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## Mobile health applications for people with dementia

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## **Title**

Mobile health applications for people with dementia: a systematic review and synthesis of qualitative studies

## **Citation**

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## **Abstract**

**Objective:** To review the qualitative literature on mobile health applications for people with dementia.

**Methods:** A systematic review was undertaken. Six databases were searched using relevant keywords. Titles, abstracts and full-text papers were screened independently by two reviewers. Data extraction and quality assessment was conducted. Analysis was guided by framework synthesis and underpinned by the Digital Health Engagement Model.

**Results:** Nine studies were included. Three themes emerged around the experiences of people with dementia when using health apps. The technology seemed to improve some aspects of physical, mental and social health such as stimulating cognitive function and communication skills. When implementing health applications with persons with dementia six themes came to light. How well an application or mobile device was designed and the quality of information on it, seemed to influence use. Digital knowledge and skills were also needed to engage with the technology. One's personal lifestyle and agency were other relevant factors affecting implementation, along with the health of an individual with dementia.

**Conclusion:** Further research examining the efficacy of health apps for people with dementia is required. Utilising co-design approaches to create mobile technology with those with dementia should also be considered.

**PROSPERO Registration Number:** CRD42015029846

**Key Words**

dementia, Alzheimer's, mobile application, health app, mobile health

## **Introduction**

As populations age worldwide, dementia is becoming more prevalent with 44 million people estimated to suffer from the chronic neurological condition. It is estimated that the number will be close to 150 million people by 2050.<sup>1</sup> The term dementia refers to an impairment of cognitive brain function such as language, memory, perception and thought. A diagnosis of dementia is made when two or more of these core mental functions are impaired. This loss of cognitive function is often also associated with behavioural and psychological symptoms. These usually manifest as either anxiety or apathy, resulting in a decreasing ability to maintain one's essential activities of daily living such as eating, drinking and sleeping. The most common form of dementia is Alzheimer's disease which accounts for between 60% and 70% of cases. Its aetiology is poorly understood but risk factors are thought to include genetics, hypertension, depression and a history of brain injury.<sup>2</sup>

At present there are no efficacious treatments that cure Alzheimer's disease or other dementias or stop its progression. Hence, healthcare providers focus on providing pharmacological solutions such as acetylcholinesterase inhibitors and non-pharmacological interventions such as counselling and music and reminiscence therapies. These can help manage symptoms as many people with dementia need a great deal of support, particularly as the disease worsens.<sup>3</sup> The economic cost of caring for people with dementia worldwide is estimated to be more than US\$1.2 trillion by 2030.<sup>4</sup> In addition, family carers provide innumerable hours of informal care to people with dementia, with over 700,000 carers in the UK alone, the majority of whom are women.<sup>5</sup> Carers often lack meaningful activities and ways to interact with people with dementia, report safety issues in the home due to personality changes, aggressive behaviour and social isolation, and difficulties communicating as some of the main challenges faced when caring for a person with dementia.<sup>6</sup>

Mobile health (mHealth) is a rapidly growing area which has been defined as “*the use of mobile and wireless devices to improve health outcomes, health care services and health research*”.<sup>7(p6)</sup> People are starting to use health applications (apps) on smartphones or tablet computers to enable the management of chronic illness or to support healthy lifestyles and behaviours. In 2015, there were around 2.6 billion mobile phone app users, corresponding to over 100 billion app downloads which generated revenues of approximately US\$ 51 billion.<sup>8</sup> More than 100,000 health apps are available on iTunes and Google play stores, although evidence of their effectiveness is limited.<sup>9</sup>

Technology including mobile apps has been recognised as a tool that can improve the quality of life for people with dementia.<sup>10</sup> Many mobile apps for dementia now exist such as those offering music, memory aids or medication management. Padala et al.<sup>11</sup> showed that digital games that promote physical fitness seemed to positively affect people with mild Alzheimer’s disease. O’Connor<sup>12</sup> demonstrated how a mobile app that was co-designed with people with dementia and their carers appeared to improve communication, memory and cognitive function. A review of mHealth apps for people with mild cognitive impairment, including those with Alzheimer’s disease and dementia, highlighted the technology appeared to improve health outcomes.<sup>13</sup> However, only quantitative study designs were included and their quality was reported as being low. Hence, these findings should be interpreted with some caution.

In addition, concerns about digital literacy, data privacy and security, and the interoperability of health-related apps are emerging.<sup>14</sup> Literature examining the barriers and facilitators to deploying mobile health technologies including apps, wearables and other devices with older people with chronic conditions exists.<sup>15</sup> Some of the difficulties found included negative perceptions of these technologies by health professionals and problems logging in or installing software, while the ability to customise the digital tools for a persons’

individual preferences seemed to help. However, this scoping review only included three studies involving people with dementia or cognitive impairment and none of these focused exclusively on health apps or reported qualitative findings. As people with dementia have specific needs, how health apps are rolled out with this particular population is important to understand to ensure this technology can be implemented and used.

Given the emphasis on quantitative studies and outcomes reported in prior reviews, this review aimed to identify and synthesise the qualitative literature on health apps specifically for people with dementia to complement and extend existing work in this area. The review questions were:

- What are the experiences of people with dementia when using health apps?
- What factors (barriers and facilitators) affect the implementation of a health app with a person with dementia?

## **Method**

A systematic review of the qualitative literature was undertaken and a review protocol registered on PROSPERO (CRD42019130524). The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines<sup>16</sup> and Enhancing Transparency in Reporting the Synthesis of Qualitative Research (ENTREQ) statement<sup>17</sup> were followed to enhance the transparency and reporting of the review (see Appendices 1 and 2).

### ***Search strategy***

A search strategy was developed using the PICO framework<sup>18</sup> to clearly identify each element of the review questions. A combination of free text keywords and Medical Subject Heading (MeSH) terms were used (see Appendix 3). The search was conducted in July 2018, and updated in April 2019, using five online bibliographical databases; CINAHL, Cochrane Library, MEDLINE, PsycINFO and PubMed. Reference lists of included studies were hand

searched and articles citing these papers screened to help identify additional studies of relevance. The inclusion and exclusion criteria for the review are outlined in Table 1. No publication dates were stipulated due to the recent emergence of health apps for dementia. Endnote was used to remove duplicate citations before screening.

**Table 1. Inclusion and exclusion criteria for the systematic review**

|              | <b>Inclusion / Exclusion Criteria</b>  |
|--------------|--|
| Population   | An article had to contain participants who were diagnosed with some form of dementia (at any stage in the disease trajectory). Studies were excluded if participants were mixed groups of patients with a variety of cognitive impairments or sensory deficits and those with dementia were not clearly identifiable.  |
| Intervention | The intervention had to be a software application of any kind, that could be used on contemporary mobile devices, and had a health, care or wellbeing focus. Studies exploring a mixture of technologies, such as combinations involving wearable devices or home monitoring systems, where the app was not a distinct component or those used solely for clinical assessment or diagnostic screening were excluded. |
| Comparison   | None   |
| Outcome      | Studies must have undertaken empirical research and report qualitative   |

|              |   |
|--------------|---|
|              | outcomes related to the experiences of persons with dementia.   |
| Study design | Qualitative study designs such as ethnography, phenomenology, grounded theory, case study or other types of qualitative designs including mixed method studies where the qualitative approach and outcomes were clearly reported. Literature reviews, discussion or opinion articles, theses and conference proceedings were omitted. |
| Language     | Studies must have been published in an English language, peer-reviewed journal.   |

### ***Screening and data extraction***

Screening was undertaken by the research team, both of whom worked independently. Titles and abstracts were assessed first and those that did not meet the inclusion criteria were discarded. Then, full text screening took place and studies that did not align with the reviews' inclusion criteria were rejected. Data from eligible papers was extracted into an Excel template, which was piloted with a handful of studies and then refined. Bibliographic information, study characteristics, participant and intervention characteristics and the main findings from the results and discussion sections related to the review questions were extracted (see Table 2). Any disagreements during the screening and data extraction process were resolved through consensus discussion.



