Investigating the potential of touchscreen technology to create opportunities for independent activity with people living with dementia

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Abstract

This thesis reports an investigation into the potential of touchscreen technology to create opportunities for independent leisure activity for people living with dementia. The work was motivated by an Alzheimer's Society members survey highlighting the need for stimulating recreational activities for people with dementia. A literature review was conducted to ascertain how the touchscreen format was being used in the context of dementia, and what could be learned from previous applications. The results of the review highlighted the scarcity of research employing touchscreen technology as a means of facilitating leisure activity for people with dementia. Four research questions were formulated: (1) What types of touchscreen activities are effective? (2) Can touchscreen games be played independently? (3) How can suitable apps be identified? and (4) How can touchscreen apps be customised to improve their accessibility? Three studies were conducted involving 66 people with dementia, either living in or attending care services. Study 1 investigated the types of touchscreen games that are most suitable for people living with dementia. Study 2 evaluated the effectiveness of accessibility settings implemented for people with dementia. Study 3 examined the role of prompt features in the design of touchscreen games for people with dementia. The results revealed that touchscreen games can provide enjoyable and engaging independent activity for people living with dementia. However, selecting games requires consideration of familiarity, novelty and complexity. Furthermore, the potential for collaboration between researchers and developers to improve the design and accessibility of apps for people living with dementia was highlighted. The legacy of the thesis is represented by (i) observable indicators of engagement when people with dementia are interacting with touchscreen activities; (ii) a framework for identifying accessible apps for people with dementia, and (iii) an online resource recommending existing apps to the public.

Dissemination

Publications of thesis chapters

Chapter 2

Joddrell, P., & Astell, A. J. (2016). Studies involving people with dementia and touchscreen technology: A literature review. *JMIR Rehabilitation and Assistive Technologies*, 3(2), e10. http://doi.org/10.2196/rehab.5788

Chapter 3

Astell, A. J., Joddrell, P., Groenewoud, H., de Lange, J., Goumans, M., Cordia, A., & Schikhof, Y. (2016). Does familiarity affect the enjoyment of touchscreen games for people with dementia? *International Journal of Medical Informatics*, 91, e1–e8. http://doi.org/10.1016/j.ijmedinf.2016.02.001

Other publications

Groenewoud, H., de Lange, J., Schikhof, Y., Astell, A. J., Joddrell, P., & Goumans, M. (2017). Experiences of people with dementia playing casual games on a tablet. *Gerontechnology*, 16(1), 37–47.

Joddrell, P., & Astell, A. J. (2017). Dementia: There are so many apps for that… *Journal of Dementia Care*, 25(1), 32–34.

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Joddrell, P., Hernandez, A., & Astell, A. J. (2016). Identifying existing, accessible touchscreen games for people living with dementia. In K. Miesenberger, C. Buhler, & P. Penaz (Eds.), *Lecture Notes in Computer Science* (pp. 509–514). Berlin: Springer International Publishing. http://doi.org/10.1007/978-3-319-41264-1_69

Joddrell, P., Smith, S. K., & Astell, A. J. (2017). Improving app accessibility for people living with dementia: Bridging the gap between developers and users *HCIxDementia Workshop: The Role of Technology and Design in Dementia.*

Powell, L., Joddrell, P., & Parker, J. (2017). Involving users in the evaluation of apps for specific health conditions. In P. Cudd & L. De Witte (Eds.), *Harnessing the Power of Technology to Improve Lives* (pp. 646–653). IOS Press. http://doi.org/10.3233/978-1-61499-798-6-646

Schikhof, Y., Goumans, M., Joddrell, P., & Astell, A. J. (2017). Comparing recent reviews about touchscreens for dementia with lessons learnt from the field. In P. Cudd & L. De Witte (Eds.), *Harnessing the Power of Technology to Improve Lives* (pp. 1–4). IOS Press. http://doi.org/10.3233/978-1-61499-798-6-1

International and national conference presentations

Oral presentations

Joddrell, P., & Astell, A. J. (2017, November). *AcTo Dementia: Working with developers to improve the accessibility of touchscreen apps for people living with dementia.* Oral session presented at the 12th UK Dementia Congress, Doncaster, UK.

