals, progressions and rewards; 'exposure therapy' which opens the user to specific simulated environments; and 'teaching by example' with step-by-step instructions. Benefits of using VR for rehabilitation include economy of scale, not having to travel for treatment, and interactivity [Bur03]. Some of the pitfalls include the need for more evidence based research into the efficacy of VR and its application in healthcare, the initial cost of purchasing the equipment, and potential side effects (i.e. motion sickness).

VR has been shown to be successful in the reduction of body dissatisfaction [RM97], as an intervention in psychotherapy [Riv05] and in the management of pain [MAS17; MAM*17; MAM*18]. VR has successfully been used in psychological treatment, particularly exposure therapy for the treatment and management of anxiety in the context of phobias [RH99]. In addition, the efficacy of VR exposure therapy was found to be similar to that of cognitive behavioural methods in reducing anxiety in fear of flying, panic disorder, social phobia, arachnophobia and acrophobia [OPG*12]. VR has also been used in the assessment and rehabilitation of people with brain injuries. Virtual equivalents of neuropsychological assessment have been created including the Wisconsin Card Sorting task (WCST) [RBR05] and the VR Multiple Errands Test (VMET) [CAS*14]. More recently, VR has been used to improve patients experience in a medical centre and was found to be successful in improving mood and providing a welcomed distraction [MRM*16].

The growth of VR has increased considerably over the last four decades; with evidence of successful and promising application to different clinical populations. However, publications exploring the use of VR with people living with dementia have only been prominent across the last two decades, forming only a fraction of

the overall VR literature (Table 1). Much of the research appears to focus on efficacy of VR interventions, task performance and physical health as well as treatment for anxiety and/or phobias. The application of VR in dementia populations is underdeveloped and the feasibility of VR systems with individuals living with dementia is unclear. The evidence base for the feasibility of VR technology in terms of technology acceptability, user experience and practicality with this client group (i.e. safety) as well as its impact on the wellbeing and clinical presentation of individuals living with dementia, therefore, warrants further investigation. At this stage our focus was not on efficacy of treatment or cost benefit analysis.

Year	PsychINFO		Medline		Embase	
	VR	VR & Dementia	VR	VR & Dementia	VR	VR & Dementia
2007-2017	5809	37	4673	35	11, 570	86
1996-2006	1941	8	1663	4	3736	10
1985-1995	70	0	101	0	124	0
1974-1984	0	0	0	0	0	0

Table 1: *The growth of VR literature overall compared to literature relating to VR and dementia (21/09/2017).*

2. Aims and Objectives

The aim of this paper was to conduct a review of the literature reporting on the feasibility of VR technology amongst individuals living with dementia. For the purpose of this review feasibility covered acceptability, practicality, and user experience as well as the effect on wellbeing. Specific objectives were:

1) To establish the different types of VR technology systems that have been used with individuals living with dementia.

2) To explore whether the feasibility of VR technology has been investigated with individuals living with varying stages of dementia.

3. Method

3.1 Search Strategy

The Healthcare Databases Advanced Search Engine (HDASE) was used to identify relevant studies using the key word search with the assistance of a librarian. Three databases were included as part of the search: Medline, PsychINFO, and EMBASE. The search was conducted across all three databases via the HDASE, removing any duplicates, and reflected the terms 'Dementia and Virtual Reality' and/or 'Virtual Reality Exposure Therapy' which was searched by 'thesaurus and/or title and abstract'. There were no studies returned from the specific search relating to VR and dementia prior to 1996 and, therefore, the search was conducted from 1996- 21st September 2017. Relevant studies were also sought using the 'snowballing method' consisting of: Google Scholar internet searches and reference lists from papers identified in the search.

It is evident that VR is used within the wider healthcare sector for rehabilitation, with outcomes that measure task performance. However, it appears that less is known regarding the feasibility of using VR technology systems with individuals living with dementia including their user experience. Consequently, this became the primary focus of the literature search, which is reflected in the inclusion and exclusion criteria below:

3.2 Inclusion Criteria

a) study included VR and participants with a diagnosis of dementia

b) mention of feasibility of VR equipment for use with individuals living with dementia

c) involved the application of VR (non-immersive/ semi-immersive VR and/or fully-immersive VR)

d) reflected on the user experience in relation to VR

3.3 Exclusion Criteria

a) the publication was not in English

b) the primary outcome measure did not include discussion of the feasibility of VR technology (i.e. the outcomes measured the performance of the participant for a given task only)

c) studies limited to a review of the previous published studies

d) non-peer reviewed publication type resources.