**Table 2. Details of included studies**

| No | Author, Year, Country                    | Research Aims, Theory & Setting  | Methods   | Participants   | Mobile health application  | Findings  |
|----|--|--|---|--|--|---|
| 1  | Critten & Kucirkova, 2017, UK            | <p><u>Aim:</u> How can an iPad app create personalised stories for people with dementia and what role does this technology have in stimulating, preserving and sharing these memories?</p> <p><u>Theory:</u> none reported.</p> <p><u>Setting:</u> club for people with dementia run by a housing association. <u>Quality:</u> 6/10 medium</p> | <p><u>Ethics:</u> university ethical approval.</p> <p><u>Design:</u> case study.</p> <p><u>Data collection:</u> one-to-one interviews with the participants over several occasions (including field notes and observations).</p> <p><u>Analysis:</u> content analysis.</p>                  | <p><u>Gender:</u> two men and one woman. <u>Age:</u> 72, 84 and 94. <u>Ethnicity:</u> not reported.</p> <p><u>Socioeconomic background:</u> not reported. <u>Diagnosis:</u> mild to moderate dementia (no specific diagnostic criteria reported).</p>    | <p><u>Hardware:</u> iPad. <u>Software:</u> Our Story app. <u>App development:</u> free app created by researchers at the Open University, UK. <u>App functionality:</u> users can create any digital stories with no restriction on the number of pictures, length of audio- or video-recordings. <u>App content:</u> created by the person with dementia.</p> | <p>The qualitative study reported that the multitude of features on the Our Story app offered people living with dementia the ability to store, access and generate memories. This could be done using text based or audio content, enabling personalised stories to be created and shared. Study limitations include the small sample size, poor digital literacy of participants (training was provided) and use of a single app.</p> |
| 2  | Ekström, Ferm & Samuelsson, 2017, Sweden | <p><u>Aim:</u> explore communication using a digital device with people with dementia. <u>Theory:</u> none reported.</p> <p><u>Setting:</u> at patients' home. <u>Quality:</u> 4/10 low.</p>   | <p><u>Ethics:</u> ethical recommendations provided. <u>Design:</u> qualitative approach. <u>Data collection:</u> interviews with participants and video recordings before and after using the tablet PC. <u>Analysis:</u> not explicitly described – conversational domains identified.</p> | <p><u>Gender:</u> woman and her husband. <u>Age:</u> 52 years old (woman). <u>Ethnicity:</u> not reported.</p> <p><u>Socioeconomic background:</u> not reported. <u>Diagnosis:</u> Alzheimer's disease (does not specific diagnostic criteria used).</p> | <p><u>Hardware:</u> tablet computer. <u>Software:</u> GoTalk NOW app. <u>App development:</u> commercial app costing £74.99 from Attainment Company Inc. <u>App functionality and content:</u> individually designed with personal pictures, video clips, and digitized and synthetic speech. It also supports writing.</p>                                    | <p>Results indicate that the amount of interactive actions and the number of communicative actions seem to increase with the use of the communication application. Study limitations include its small sample size and use of a single app.</p>   |

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|---|-------------------------------------|---|--|--|---|---|
| 3 | Groenewoud et al, 2017, Netherlands | <p><u>Aim:</u> explore the experiences and views of the iPad games by people with dementia.</p> <p><u>Theory:</u> none reported.</p> <p><u>Setting:</u> two day-care centres for people with dementia and five small-scale living facilities from three health care organizations. <u>Quality:</u> 5/10 medium.</p>                 | <p><u>Ethics:</u> university ethical approval.</p> <p><u>Design:</u> mixed-method.</p> <p><u>Data collection:</u> frequency and duration of game play along with observations and interviews. <u>Analysis:</u> descriptive statistics and content analysis.</p>  | <p><u>Gender:</u> 24 men, 30 women. <u>Age:</u> men mean age: 83.5 and women mean age: 83.5. <u>Ethnicity:</u> not reported. <u>Socioeconomic background:</u> not reported. <u>Diagnosis:</u> 23 had moderately severe and 31 had mild to moderate dementia (as assessed by nursing staff)</p>   | <p><u>Hardware:</u> iPad. <u>Software:</u> 10 existing games and 3 new games. <u>App development:</u> not reported in detail. <u>App functionality and content:</u> Four board and card games for the iPad; One musical instrument app; Three interactive visual or sound apps; One virtual fish pond; One virtual pet; Three games designed with people with dementia (Shopping, Pets and Soccer).</p>   | <p>The study reported mixed outcomes as positive experiences of gaming by people with dementia related to a sense of achievement, connection, belonging, and identity, better self-esteem and having something to do. However, negative experiences were reported including a sense of insecurity, low self-esteem connected with failure at gaming and annoyance at overly simplistic or complex games that did not suit the needs of the person with dementia.</p>                            |
| 4 | Kwan et al, 2018, Hong Kong         | <p><u>Aim:</u> compare acceptability and feasibility and explore usability of smartphones for wayfinding between older people with and without mild dementia.</p> <p><u>Theory:</u> none reported.</p> <p><u>Setting:</u> community elderly centres and day care centres for people with dementia. <u>Quality:</u> 5/10 medium.</p> | <p><u>Ethics:</u> university approval. <u>Design:</u> Cross-sectional and observational. <u>Data collection:</u> Mini Mental State Exam (MMSE) for cognitive measurement, app usage data, STAM questionnaire, interviews and dementia group were video-recorded.</p> <p><u>Analysis:</u> non-parametric statistics and content analysis.</p> | <p><u>Gender:</u> Male - 16, Female - 30. <u>Age:</u> median age of dementia group was 79 and median age of healthy group was 66.5. <u>Ethnicity:</u> not reported. <u>Socioeconomic background:</u> not reported. <u>Diagnosis:</u> healthy adults (n=30) &amp; people with mild dementia (n=16) (diagnosis MMSE score of 20–25).</p> | <p><u>Hardware:</u> Apple iPhone 7. <u>Software:</u> map application and voice command application namely Siri (in Cantonese).</p> <p><u>App development:</u> apps pre-installed on the iPhone. <u>App functionality and content:</u> maps identify the position of the users by a GPS and give instructions including both visual and verbal. Siri - transform the voice commands of users to operate the smartphone and give instructions to the users.</p> | <p>The study results found no significant differences between healthy older adults and those with dementia on the feasibility markers (app usage) or on the acceptability items (STAM). However, people with mild dementia needed more time to complete the wayfinding tasks and training workshop. Cognitive impairment and GPS signal reliability affected usability for people with mild dementia. Mild dementia does not limit older people using smartphones to navigate environments.</p> |
| 5 | McAllister et al, 2017,             | <p><u>Aim:</u> exploring barriers and facilitators to Memory Keeper app use with persons with</p>   | <p><u>Ethics:</u> university ethical approval.</p> <p><u>Design:</u> pilot study.</p>  | <p>Three persons with dementia; six family members &amp; one lifestyle</p>   | <p><u>Hardware:</u> Apple iPad. <u>Software:</u> Memory Keeper is a prototype</p>   | <p>The study reported family members felt the Memory Keeper app was valuable as it helped improve the quality of engagement they had</p>  |