Joddrell, P., Astell, A. J., & Hernandez, A. (2017, October). *AcTo Dementia: Accessible apps for people living with dementia.* Oral presentation at the Canadian Association on Gerontology, Winnipeg, Canada (presented by Astell, A. J.).

Astell, A. J. & Joddrell, P. (2017, April). *AcTo Dementia: Accessible apps for people living with dementia.* Oral presentation at the 32nd International Conference of Alzheimer's Disease International, Kyoto, Japan (presented by Astell, A. J.).

Joddrell, P., & Astell, A. J. (2016, November). *AcTo Dementia: Identifying accessible touchscreen apps for people living with dementia.* Oral session presented at the 11th UK Dementia Congress, Brighton, UK.

Joddrell, P., & Astell, A. J. (2016, July). *Maximising the value of touchscreen tablet devices for people living with dementia.* Oral session presented at Alzheimer's Association International Conference (AAIC), Toronto, Canada.

Joddrell, P., & Astell, A. J. (2016, July). *Identifying existing, accessible touchscreen games for people living with dementia.* Oral session presented at 15th International Conference on Computers Helping People with Special Needs (ICCHP), Linz, Austria.

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Poster presentations

Joddrell, P., & Astell, A. J. (2017, July). *AcTo Dementia: Implementing accessibility options for dementia in existing touchscreen apps*. Poster session presented at Technology & Dementia Preconference, Alzheimer's Association International Conference (AAIC), London, UK.

Joddrell, P., Hernandez, A., & Astell, A. J. (2016, July). *Developing a framework to support the identification of accessible touchscreen apps for people living with dementia*. Poster session presented at Technology & Dementia Preconference, Alzheimer's Association International Conference (AAIC), Toronto, Canada.

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Workshops

Astell, A. J., Joddrell, P., Dove, E., & Smith, S. (2017, November). *How to have fun: An interactive workshop on making the most of technology*. Workshop facilitated at the 12th UK Dementia Congress, Doncaster, UK.

Joddrell, P., Smith, S. K., & Astell, A. J. (2017, May). *Improving app accessibility for people living with dementia: Bridging the gap between developers and users*. Paper presented at the HCIxDementia Workshop: The Role of Technology and Design in Dementia, CHI2017, Denver, USA.

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Chapter 1. Introduction

1.1 Dementia

Dementia is a syndrome caused by a chronic or progressive disease of the brain (Prince et al., 2013). At a cortical level, dementia affects multiple areas of higher functioning, including memory, thinking, comprehension, learning capacity, orientation, judgement and language (World Health Organisation, 2012). In addition to the cognitive impairments, there is commonly an impact on motivation, social behaviour and emotional control (Werner, Savva, & Maidment, 2016). Age is the biggest risk factor for developing dementia, and with an ageing population, numbers are predicted to rise dramatically over the next 30 years (Norton, Matthews, Barnes, Yaffe, & Brayne, 2014).

The impact of dementia is diverse, with impairments and symptoms affecting each individual in different ways depending on the subtype of the condition and personal and social circumstances (Werner et al., 2016). Subtypes include Alzheimer's disease,

which is estimated to account for between 60-70% of cases worldwide (World Health Organisation, 2012), vascular dementia, accounting for a further 10% of cases globally (Alzheimer's Association, 2015), and less common subtypes such as dementia with Lewy bodies and fronto-temporal dementia (The British Psychological Society, 2016). It is thought that half of dementia cases worldwide are solely attributable to Alzheimer's disease; whilst in the remaining cases there is evidence of pathological effects most likely caused by other types of dementia, classed as mixed dementia (Alzheimer's Association, 2015). Recent evidence suggests that the boundaries between the various subtypes of dementia are less distinct, and that a large proportion of people with dementia have a mixed type (Alzheimer's Association, 2015; World Health Organisation, 2012).