3.4 Data Extraction

Three researchers identified appropriate inclusion and exclusion criteria and implemented the criteria on a sample of the identified papers. Study relevance was evaluated using the researchers' objectives, inclusion and exclusion criteria.
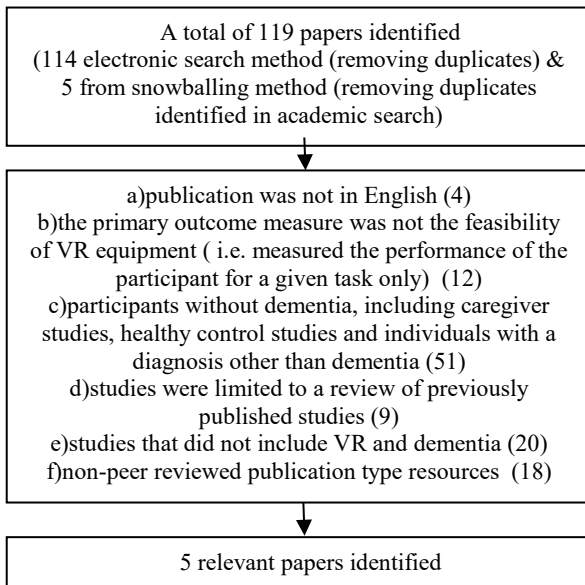
4. Results

Based on the stated search strategy, inclusion and exclusion criteria with the researcher's objectives in mind, only five out of 119 papers identified met all criteria and were included in this scoping review. Figure 1 describes the search strategy and the results. Table 2 displays the characteristics including the aims of the five relevant identified studies.

Using semi-immersive VR, Flynn and colleagues [03] explored the usability of VR with individuals living with dementia in the early stages, when immersed in a large outdoor park VE. Participants reported little difficulty in using the joystick as well as finding the overall experience enjoyable. High rates of 'presence' were found (the extent the participant felt they were really present in the VE) indicating that the VR intervention presented an ecologically valid environment. Overall, there were no significant increases or decreases in psychological and physical wellbeing observed post-intervention compared to pre-intervention in both participants living with dementia and a second group comprising carers. When looking at individual scores, however, one participant's heart rate did increase considerably, resulting in the session being stopped for safety reasons. The participant became frustrated trying to search for an item within the VE that she had seen in a previous session, which the authors predicted was likely to have contributed to the rapid rise in heart rate. There was no significant increase in symptoms of simulator sickness across participants with dementia and carers. Results must be interpreted with caution however, as the Simulator Sickness Questionnaire for Individuals with Dementia (SSQPWD) and the Dementia Virtual Reality Use (DVRuse) tool [Kal99] used to test for adverse effects and usability of the VR application, were adapted, unvalidated versions of the originals. Thus, the psychometric properties are unknown and the validity of the findings potentially compromised. In addition, the DVRuse tool may have contributed as a confounding variable as questions were posed to participants whilst they were engaged in the VE, requiring them to divide their attention between the VE and the researcher. The authors reported that the findings could not be generalised outside of the study

due to the small sample size, however, a good insight into the potential feasibility amongst a small group of individuals living with dementia was established.

Siriaraya and Ang [14] also used semi-immersive VR. The results highlighted experiences provided by a Virtual World (VW) invoking memories and creating a sense of self through virtual reminiscence, as well as providing participants with opportunities they would otherwise not have. One user of the gardening VW commented on wanting to grow a lily as she was unable to do this in reality due to allergies.

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│           A total of 119 papers identified       │
│ (114 electronic search method (removing duplicates) & │
│   5 from snowballing method (removing duplicates │
│         identified in academic search)           │
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                         ↓
┌─────────────────────────────────────────────────┐
│        a)publication was not in English (4)      │
│    b)the primary outcome measure was not the feasibility │
│  of VR equipment ( i.e. measured the performance of the │
│      participant for a given task only)  (12)    │
│   c)participants without dementia, including caregiver │
│  studies, healthy control studies and individuals with a │
│         diagnosis other than dementia (51)       │
│    d)studies were limited to a review of previously │
│             published studies (9)                │
│   e)studies that did not include VR and dementia (20) │
│  f)non-peer reviewed publication type resources  (18) │
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                         ↓
┌─────────────────────────────────────────────────┐
│           5 relevant papers identified           │
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Figure 1: *Search results flow diagram.*

The authors commented that continuous use of some of the software, including the sensor equipment, caused fatigue. Further, different VWs were more favourable amongst females compared to males. In addition, negative memories were triggered in some individuals and emotional distress observed as an outcome (patients were redirected back to positive aspects for the VW to good effect). The perceived time it took for care staff to support in the implementation of the software was not favourable and participants with more severe cognitive decline were unable to perform some simple touch screen tasks provided as part of the VR experience.