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|   | Australia                   | dementia, the benefits (or otherwise) when app is used and how to implement the app in a long-term care setting.<br><br><u>Theory:</u> none reported.<br><br><u>Setting:</u> dementia wing of a long-term care facility.<br><u>Quality:</u> 5/10 medium.                                  | <u>Data collection:</u> field notes (recording peoples' reactions and interactions to the app), focus groups and one individual interview.<br><br><u>Analysis:</u> framework analysis.  | coordinator.<br><br><u>Gender:</u> 2 men and 1 woman with dementia.<br><u>Age:</u> Persons with dementia aged 76 – 83.<br><u>Ethnicity:</u> Not reported<br><u>Socioeconomic background:</u> occupation<br><u>Diagnosis:</u> moderate to advanced dementia. | digital application.<br><br><u>App development:</u> prototype app created by study authors in collaboration with families of persons with dementia. <u>App functionality and content:</u> personalised prompts to stimulate reminiscence - photographs, music, video clips etc can be added to the app. Training provided to family and person with dementia. | with a person with dementia and made visits more enjoyable.<br><br>Recommendations were to engage people with dementia as early as possible to populate the app with personalised content and provided more training to people with dementia, their families and staff in the long-term care facility.  |
| 6 | Postman, 2016, USA          | <u>Aim:</u> explore integrating computer-mediated therapy into cognitive-communicative rehabilitation for people with dementia.<br><br><u>Theory:</u> none reported.<br><br><u>Setting:</u> lockdown dementia unit within an expansive retirement community.<br><u>Quality:</u> 4/10 low. | <u>Ethics:</u> not reported.<br><u>Design:</u> descriptive case study / feasibility narrative. <u>Data collection:</u> performance of Constant Therapy app tasks (12 sessions of 30-60 minutes duration). <u>Analysis:</u> not described. | <u>Gender:</u> female resident (n=1). <u>Age:</u> 83 years old. <u>Ethnicity:</u> Caucasian, English-speaking resident. <u>Socioeconomic background:</u> not reported. <u>Diagnosis:</u> primary medical diagnoses of senile dementia.                      | <u>Hardware:</u> iPad. <u>Software:</u> Constant Therapy app<br><br><u>App development:</u> created by the Learning Corp. <u>App functionality and content:</u> systematic and customized therapy tools for people with impairments of cognition and language (e.g. symbol, word and picture matching, pattern recreation).                                   | The study reported that the resident improved in performing the Constant Therapy app tasks which seemed to increase her independence and safety and enhanced her participation in non-computerized therapeutic tasks, helping to reduce of negative behaviours. The study limitations include its small sample size and weak data collection and analysis methods.  |
| 7 | Thorpe et al, 2016, Denmark | <u>Aim:</u> Investigate adoption among users with mild dementia of a pervasive AT solution using only off-the-shelf technology.<br><br><u>Theory:</u> people, activities, context and technology (PACT) framework.  | <u>Ethics:</u> not reported.<br><u>Design:</u> not described. <u>Data collection:</u> system usability scale questionnaire, video recordings of app usage, app usage logs, participants kept logbooks, and                                | <u>Gender:</u> five pairs included three male and two female people with dementia. <u>Age:</u> 61 and 73 years. <u>Ethnicity:</u> not reported. <u>Socioeconomic background:</u> not reported. <u>Diagnosis:</u> dementia (diagnostic                       | <u>Hardware:</u> smartwatch (Sony Smartwatch 3) and smartphone (Sony Xperia E4 - Android platform). <u>Software:</u> off-the-shelf apps and widgets - Google Keep, Google Calendar, DigiCal Widget, Agenda, Google Maps, contact widget, AccuWeather, Custom watchface, IFTTT, moves & fit. <u>App functionality and content:</u>                             | The study found most participants perceived usability was higher after field testing the apps and watch. However, participants only successfully completed some tasks on the apps; calendar notifications (n=5/5), communication – call partner (n=5/5), orientation (n=5/5), charge watch (n=4/5), use to do list (n=2/5), emergency help (n=0/5), navigation (n=0/5). The use of multiple apps for scheduling caused confusion. Users did not |

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|---|-----------------------------|---|---|---|---|---|
|   |                             | <u>Setting</u> : controlled setting and a real-world context (took the devices home). <u>Quality</u> : 3/10 low.  | interviews.<br><u>Analysis</u> : not described.   | criteria not reported)  | multiple depending on the app.  | intuitively swipe to see widgets on the smartphone.   |
| 8 | Tyack et al, 2017, UK       | <u>Aim</u> : 1. How does viewing art on a tablet-style computer impact the wellbeing of people with dementia? 2. What are informal caregivers' impressions of this activity's impact on the people with dementia they care for? 3. How does a person with dementia experience viewing art on a tablet style computer.<br><br><u>Theory</u> : none reported.<br><br><u>Setting</u> : real-world. <u>Quality</u> : 7/10 medium. | <u>Ethics</u> : university ethical approval. <u>Design</u> : quantitative data followed a quasi-experimental repeated measures design. <u>Data collection</u> : QoL-AD scale, three visual analogue (VAS) subscales measuring happiness, wellness and interestedness, and interviews.<br><br><u>Analysis</u> : statistical and thematic analysis. | <u>Gender</u> : Twelve people with dementia (men=8, female=4) and 12 carers (men=2, female=10). <u>Age</u> : people with dementia aged 64-90 and carers aged 48-77. <u>Ethnicity</u> : all were white. <u>Socioeconomic background</u> : not reported. <u>Diagnosis</u> : formal diagnosis of dementia (criteria not disclosed) | <u>Hardware</u> : Android-type tablet computer. <u>Software</u> : app was divided into objects, paintings, and photography (>100 images from three London museums and collections from a photographer and a painter.<br><br><u>App development</u> : created by research team & piloted with dementia volunteers. <u>App functionality and content</u> : choice of art genres to view content with VAS scales before and after. | The study findings revealed that the well-being subdomains generally increased with number of sessions a person with dementia had with the art-based app. They also indicated that viewing art on a table computer improved cognition, behaviour, mood, and relationships.  |
| 9 | Tziraki et al, 2017, Israel | <u>Aim</u> : Are serious games acceptable, accessible and engaging for people with dementia? Can they use a tablet and improve the speed of performing a task with practice? <u>Theory</u> : learning theories, physiological aging, dementia neuro-psychosocial changes, and external compensatory mechanisms. <u>Setting</u> : participants homes   | <u>Ethics</u> : participatory consent process. <u>Design</u> : pilot study for proof of concept (mixed methods). <u>Data collection</u> : game performance data and observations of people with dementia using the serious games.<br><br><u>Analysis</u> : mixed-model  | 24 people with dementia and 14 healthy older adults. <u>Gender</u> : 15 women and 9 men with dementia; 11 female and 3 male healthy volunteers. <u>Age</u> : 65–90 years. <u>Ethnicity</u> : not reported. <u>Socioeconomic background</u> : not reported. <u>Diagnosis</u> :   | <u>Hardware</u> : laptops to tablets. <u>Software</u> : theory-based serious game for people with dementia (39 game screens).<br><br><u>App development</u> : created by the research team. <u>App functionality and content</u> : simple daily tasks that are culturally relevant.   | The study reported that the average speed of successfully completing the game screens were significantly longer for people with dementia than health older adults. However, the rate of improvement in terms of how quickly a person could progress through the game increased with practice for both groups. The people with dementia found the game engaging and fun, reporting it increased self-efficacy. |

|  |  |  |   |  |  |  |
|--|--|--|---|--|--|--|
|  |  | and MELABEV dementia day centre. <u>Quality</u> : 6/10 medium. | repeated measure ANOVA and grounded theory used for qualitative data. | moderate to advanced dementia as tested by a Montreal Cognitive Assessment or a Mini-Mental State Examination. |  |  |
|--|--|--|---|--|--|--|

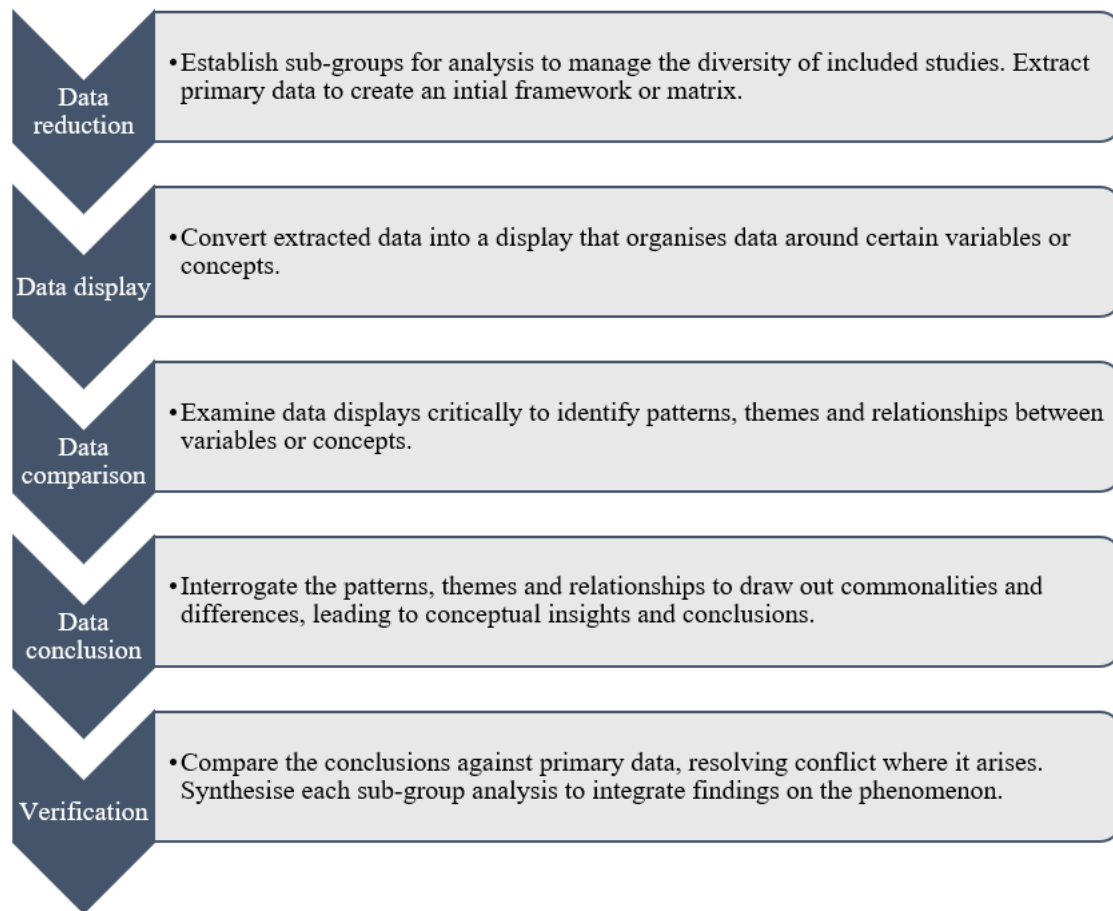
### ***Quality assessment***

The Critical Appraisal Skills Programme (CASP) checklist for qualitative research was used to assess the quality of included studies.<sup>19</sup> Each were evaluated against the ten questions in the checklist and an assessment made as to whether the study met the quality criteria or not. These were then scored, tabulated and summarised (see Appendix 4).

### ***Data Analysis***

Analysis of the qualitative data followed a constant comparative approach,<sup>20</sup> where extracted data were converted into systematic categories and then compared and contrasted to enable an in-depth understanding of the perspectives of people with dementia towards health apps. The five stages of the constant comparative method: data reduction; data display; data comparison; data conclusion and verification, were followed (see Figure 1). These analytical processes were undertaken by the primary author, using N-Vivo QSR 12, and samples of coding checked with the other researcher. Any disagreements raised were resolved through group discussion. The Digital Health Engagement Model (DIEGO) was employed to underpin aspects of the analysis process and provide a more robust understanding of implementing health apps with people with dementia<sup>14,21</sup>.

**Figure 1.** Constant comparative approach



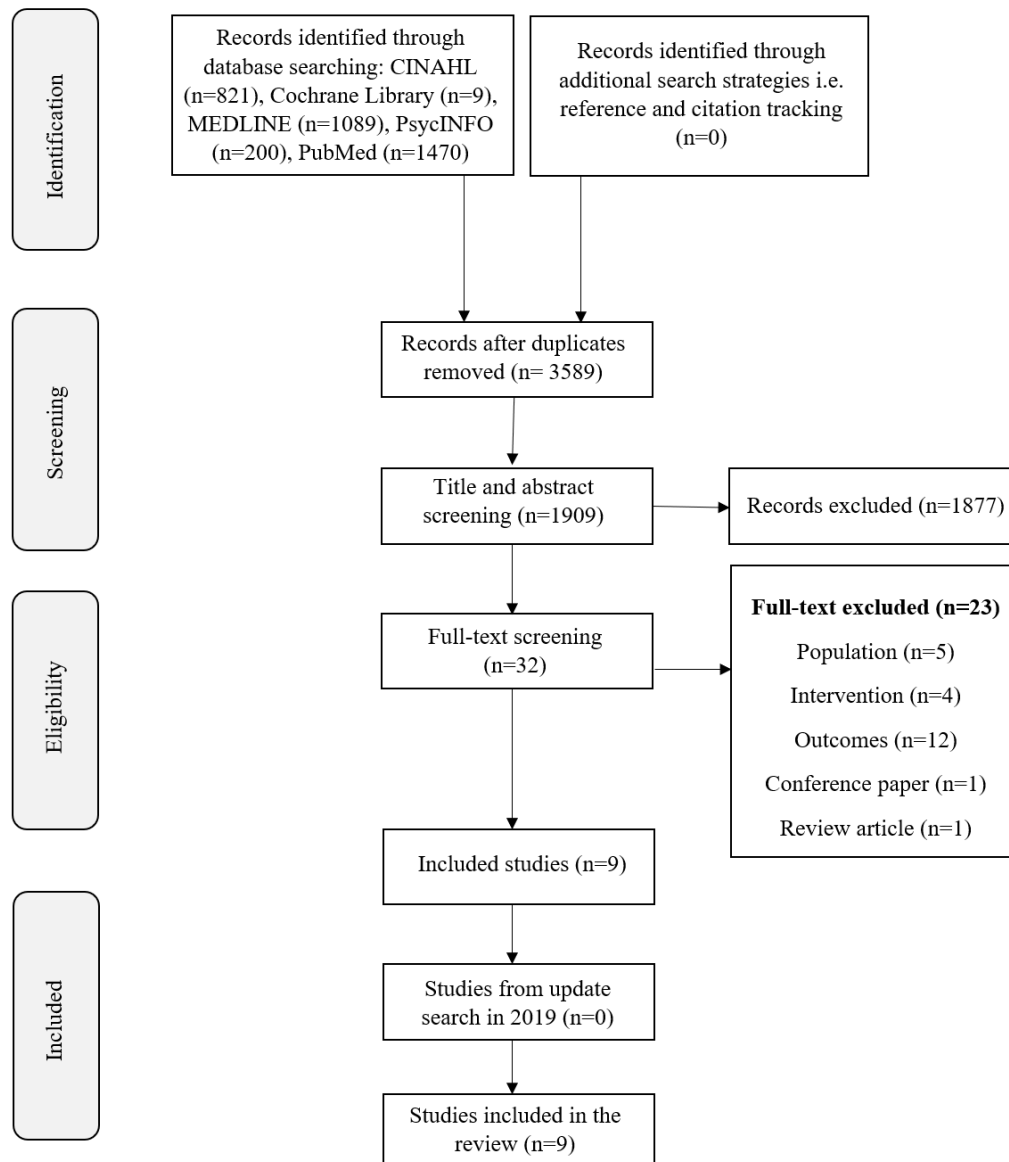
## Results

### *Characteristics of included studies*

Nine studies were included in the review as shown in the PRISMA flowchart in Figure 2.<sup>22</sup> They took place from 2016 to 2018, across eight countries. Two articles were from the United Kingdom,<sup>23,24</sup> and one from Australia,<sup>25</sup> Hong Kong,<sup>26</sup> Denmark,<sup>27</sup> Israel,<sup>28</sup> the Netherlands,<sup>29</sup> Sweden<sup>30</sup> and the United States<sup>31</sup> (see Table 2). Overall, the quality of included studies was moderate, with six rated medium quality and three studies rated low quality. The population of people with dementia varied, with a mixture of genders and ages ranging from 52 to 94 years old. The majority were diagnosed with mild to moderate dementia although the

diagnostic criteria used to assess the clinical stage of the disease varied or was not reported. In addition, the ethnicity and socioeconomic status of participants were rarely described.

**Figure 2.** PRISMA diagram of the screening process



The health applications reported in the included studies were mainly used on tablet computers such as iPads,<sup>23-25,29,30</sup> although two studies used a smartphone<sup>26,27</sup> and one used a combination of laptops and tablets.<sup>28</sup> The types of software applications tended to vary between studies with some supporting the curation or creation of digital objects and stories,<sup>23-25,30</sup> while others provided a range of interactive games,<sup>28,29</sup> navigation,<sup>26</sup> therapy tools<sup>31</sup> or



had a mix of uses<sup>27</sup>. Some apps had been created by the team conducting the research,<sup>23-25,28</sup> while others used commercially available apps that could be paid for and downloaded<sup>30,31</sup> or pre-installed apps on mobile devices.<sup>26,27</sup>

Numerous outcomes for people with dementia who used a health app were reported in ranging from whether the technology can stimulate and preserve memory,<sup>23</sup> support communication<sup>30,31</sup> and wellbeing,<sup>24</sup> general experiences of adopting and using a health app<sup>26-29</sup> and how to implement one in particular settings.<sup>25</sup> These were gathered using a mix of methods<sup>24,26-29</sup> or purely qualitative approaches employing interviews, video recordings, observation, focus groups or participant log books.<sup>23,25,30,31</sup> The settings reported in the included studies took place in people's homes<sup>24,27,28,30</sup>, day centres for people with dementia<sup>26,29</sup>, a long-term care facility,<sup>25</sup> a retirement community with a specific unit for people with dementia,<sup>31</sup> and a club for people with dementia run by a housing association.<sup>23</sup>

A number of themes emerged relating to the experiences of people with dementia when using health apps which were; 1) physical health, 2) mental health, and 3) social health.