Manera and colleagues [16] used semi-immersive VR to explore the feasibility of VR with individuals living with mild to moderate dementia by comparing a paper and pencil exercise with VR. Participants reported feeling less secure in the VR condition, although this did not have a detrimental impact of how VR was viewed as participants were equally as interested in both interventions. Overall, 68.4 percent of participants preferred the VR condition, with it being viewed as more immersive, engaging and motivating compared to the paper condition. More participants (9 individuals) continued engaging with VR when invited to, compared to the paper condition (3 individuals). Interestingly, apathetic participants were significantly more interested in the VR intervention compared to non-apathetic participants. Whilst exploring task performance was not a primary aim of this literature search, it is worth noting that participants found more targets in the paper condition compared to the VR condition. Manera and colleagues concluded that some participants experienced difficulties with

using the mouse, which may have contributed to reduced performance in the study.

Moyle, Jones, Dwan and Petrovich [17] also utilised semi-immersive VR, however, to our knowledge, this study was the first to explore the feasibility of VR amongst individuals with a range of cognitive impairment from mild to more severe stages of dementia. The Virtual Reality Forest (VRF) was well received by individuals living with dementia, inferring its feasibility for this user group. It was perceived by participants with dementia, family members and staff to have a positive effect, including increased pleasure and alertness whilst immersed in the VE compared to norms from participants with dementia in a non-VR activity context. There were no significant observations for anger and sadness during the VR experience. Environmental stimulation also increased and apathy decreased during the VR intervention compared to before and after the experience. Staff views were that a VRF was more stimulating for individuals in the later stages of dementia compared to earlier stages where they seemed to become easily bored. There were also no significant differences between the observed types of engagement during the VRF. Nevertheless, there was evidence of adverse effects, as participants with dementia reportedly experienced more fear and anxiety during the VRF experience when compared to the normative sample. Moyle and colleagues did not make inference as to what may have contributed to increased fear and anxiety; however, they suggested that results should be treated with caution due to the small sample size.

The Mendez, Joshi and Jimenez [14] paper presented the only research identified in the current review that used fully-immersive VR. Participants with behavioural variant frontotemporal dementia wore a head mounted display to create a fully-immersive VE in which they were assessed using a structured interview facilitated by avatars. Participants tolerated the equipment well with no complaints of discomfort or distress. There were also no post intervention side effects for arousal, stress, anxiety, anger, fatigue and attention. The results indicated high levels of presence as well as increased levels of interaction in the VR condition compared to a real world condition. The generalisations of the findings were limited due to the small sample size. Nonetheless, the research did provide positive evidence for the feasibility of fully-immersive VR with individuals living with dementia.

5. Discussion

It has become apparent that much of the current published research that includes both VR technology and participants living with dementia has been conducted within the context of assessment and task performance, without reference to the feasibility of the equipment or the user's experience of the VR system. Given this was not specifically relevant to our area of interest; it is not surprising that the systematic search only revealed five relevant studies. We were interested in this specific area of feasibility to further explore the potential implementation of VR as a therapeutic activity with individuals living with more moderate to severe dementia. The practicality of using VR is uncertain due to various factors including presentation, risk and engagement of the individual. Of those studies, participants were typically diagnosed with the mild to moderate stages of dementia. Only one paper explored the feasibility of VR with individuals living with dementia across a range of stages, which included more severe dementia.

Overall, the five papers analysed revealed that the use of VR technology systems can be feasible amongst individuals with mild

to moderate dementia. With regard to clinical presentation, VR can have a positive impact on wellbeing, including an increase in pleasure and alertness futher validating the feasibility of VR [MJD*17]. On the contrary, there is also evidence of adverse effects of VR including negative memories [SA14] and an increase in fear and anxiety [MJD*17]. It was also reported that VR was more stimulating for individuals in the later stages of dementia compared to the earlier stages [MJD*17] implying that stage of dementia may be a variable that could potentially affect the VR experience. Elsewhere in the literature, potential negative side effects included nausea and disorientation [Che*11].