### ***Physical health***

Three studies reported some type of physical health benefit for persons with dementia from using a health app. McAllister et al (2017)<sup>25</sup> found a Memory Keeper app seemed to help people with dementia maintain physical function, which was supported by Groenewoud et al (2017)<sup>29</sup> whose findings indicate that gaming apps can stimulate cognitive function. Tyack (2015)<sup>24</sup> also reported that an app which showed art and photography appeared to assist individuals with dementia to concentrate, although for some attention waned over time (see Table 3).

**Table 3. Participant quotes linked to the experiences of people with dementia when using health apps**

| Theme           | Participant Quote   |
|-----------------|---|
| Physical health | <p><i>“We sit and peer all day. It is nice to have something to do. And it is intelligent. It is a nice therapy”</i>.<sup>29</sup></p> <p><i>“Yes. Because your brain will develop well”</i><sup>29</sup></p> <p><i>“One person with dementia, for example, said the pace of life or watching television, meant “you pass by things,” whereas the app’s content and structure helped them concentrate.”</i><sup>24</sup></p>  |
| Mental health   | <p><i>“It has been so nice talking about things that happened in the past. Sometimes I feel very down and things seem bleak, but I really enjoyed putting together my story”</i><sup>24</sup></p> <p><i>“It was nice, because I used to be a football goalkeeper myself”</i><sup>30</sup></p> <p><i>“I like the score counting. I want to reach higher scores”</i><sup>30</sup></p> <p><i>“I love technology. It is wonderful to use this small computer and use the internet”</i><sup>24</sup></p> |
|                 | <p><i>“it gives me goose bumps . . . the other day, he stood up in front of me and put his hand [mimes holding his hands on her shoulder and waist to dance] and I said “Do you want to dance?” And so, I got up and we danced!!”</i><sup>26</sup></p>  |

|                          |  |
|--------------------------|--|
| <p>Social<br/>health</p> | <p><i>“Yes, I showed it to my son and my grandchildren. They took it and I haven’t seen it since! My son said, you never told me about this, but he never talks to me! He comes in to see me, asks how I am and then sits down and watches the telly. My grandchildren loved it especially learning about my grandad and the steam trains. I won’t see that again now they’ve got it (smile)”<sup>24</sup></i></p> |
|--------------------------|--|

### ***Mental health***

A number of studies reported that the mental health of someone with dementia was affected by using a health app, often in a positive way. The results from seven studies indicated that using a health app appeared to improve the persons mood.<sup>23-25,27,29-31</sup> For example, in Tyack et al.<sup>24</sup> participants reporting that seeing digital images or video left them feeling happy, as it reminded them of some aspect of their personal history, although there was a risk that some negative experiences would be recalled. McAllister et al.<sup>25</sup> had similar findings as people with dementia started smiling or singing along when listening to music via an app (see Table 3).

Five studies noted that using health apps appeared to imbue a person with dementia with a sense of achievement which could have a positive mental health benefit.<sup>23,24,28,29,31</sup> A gamification component in an app, where an individual had to undertake a challenging task, appeared to appeal to some people’s competitive nature and led to positive emotions if it was successfully completed. For example, Groenewoud et al.<sup>29</sup> tried a range of gaming apps with people with dementia who reported enjoying their engaging nature such as carrying out a range of stimulating activities and scoring points. Postman<sup>31</sup> also found participants expressed pride in achieving high levels of accuracy when using a therapy app that had of a range of brain training functions. An opportunity to learn via a health app also seemed to improve someone’s feelings of self-efficacy, as one study reported a person with dementia felt they

could acquire new knowledge and skills despite through the technology despite their illness (see Table 3).<sup>23</sup>

### ***Social health***

A number of studies reported that a health app facilitated communication and interaction between a person with dementia and their families or friends and encouraged participation in other activities, which may have enhanced social health.<sup>23-25,28-31</sup> For instance, McAllister et al.<sup>25</sup> showed that some family members were keen to use a health app that enabled digital reminiscence with their loved one with dementia, as it could stimulate conversations, enabling them to better understand their needs and maintain or strengthen relationships with them. An intergenerational aspect emerged in Critten<sup>23</sup> as older adults with dementia were able to connect with their grandchildren via mobile technology, as it was an interest they both had in common. Tyack et al.<sup>24</sup> also highlighted that an app for viewing art and photograph inspired one person with dementia and their partner to visit an art gallery, while another couple reviewed their family photo album (see Table 3).

A number of themes emerged from mapping the results from included studies to the Digital Health Engagement Model (DIEGO). These related to the barriers and facilitators that impacted how the health app was implemented with an individual with dementia which affected engagement with and use of the technology. These issues were; 1) quality of design of a health app or device, 2) quality of digital health information, 3) digital knowledge and skills, 4) personal lifestyle, 5) personal agency, and 6) health and wellbeing.

### ***Quality of design of a health app or device***

The quality of the design of the software application was one aspect that affected a person with dementia when engaging with a health app. In some cases, the app was straightforward

to use those with dementia could understand the design and how it functioned.<sup>23-26,28,30</sup> For example, in Critten et al.<sup>23</sup> participants were able to easily interact with the icons and interface of the application to create a digital story. However, a number of studies reported that a health app was not user friendly and people with dementia found it challenging to use.<sup>24-27,29</sup> In one instance, Groenewoud et al.<sup>29</sup> highlighted that participants felt a gaming app was not logical to follow, as some functions they thought should be included were not available which caused confusion and pop-up ads were an annoyance. Kwan et al.<sup>26</sup> also emphasised that navigation apps were sometimes problematic if a GPS signal was lost as they could crash due to a technical error when re-routing, making them frustrating to use (see Table 4).

**Table 4. Participant quotes linked to barriers and facilitators to implementing health apps with people with dementia**

| Theme                                       | Participant Quote   |
|---|---|
| Quality of design of a health app or device | <p><i>“Yes, I liked pulling out the pictures and putting them down there [story line]. It was very easy to put together the story”<sup>23</sup></i></p> <p><i>“It didn’t go very well. [...] You could not jump backwards and the board didn’t cover the whole board”<sup>29</sup></i></p> <p><i>“She reported that she could not clearly hear the verbal instructions from the iPhone.”<sup>24</sup></i></p> |
| Quality of digital health                   | <p><i>“Regarding personalisation, a standard set of support features was tested rather than a set tailored to each participant’s preferences. By including</i></p>  |

|                              |  |
|------------------------------|--|
| information                  | <i>only those solutions that the user is interested in, the solution may be less overwhelming and seem more relevant</i> <sup>27</sup>   |
| Digital knowledge and skills | <p><i>“P8: So, the reason I keep asking this [P1], is because you were very apprehensive about technology, and you’ve said this a number of times that you don’t understand it or you’re . . . P1: True. P8: And yet you still haven’t brought that up, as something that you think has been challenging, really. So? P1: Well I think that I just amazed myself that I could do as much I can do!”</i><sup>25</sup></p> <p><i>“I didn’t fully understand it. I would if someone told me to do such and such”</i><sup>29</sup></p> <p><i>“He always presses the area surrounding the Home button of the iPhone and could not hit the button in one attempt”</i><sup>26</sup></p> <p><i>“Participants also discussed whether group training may provide additional opportunities for staff, volunteers and family members who may need more practice and guided support”</i><sup>25</sup></p> |
| Personal lifestyle           | <i>“An important benefit of starting earlier is that populating the Memory Keeper would provide a meaningful and proactive occupation for the person with dementia and their loved one(s) at a critical time when the person receiving the diagnosis”</i> <sup>25</sup>  |
| Personal                     | <i>“It’s a bit simple, with little variation. You tap somewhere and you will</i>   |

|                      |  |
|----------------------|--|
| agency               | <p><i>score or you won't. [...] It's not very exciting</i>"<sup>29</sup></p> <p><i>"No, for now it is okay, but it doesn't excite me. I'd rather read a book"</i><sup>29</sup></p>   |
| Health and wellbeing | <p><i>"Robert dictated his story. He had used a keyboard before but his fingers were stiff. He decided not to be audio-recorded, but was happy to talk about his memories."</i><sup>23</sup></p> <p><i>"Audrey was unable to use the keyboard so she dictated her captions. She started doing an audio-recording but found it difficult to remember names and events when shown her story."</i><sup>23</sup></p> |

In a handful of studies, a person with dementia found the design of the mobile device difficult as they had trouble using the touchscreen such as tapping or swiping buttons, charging the technology, or transferring data between devices as the Bluetooth connection was not always reliable.<sup>24-27,29</sup> Kwan et al.<sup>26</sup> also reported that someone with dementia using a wayfinding app had problems with the voice activation, as the oral instructions were not always easy to hear. In addition, Thorpe<sup>27</sup> mentioned that iPhone users had interoperability issues as they could not connect other devices such as some wearable technologies to their smartphone, which limited the functionality of some health apps (see Table 4).

### ***Quality of digital health information***

A number of studies reported that the quality of the information on a health app seemed to facilitate engagement with the technology.<sup>24,25,27,29</sup> For instance, Groenewoud et al.<sup>29</sup> noted that for gaming apps the personal interests and ambitions of a person with dementia should be considered and then matched to the right type of game to ensure they began using it. Similarly, McAllister et al.<sup>25</sup> reasoned that someone with dementia would be more inclined to

use a health app if it were person-centred and the information and activities tailored to their needs where possible (see Table 4).

### ***Digital knowledge and skills***

Digital literacy was highlighted in a number of studies as affecting use of a health app by those with dementia.<sup>23-27,29</sup> McAllister et al.<sup>25</sup> reported mixed results with some people having no difficulties with the technology, while others with dementia and their carers struggled to use a health app as they had limited technical skills. Similarly, Tyack<sup>24</sup> found that those with dementia who were already familiar with touchscreen devices seemed to have fewer problems when it came to using a health app. On the other hand, Groenewoud et al.<sup>29</sup> noted that some persons with dementia did not understand how a health application worked and hence struggled to use it, while in Kwan et al.<sup>26</sup> a lack of skills hindered some people's ability to engage with the technology. Three studies highlighted that sometimes a person with dementia needed help with using a health app which was often provided by a family member or carer<sup>24,25,29</sup> and McAllister et al.<sup>25</sup> suggested training could be provided to support use of any software applications and mobile devices (see Table 4).

### ***Personal lifestyle***

The lifestyle that an individual with dementia had sometimes appeared to influence whether they could use a health app or not, particularly the length of time they had to engage with the technology as they were often busy with other activities.<sup>25,29</sup> Furthermore, McAllister et al.<sup>25</sup> revealed that an app could be time consuming for families and carers to use, if the person with dementia needed support with it, meaning they could not always utilise the digital tool. McAllister et al.<sup>25</sup> suggested that a health app should be introduced to a person with dementia as early as possible to support different aspects of their personal life such as health and wellbeing as they could become familiar with the technology over time (see Table 4).

### ***Personal agency***



A number of studies reported that one barrier to implementing health apps was some people with dementia were disinterested in the technology and preferred to use other modes of communication and entertainment.<sup>24,26-29</sup> Thorpe<sup>27</sup> found that certain people with dementia did not need navigation support available via mobile technology, while in Groenewoud et al.<sup>29</sup> some participants perceived the gaming apps to be childish or boring and choose to do other non-digital activities (see Table 4).

### ***Health and wellbeing***

Four studies noted that a person's ability to use a health app or mobile device sometimes depended on their health status, which could be affected by dementia or ageing more generally (see Table 4).<sup>23-26</sup>

## **Discussion**

### ***Overview of findings***

A systematic review of the qualitative literature on mobile health applications for people with dementia was carried out, to provide a robust summary of the current evidence on the experiences of this population when using mobile technology and the barriers and facilitators that affect its implementation. Synthesis of the results from the nine included studies revealed using health apps appear to affect the physical, mental and social health of a person with dementia in a number of ways. In some instances, a health app seemed to help maintain some aspects of cognitive function and improved mood and feelings of self-worth, although it could stimulate negative emotions. Importantly, an app appeared to enable communication and interaction with family members and other care givers, who could use the software on a mobile device with a person with dementia.

However, a number of issues arose when implementing health apps which tended to affect how they were used by someone with dementia. The quality of design of both the software and hardware seemed to impact on whether a person with dementia could use a

health app or the mobile device it was accessible on. Some people with dementia appeared to struggle with certain design features, meaning an app could be used less often. The quality of information on a health app was another aspect that seemed to influence use, as content that could be personalised and tailored to the individual with dementia was more appealing and could influence engagement with the technology. Digital literacy was another factor as those who had good technical skills tended to utilise a health app more. An individual's personal lifestyle and agency also seemed to be contributing factors, as some people with dementia chose to use the technology while others preferred alternative activities and in a few instances families and carers were needed for additional support. Finally, how healthy and well an individual with dementia felt also appeared to affect whether they used and benefitted from a health app or not, with those experiencing symptoms of the disease or low mood less likely to take part in using the digital tool.

### ***Strengths and limitations***

This systematic review has a number of strengths. Firstly, a rigorous approach was taken to identify relevant qualitative literature on mobile health applications for people with dementia and a detailed protocol published online to enhance transparency. Secondly, a robust synthesis of qualitative studies was conducted and underpinned by a conceptual model, to aid our understanding of how someone with dementia can engage with mobile technology for their health. Thirdly, internationally recognised best practice guidelines such as the PRISMA checklist<sup>16</sup> and ENTREQ statement<sup>17</sup> were used to improve reporting.

However, several limitations were present such as the exclusion of studies in languages other than English and alternative sources of information such as grey literature<sup>32</sup>, conference proceedings and theses, which may have reduced the number of potentially relevant articles reviewed. In addition, commercially available health apps for dementia that have not undergone academic evaluation were not included, meaning some useful apps could

be missing from the review.<sup>33</sup> Furthermore, the included studies were mainly from high-income countries with a Western outlook, which may have introduced some cultural or socioeconomic bias in the review results as mobile technology may be used differently or not at all by people with dementia in low resource settings. The included studies were also heterogeneous in nature and some did not describe participant or intervention characteristics in detail, limiting the extent to which themes could be explored. Finally, the review team did not have access to the original research and primary dataset. This may have resulted in the loss of some understanding of the context, meaning the review results should be interpreted with caution.

### ***Comparison with existing literature***

Some of the physical and mental health benefits of health apps for people with dementia identified in this review of qualitative studies have been reported elsewhere. Astell et al.<sup>34</sup>, using a Game Experience Questionnaire, showed that persons with dementia seemed to enjoy playing games such as Solitaire and Bubble Xplode on touchscreen devices. Similarly, Vahia et al.<sup>35</sup> reported that older inpatients with dementia used a mixture of applications such as gaming, music and picture viewing apps on a tablet device and appeared to be less agitated after using the technology, in keeping with the findings of this review<sup>23-25,27,29-31</sup>. However, Bateman et al.<sup>13</sup> undertook a systematic review of the efficacy of mobile health interventions in improving the outcomes for people with cognitive impairment. Twenty-four studies were included in this review, many of which had participants with dementia. They concluded that improvements in health outcomes were noted in the majority of studies but highlighted the studies were of low quality and recommended more randomised controlled trials to determine the benefits of using health apps, if any, for people with cognitive impairment.

This review also found that mobile health applications tended to improve the social health of individuals with dementia, by increasing conversations and interactions with family

members and friends and participation in alternative activities.<sup>23-25,28-31</sup> Similarly, O'Rourke et al.<sup>36</sup> reported that people with dementia who viewed YouTube videos on flat screen televisions seemed to have better social interaction and communication after engagement with the technology. Yasuda et al.<sup>37</sup> also stated that people with dementia living at home appeared to enjoy conversing with family and relatives over a videophone, which may have had a positive impact on their psychological stability. However, Meiland et al.<sup>38</sup> highlighted that a navigation system composed of a touchscreen computer, mobile device and sensors looked as if it had little to no impact on the quality of life of a person with dementia or how they functioned day-to-day.