With regards to the types of VR technology systems, the literature revealed that the head mounted display was feasible amongst participants living with dementia [MJJ14], but the additional equipment may not be, with some evidence of user difficulties [SA14; MCB16].

6. Recommendations and Future Research

In three of the five studies reviewed [FvSB*03; MJD*17; MJJ14], a small sample of 10 or less participants with dementia was recruited, making the applicability of findings limited. Future research should explore VR with larger populations to increase the generalisability and thus the validity of the research.

Much of the published VR and dementia research has accessed participant populations with a diagnosis of either 'mild' or 'mild to moderate' dementia, living at home or in residential settings. This was evident in our review, with only one study that included participants living within the later stages of dementia [MJD*17] who resided in a residential care home. More research is needed with participants living within the later stages of dementia; however, there could be inherent challenges with this. Researchers should be aware of the potential ethical implications regarding capacity to consent to participation.

The Mental Capacity Act [05] guidelines should be referred to in relation to conducting research with individuals who may lack capacity. Capacity assessments, involving relatives or a suitable consultee, and maintaining assent are integral. With all potential participants living with dementia in future research, a number of factors for consideration have been highlighted. For example, the potential for detrimental psychological consequences, such as reported increased fear and anxiety [MJD*17], experience of negative memories [SA14], or exacerbation of existing cognitive difficulties, such as confusion and disorientation that may already be evident. Future studies involving VR should consider a method that minimises the potential for negative outcomes (such as fear) and maximises opportunity for well-being.

Moyle and colleagues recommended that VR interventions should create "an engaging, attractive, and colourful interface that promises enjoyment" (p8, 2017). Due to individual differences, we feel that offering a choice of a VE may increase the opportunity for enjoyment if the VR user can select from a menu according to their preferences and could be considered within clinical applications as well as when carrying out future research. Furthermore, given the difficulty highlighted for some participants living with dementia using some of the additional equipment (e.g. a motion sensor or mouse) [MCB*16], future VR research could consider the design of the VR system and offer one that maximises opportunity to engage and interact with the VE with minimal equipment burden.

Whilst the research conducted by Blackman, Van Schaik and Martyr [07] was excluded from the review (outcomes were based only on task performance), upon reflecting on their study they highlighted an important limitation in their design of the VR software, which is deemed relevant here. In their study, poor resolution of the sign posts in the VE made it difficult for participants to read them. They conclude that this may have had a detrimental effect on the virtual experience, lowering individual performance and decreasing the ecological validity of the VE. This is a simple yet valuable design issue that can be considered for clinical interventions or future studies and easily resolved to increase presence for the VR user in the VE.

7. Limitations of Current Review

The small review sample size of five papers is open to critique. Further, each of the reviewed studies used small participant numbers. Given that the area of interest is in its infancy perhaps this is not unexpected at this stage. We have been unable to look at publication bias or selective reporting within the literature. Therefore, we have been unable to comment on the risk of bias within the limited cumulative evidence generated to date. We also only included papers in English, excluding four papers without knowing the applicability of the content. If a future review were to be carried out, given the sparseness of research in this particular field, the researcher could explore the translation of foreign papers in order to establish applicability to the research area with a view to potentially widening the sample size. Further, the reviewer could consider exploring a wider variety of databases that focus upon the technical field of VR but which may also address the focus of this review directly or indirectly.

In addition, whilst inclusion and exclusion criteria were selected by three of the researchers, the method of including or excluding papers was completed mainly by one researcher and may potentially have contributed to a selection bias with regards to identifying relevant papers. It should be noted, however, that discussions were held with regards to the criteria, and a selection of papers were examined in order to ensure confidence in the process and that selection was similar across the three researchers. Consultation was sought with the additional two researchers in any instance where the reviewer was unsure as to whether a paper met the criteria.