Some of the implementation issues raised in this review have also been noted elsewhere. Lim et al.<sup>39</sup> ran a trial where dementia patient-carer dyads used iPads loaded with a range of interactive applications such as art or music, games and relaxation apps. They found that formal support from a person's family influenced whether a person with dementia wanted to use the iPad or not. A 16-week clinical trial of a mobile health app that promoted physical activity in persons with Alzheimer-related cognitive impairment reported that some participants withdrew due to discomfort with the technology, problems setting it up or health issues.<sup>40</sup> There was also evidence that a supportive carer or partner facilitated take up of the physical activity app. Leng et al.<sup>41</sup> also highlighted that good computer skills were necessary for people with dementia to use iPads and engaging, relevant content and functionality were also important to incorporate in the technology. Finally, Meiland et al.<sup>38</sup> emphasised persons with dementia wanted more personalised resources on a mobile device and recommended that they be included in its development from the beginning to ensure the technology is tailored to patients' needs as this could enhance uptake. These are in keeping with some of the barriers and facilitators around deploying health apps with people with dementia identified in this review.

### ***Recommendations for future research***

As dementia can impact people differently and the disease progresses in various ways, the people who suffer from this illness are not a homogenous group. Therefore, more research is needed into how characteristics such as gender, age, clinical stage of the disease, and other aspects affect how a person with dementia engages with and experiences health apps.<sup>42,43</sup> No studies included participants with severe dementia or those receiving palliative or end of life care. Whether mobile technology is of any value to these populations requires further examination.<sup>44</sup> While a range of mobile devices and applications were reported in the review, iPads and storytelling apps were the most popular. Now that wearable and other devices such as virtual reality headsets are available that connect to mobile platforms<sup>45,46</sup> and the number and type of apps are skyrocketing, further research would be helpful to determine if integrating newer technologies with health apps would benefit those with dementia and their families.

Mobile health applications also need to be better described as detailed descriptions of how they worked were missing from some studies in the review. The Template for Intervention Description and Replication (TIDieR) is a useful checklist that could be used to provide more accurate accounts of these types of mobile tools.<sup>47</sup> This could enhance the quality, replicability and transparency of dementia research. In addition, most mobile health applications in the review were designed and developed by a research team or off the shelf commercial ones were used. In future, there may be benefit from including people with dementia and their carers in co-designing and co-researching mobile apps to meet their needs, as this could lead to improvements in health and wellbeing.<sup>12</sup> Only three studies in the review were theoretically grounded and future research could benefit from incorporating robust mobile health and implementation theories into the design and conduct of scientific evaluation of mobile apps with people with dementia.<sup>14</sup>

## Conclusion

This systematic review synthesised the qualitative literature on mobile health applications for people with dementia. It showed health apps have the potential to positively and negatively affect the physical, mental and social health of people with dementia. How this technology can be deployed with people with dementia in terms of some of the barriers and facilitators in the implementation process were identified. Further research exploring the longitudinal benefits and drawbacks of health apps would be beneficial, to complement experimental studies that examine their efficacy with individuals with dementia.

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## Appendix 1 - Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines

| Section/topic             | #  | Checklist item  | Reported on page # |
|---------------------------|----|---|--------------------|
| <b>TITLE</b>              |    |   |                    |
| Title                     | 1  | Identify the report as a systematic review, meta-analysis, or both.   | Yes, #1            |
| <b>ABSTRACT</b>           |    |   |                    |
| Structured summary        | 2  | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | Yes, #1            |
| <b>INTRODUCTION</b>       |    |   |                    |
| Rationale                 | 3  | Describe the rationale for the review in the context of what is already known.  | Yes, #3 & #4       |
| Objectives                | 4  | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).  | Yes, #5            |
| <b>METHODS</b>            |    |   |                    |
| Protocol and registration | 5  | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.   | Yes, #5            |
| Eligibility criteria      | 6  | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.  | Yes, #6            |
| Information sources       | 7  | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.  | Yes, #5            |
| Search                    | 8  | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.   | Yes, Appendix 3    |
| Study selection           | 9  | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).   | Yes, #6            |
| Data collection process   | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.  | Yes, #6            |
| Data items                | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.   | Yes, #6            |

|                                    |    |  |                |
|------------------------------------|----|--|----------------|
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | Not applicable |
| Summary measures                   | 13 | State the principal summary measures (e.g., risk ratio, difference in means).  | Not applicable |
| Synthesis of results               | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$ ) for each meta-analysis.  | Yes, #7        |

## Appendix 2 – The Enhancing Transparency in Reporting the Synthesis of Qualitative Research (ENTREQ) Statement

| No | Item                  | Guide & Description  | Review (qualitative studies only)   |
|----|-----------------------|--|---|
| 1  | Aim                   | State the research question(s) the synthesis addresses.  | <p>1) What are the experiences of people with dementia when using mobile health applications?</p> <p>2) What factors (barriers and facilitators) affect the implementation of a mobile health app with persons with dementia?</p>   |
| 2  | Synthesis methodology | Identify the synthesis methodology or theoretical framework which underpins the synthesis, and describe the rationale for choice of methodology (e.g. meta-ethnography, thematic synthesis, critical interpretive synthesis, grounded theory synthesis, realist synthesis, meta-aggregation, meta-study, framework synthesis). | Analysis of the qualitative data followed a constant comparative approach, where extracted data were converted into systematic categories and then compared and contrasted to enable an in-depth understanding of the perspectives of people with dementia towards health apps. The five stages of the constant comparative method: data reduction; data display; data comparison; data conclusion and verification, were followed. |
| 3  | Approach to searching | Indicate whether the search was pre-planned (comprehensive search strategies to seek all available studies) or iterative (to seek all available concepts until they theoretical saturation is achieved).   | A systematic search using predefined terminology relevant to the review topic was undertaken.   |
| 4  | Inclusion criteria    | Specify the inclusion/exclusion criteria (e.g. in terms of population, language, year limits, type of publication, study type).  | <p>Population – a person with dementia at any stage of disease progression</p> <p>Intervention – software application used on a mobile device with a health/wellbeing focus</p>   |

|   |                            |  |   |
|---|----------------------------|--|---|
|   |                            |  | <p>Control – None</p> <p>Outcome – All outcomes reported used a qualitative methodology</p> <p>Language – English language only</p> <p>Year – no limitations</p> <p>Study type – all study designs; only peer reviewed primary research studies were included</p>   |
| 5 | Data sources               | Describe the information sources used (e.g. electronic databases (MEDLINE, EMBASE, CINAHL, psycINFO, Econlit), grey literature databases (digital thesis, policy reports), relevant organisational websites, experts, information specialists, generic web searches (Google Scholar) hand searching, reference lists) and when the searches conducted; provide the rationale for using the data sources. | <p>Five electronic databases were used - CINAHL, Cochrane Library, MEDLINE, PsycINFO and PubMed.</p> <p>Reference lists of included studies were hand searched and articles citing these papers screened to help identify additional studies of relevance.</p> <p>No date limitations were employed. Searches were undertaken in July 2018 and an update ran in April 2019.</p> |
| 6 | Electronic Search strategy | Describe the literature search (e.g. provide electronic search strategies with population terms, clinical or health topic terms, experiential or social phenomena related terms, filters for qualitative research, and search limits).   | Please see Appendix 3 for a detailed search strategy.   |
| 7 | Study screening            | Describe the process of study screening and sifting (e.g. title, abstract and full text review, number of  | Titles and then abstracts were screened by two independent reviewers, who then undertook full paper screening (also done independently). Disagreements were resolved through group  |



|    |                         |  |  |
|----|-------------------------|--|--|
|    | methods                 | independent reviewers who screened studies).   | consensus.   |
| 8  | Study characteristics   | Present the characteristics of the included studies (e.g. year of publication, country, population, number of participants, data collection, methodology, analysis, research questions).   | Please see Table 2 in the paper.   |
| 9  | Study selection results | Identify the number of studies screened and provide reasons for study exclusion (e.g. for comprehensive searching, provide numbers of studies screened and reasons for exclusion indicated in a figure/flowchart; for iterative searching describe reasons for study exclusion and inclusion based on modifications to the research question and/or contribution to theory development). | Please see Figure 2 the PRISMA diagram in the paper.   |
| 10 | Rationale for appraisal | Describe the rationale and approach used to appraise the included studies or selected findings (e.g. assessment of conduct (validity and robustness), assessment of reporting (transparency), assessment of content and utility of the findings).  | The Critical Appraisal Skills Programme (CASP) checklist for qualitative research was used to assess the quality of included studies. Please see Appendix 4 for CASP scores of the included studies. |
| 11 | Appraisal items         | State the tools, frameworks and criteria used to appraise the studies or selected findings (e.g. Existing tools: CASP, QARI, COREQ, Mays and Pope [25]; reviewer developed tools; describe the domains assessed: research team, study design, data analysis and interpretations, reporting).   | CASP measures a number of quality indicators (ten questions) such as a study's research design and methodology. Please see Appendix 4 for CASP scores of the included studies.                       |