8. Conclusion

The current paper aimed to specifically explore the feasibility of VR technology system use with individuals living with a dementia that included acceptability, practicality, user experience and the effects on well-being. It is perhaps not surprising that only four percent of the literature identified from the search was relevant, demonstrating the infancy of an area which warrants further investigation. Of the relevant literature identified, there is evidence that both semi-immersive and fully-immersive VR technology can be feasible amongst individuals living within the earlier stages of dementia outside of a hospital environment. Comfortable equipment resulted in views of VR as a welcome distraction that increased alertness and pleasure. However, some individuals in the earlier stages of dementia experienced boredom, and VR technology was also found to increase fear and anxiety in one study. In order to further develop this field and add to the person-centred intervention toolbox available for people with a dementia diagnosis, more feasibility research is required. The current evidence-base leaves a predominant gap around the exploration of VR technology system use for people within the moderate to later stages of dementia, living in a hospital environment, and using fully-immersive VR.

Authors	Participant population	VR equipment & exposure	Study aims	Method	Outcome measures	Results
FvSB*03	-recruited from the local health service and Alzheimer's Society -n=6 people with dementia (specific diagnosis undisclosed) (n=3 male, n=3 female; age range 52-91) -early stage dementia -n=6 carers (controls)	-semi-immersive VR auditorium, 140 degree curved screen based on BARCO 1208 projectors; surround sound; BG systems Flybox © joystick navigation. -park environment ≤ 20 minutes exposure to VR at any 1 time	-explore the feasibility of VR in people with dementia	-exercise 1: instructed to explore the VE however they wished using the joystick. The participant was asked questions whilst they explored the VE -exercise 2: participants were given prompts to carry out functional tasks in the VE	-SSQPWD self-report pre and post intervention -DVRuse questionnaire (people with dementia) -self-rated wellbeing (5 point scale, 1=very comfortable, to 5 very uncomfortable) -physical wellbeing (people with dementia only) measured using heart rate (HR) by beats per minute	-participants felt in control of the VR with little difficulty in using a joystick for navigating the VE and viewed the VE's as naturalistic. -VR was viewed as a good way to assess functional behaviour -no increase in simulator sickness or adverse effects including psychological or physical well-being
SA14	-recruited from 2 care home across South East England -n=20 residents with dementia (specific diagnosis undisclosed; aged ranged 80-101) -n=6 carers/activities co-ordinators -n=2 care home managers - stage of dementia undisclosed	-semi-immersive -virtual world (VW) created using Unity3D -Microsoft Kinect® sensor for gesture and touch-based interactions -Zigfu development kit facilitated the development of the gesture software through Unity3D	-to explore the use of a VW to support life engagement in individuals with dementia residing in a long term care environment	-9 visits over 2 care homes during 8 months - groups of 1-5 participants were offered the opportunity to engage with the VW in an activity room and were free to enter and leave as they wished -VW presented on a large screen and arm gestures were captured through arm movements so the participant could engage whilst seated -3 different VW prototypes offered: virtual reminiscence room; river tour; gardening	-researchers observed the participants interacting with the VW and made detailed notes -2 focus groups with care staff and managers to discuss design of the VW -opened ended interviews to discuss opinions of the prototypes and clarify observations -thematic analysis was used to categorise themes from the data	-VW invoked memories and created a 'sense of self' through reminiscence -provided opportunities that participants would not have had -continued use of equipment caused fatigue -triggered some negative memories
MJJ14	-recruited from a university based clinical program -n=5 with bvFTD (n=2 men, n=3 female; mean age 56, SD 12.8 years) -MMSE mean 21.3 SD 7.3 -CDR mean 1.0 SD 0.0	-fully immersive eMargin Z800 HMD that included: a separate display screens for each eye; integrated head tracking; stereo earphones	- to assess the feasibility of placing individuals with dementia in a VE	-exercise 1: participants completed the UCLA structure insight interview (Mendez & Shapira, 2001, cited by Mendez et al., 2014) with a real life researcher -exercise 2: participants were immersed in a VE in which they were seated at a conference table and answered insight questions (from a subset of the UCLA Insight Interview on cognitive insight) posed by 5 avatars also seated at the virtual table	-verbal fluency tested with MLU -number of head turns towards the avatars in the VE -self-report standardised Likert scale to measure levels of arousal; stress; anxiety; anger; fatigue; attention -HR BioHarness 3.9 -Biopac Acqknowledge program to determine intra-subject differences	-participants tolerated the head-mounted without adverse effects -presence was demonstrated through participants interaction in the VR -participants with bvFTD demonstrated larger mean length of verbal utterances compared to interviews in the real world
MCB*16	-recruited from research centres in France -n=29 with dementia (n=15 Alzheimer's disease, n=10 mixed dementia, n=1 vascular dementia, n=2 primary progressive aphasia, n=1 organic brain syndrome; n=12 female, n=17 male; mean age 76.3 years; SD 7.2; age range 65–90 years) -n= 28 with MCI (n=13 female, n=15 male; mean age 75.0 years; SD 6.8; age range 62–89 years) -MMSE mean: dementia 20.2, SD 3.1; MCI 25.4. SD 2.6	-semi-immersive, VE displayed a well-known square in Nice created by reconstructing the 3D environment from a set of photos. The VE include animated 3D characters - displayed on a Barco OverView OLSF-721 full HD 3D stereoscopic LED video wall with a resolution of 1920 x 2160 pixels, 1.55 x 1.74 meters -participants wore Volfoni Edge 1.2 active 3D LCD shutter glasses, synchronized with a Volfoni ActivHub IR100 infrared emitter	-explore the feasibility of a VR tool for measuring attention in individuals with MCI and dementia with or without apathy -evaluate the acceptability, interest and usability of the VR intervention	-attention task completed across two conditions (VR/paper based) -required participants to find and select 5 females wearing a t-shirt that met the specified criteria(colour/pattern/colour and pattern) - the paper based condition used screen shots from the VE -participants played for 5 minutes in each condition - participants were asked to select the 5 targets across 8 different criterion scenes (using a mouse in the VR condition, and placing a rectangle over the target in the paper condition) -number or errors and correctly identified targets were recorded	-self report questionnaires to evaluate: satisfaction, interest; discomfort; anxiety; feeling of security and fatigue in relation to both conditions -scale ranged from 'not at all' to extremely' -the number of correctly and incorrectly identified targets in the attention task	-participants with MCI and dementia were satisfied and interested in the task using VR -participants reported feelings of security and no adverse effects (i.e. discomfort, anxiety and fatigue) -all participants preferred the VR condition, however apathetic participants more so than non- apathetic participants
MJD*17	-recruited from 2 residential aged care facilities in Australia -n=10 people with a dementia (n=7 Alzheimer's disease; n=3 undisclosed; n= 3 male; n= 7, female; ages undisclosed) -n= 10 family member -n= 9 care staff -PAS scores ranged 7.35-20, mean 13.21	-semi-immersive VR forest (VRF) via a large interactive screen -video game technology including sensors through Microsoft Kinect® allowing participants to interact with the scene by moving their arms and hands	-explored the effectiveness of a VRF on engagement, apathy and mood states in people with dementia -explored the experiences of using VRF from the perspectives of staff, carers and people with dementia in a residential aged care facility	-the VRF was set up across in 2 different care homes: one was dark and calm, the other was a bright and noisy -both groups of participants were exposed to a VRF session for a maximum of 15 minutes	- OERS - PEAR -type of engagement: coded into three types (self-engagement; facilitated engagement; no engagement) -semi-structured interviews analysed with thematic analysis	-the VRF was perceived as having a positive effect by all participants -people with dementia experienced: more pleasure (p= .008); more alertness (p<.001); more fear/anxiety (p<.016) than a comparative normal sample

Table 2: *Summary of studies identified following the application of inclusion and exclusion criteria.*
Abbreviations: SSQPWD: Simulator Sickness Questionnaire adapted for people with dementia (unvalidated measure adapted from the SSQ Kennedy, Lane & Berbaun, 1993, cited by Flynn et al., 2003); DVRuse questionnaire: Dementia Virtual Reality Use questionnaire (unvalidated measure adapted from the VRuse questionnaire, Kalawsky, 1999, cited by Flynn et al., 2003, unvalidated version); MCI: mild cognitive impairment; PAS: Psychogeriatric Assessment Scale (Jorm et al., 1995, cited by Moyle et al., 2017); PEAR: Person-Environment Apathy Scale (Jao et al., 2015, cited by Moyle et al., 2017); OERS: Observed emotional rating scale (Lawton et al., 1999, cited by Moyle et al., 2017); bvFTD: behavioural variant frontotemporal dementia; MMSE: Mini Mental State Examination (Folstein, Folstein & McHugh 1975 cited by Blackman et al.,2007); CDR: Clinical Dementia rating scale (Morris, 1993, cited by Mendez et al., 2014); MLU: mean length of utterance.

9. References

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