|    |                     |  |  |
|----|---------------------|--|--|
| 12 | Appraisal process   | Indicate whether the appraisal was conducted independently by more than one reviewer and if consensus was required.  | Two reviewers undertook the CASP quality assessment separately.  |
| 13 | Appraisal results   | Present results of the quality assessment and indicate which articles, if any, were weighted/excluded based on the assessment and give the rationale.  | Please see Appendix 4 for CASP scores of the included studies.<br><br>No studies were excluded based on the results of the quality appraisal as weak studies can yield relevant results.                               |
| 14 | Data extraction     | Indicate which sections of the primary studies were analysed and how were the data extracted from the primary studies? (e.g. all text under the headings “results /conclusions” were extracted electronically and entered into a computer software). | Data were extracted by two independent reviewers. Data were analysed from the results and discussion sections of the included studies. Both participant quotes and author interpretations were extracted and analysed. |
| 15 | Software            | State the computer software used, if any.  | EndNote was used to download search results and facilitate management of research data. Microsoft Excel and N-Vivo were used during the data analysis phase to code data and develop themes.                           |
| 16 | Number of reviewers | Identify who was involved in coding and analysis.  | The two independent reviewers were SOC and AB. The primary author, SOC, undertook the analysis process and corresponded with AB to discuss the analysis.   |
| 17 | Coding              | Describe the process for coding of data (e.g. line by line coding to search for concepts).   | Qualitative analysis was undertaken line by line to identify initial codes or concepts in the data.  |

|    |                      |   |   |
|----|----------------------|---|---|
| 18 | Study comparison     | Describe how were comparisons made within and across studies (e.g. subsequent studies were coded into pre-existing concepts, and new concepts were created when deemed necessary).  | Subsequent studies were coded into pre-existing concepts, and new concepts were created when deemed necessary   |
| 19 | Derivation of themes | Explain whether the process of deriving the themes or constructs was inductive or deductive.  | Themes were derived via an inductive process as they emerged through iterative rounds of qualitative coding and analysis and then mapped to the Digital Health Engagement Model.    |
| 20 | Quotations           | Provide quotations from the primary studies to illustrate themes/constructs, and identify whether the quotations were participant quotations or the author's interpretation.  | Please the results section of the manuscript, where quotes are provided from primary studies.   |
| 21 | Synthesis output     | Present rich, compelling and useful results that go beyond a summary of the primary studies (e.g. new interpretation, models of evidence, conceptual models, analytical framework, development of a new theory or construct). | The Digital Health Engagement Model was used to underpin analysis and provide a more thorough understanding of how a person with dementia engages with a mobile health application. |

### **Appendix 3 – Search strategy**

Search strategy used on PubMed

#1 Search Alzheimer Disease [MeSH Terms] 86791

#2 Search “Cognitive Disorders” [MeSH Terms] 85805

#3 Search “Cognitive impairment” [Title/Abstract] 50987

#4 Search “Creutzfeldt-Jakob Syndrome” [MeSH Terms] 6245

#5 Search Dementia [MeSH Terms] 153310

#6 Search “Frontotemporal Lobar Degeneration” [MeSH Terms] 3746

#7 Search “Frontotemporal Lobe Degeneration” [Title/Abstract] 50

#8 Search “Huntington Disease” [MeSH Terms] 11473

#9 Search “Kluver-Bucy Syndrome” [MeSH Terms] 98

#10 Search “Lewy Body Disease” [MeSH Terms] 2899

#11 Search Neurocognitive [Title/Abstract] 18013

#12 Search “Neuro cognitive” [Title/Abstract] 457

#13 Search “Temporal Lobar Degeneration” [Title/Abstract] 44

#14 Search “Temporal Lobe Degeneration” [Title/Abstract] 28

#15 Search “Vascular dementia” [Title/Abstract] 6062

#16 Search #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR

#12 OR #13 OR #14 OR #15 225329

#17 Search Android [Title/Abstract] 2115

#18 Search iTunes\* [Title/Abstract] 181

#19 Search "Google play" [Title/Abstract] 699

#20 Search iOS [Title/Abstract] 1187

#21 Search "Assistive technolog\*" [Title/Abstract] 2102

#22 Search "information technolog\*" [MeSH Terms] 203

#23 Search "Assistive Technology Devices" [Title/Abstract] 90

#24 Search "Cellular Phone" [Title/Abstract] 529

#25 Search "Cell Phone" [MeSH Terms] 9391

#26 Search "Software" [MeSH Terms] 146231

#27 Search "Computers, Hand-Held" [MeSH Terms] 75677

#28 Search "Electronic assistive device" [Title/Abstract] 104

#29 Search Handheld [Title/Abstract] 5462

#30 Search "hand held comput\* device\*" [Title/Abstract] 46

#31 Search (Information\* AND communication\* AND technolog\*) [Title/Abstract] 11302

#32 Search ICT [Title/Abstract] 4803

#33 Search iphone\* [Title/Abstract] 754

#34 Search ipad\* [Title/Abstract] 1299

#35 Search Laptop [Title/Abstract] 1395

#36 Search mHealth [Title/Abstract] 3261

#37 Search "m health" [Title/Abstract] 453

#38 Search “mobile health” [Title/Abstract] 3193

#39 Search Microcomputers [MeSH Terms] 20287

#40 Search “Mobile app” [Title/Abstract] 961

#41 Search apps [Title/Abstract] 4573

#42 Search “mobile applications” [MeSH Terms] 4001

#43 Search smartphone [MeSH Terms] 2860

#44 Search “smart phone\*” [Title/Abstract] 623

#45 Search "personal digital" [Title/Abstract] 1041

#46 Search “tablet PC” [Title/Abstract] 152

#47 Search “table computer” [Title/Abstract] 11

#48 Search “tablet device” [Title/Abstract] 109

#49 Search #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26  
OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37  
OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 OR #48  
227476

**Appendix 4. CASP Quality Assessment**

| No | Author     | Title  | Score      | Quality Score  |
|----|------------|--|------------|----------------|
| 1  | Critten    | 'It brings it all back, all those good times; it makes me go close to tears'. Creating digital personalised stories with people who have dementia. | Score 6/10 | Medium Quality |
| 2  | Ekstrom    | Digital communication support and Alzheimer's disease  | Score 4/10 | Low Quality    |
| 3  | Groenewoud | People with dementia playing casual games on a tablet  | Score 5/10 | Medium Quality |
| 4  | Kwan       | The use of smartphones for wayfinding by people with mild dementia   | Score 5/10 | Medium Quality |
| 5  | McAllister | Memory Keeper: A prototype digital application to improve engagement with people with dementia in long-term care (innovative practice)             | Score 5/10 | Medium Quality |
| 6  | Postman    | Computer-Mediated Cognitive-Communicative Intervention for Residents with Dementia in a Special Care Unit: An Exploratory Investigation            | Score 4/10 | Low Quality    |

|   |         |  |            |                       |
|---|---------|--|------------|-----------------------|
| 7 | Thorpe  | Pervasive assistive technology for people with dementia: a UCD case  | Score 3/10 | Low Quality           |
| 8 | Tyack   | Viewing Art on a Tablet Computer: A Well-Being Intervention for People With Dementia and Their Caregivers                    | Score 7/10 | Medium Quality        |
| 9 | Tziraki | Designing Serious Computer Games for People With Moderate and Advanced Dementia: Interdisciplinary Theory-Driven Pilot Study | Score 6/10 | Medium Quality        |
|   |         |  | <b>3/9</b> | <b>Low Quality</b>    |
|   |         |  | <b>6/9</b> | <b>Medium Quality</b> |