In 2016, an estimated 47 million people were living with dementia worldwide (Prince, Comas-Herrera, Knapp, Guerchet, & Karagiannidou, 2016). This is predicted to increase to 131 million by 2050, an estimate that is 12-13% higher now than in 2009 (Prince et al., 2015). The associated costs of dementia globally for direct medical care, social care and informal care are currently US$ 818 billion, having risen from US$ 604 billion in 2010 (Prince et al., 2016).

1.2 Dementia in the UK

In the UK in 2015, 850,000 people were living with dementia, and this is predicted to rise to over 1 million by 2025 (All-Party Parliamentary Group, 2016). The total annual cost of dementia is currently £26.3 billion, of which the NHS pays £4.3 billion and social care pays £10.3 million (Prince et al., 2014). The remaining costs are paid for by people with dementia and their families. It is calculated that family carers of people with dementia save the UK £11 billion each year (Prince et al., 2014).

1.2.1 Dementia care

It is estimated that two thirds of people diagnosed with dementia are living at home, with one third living in residential care (Department of Health, 2013). People with dementia occupy 25% of hospital beds, and they are more likely to stay in hospital longer than people with other conditions, more likely to be readmitted, and more likely to die in hospital than other older people who do not have dementia but were admitted for the same reason (Department of Health, 2015).

In a survey conducted by the Alzheimer's Society (2011), 83% of people living with dementia said they wanted to stay at home for as long as possible. This was further reinforced by the findings of a government poll, in which 85% of people responded that they would want to stay at home for as long as possible following a dementia diagnosis (Department of Health, 2015). The government responded with a 2015 report outlining the Prime Minister's challenge on dementia, in which increasing the number of people with dementia who live longer in their own home, was set as a target to be achieved by 2020 (Department of Health, 2015). Equally important is improving services for those who require residential care and hospital treatment, which was identified as another target to be achieved in the next five years (Department of Health, 2015).

1.2.2 Activity

A holistic view of dementia considers an individual's unique context, values and preferences, as opposed to focusing only on their diagnosis or symptoms (Prince et al., 2016). Adopting this approach can support people to live at home longer, as well as ensuring that people who are living in care services have their aspirations for quality of life met (Alzheimer's Society, 2011). One area that was highlighted as a research priority in a survey of Alzheimer's Society members, and is encompassed within the holistic model, was providing appropriate and stimulating recreational activities for people living with dementia (Alzheimer's Society, 2012). Lack of activity, or boredom, is a problem reported for people with dementia both living at home and living in care services (Harmer & Orrell, 2008; Hellman, 2014). Reducing boredom can reduce the occurrence of behaviour that care providers find challenging to deal with, thereby reducing the need for pharmacological interventions (Department of Health, 2015). Activities that are engaging can increase positive emotions and decrease boredom (Leng, Yeo, George, & Barr, 2014). Facilitating independent activity can also be beneficial to avoid dependence on caregivers and to promote autonomy, and is possible at all stages of dementia, given the selection of appropriate activities (NICE-SCIE, 2007).

1.3 Technology and dementia

Technology is increasingly being used in dementia care (Topo, 2009), and there are many examples of touchscreen devices being incorporated into interventions (Armstrong, Nugent, Moore, & Finlay, 2010; González, Mashat, & López, 2013; Meiland et al., 2012; Zmily, Mowafi, & Mashal, 2014). It has been suggested that the touchscreen format is a more effective solution for providing assistive technology to people with dementia, as it makes less demand of hand-eye co-ordination when compared with a desktop computer using a mouse, cursor and keyboard (Wandke, Sengpiel, & Sönksen, 2012). Many examples of technology application in this field have been in the form of 'assistive' devices (Kerssens et al., 2015), and often where the person with dementia is not the intended user (S. K. Smith & Mountain, 2012). Less attention has been paid to using technology to provide personal activity, which is surprising given technology's role in facilitating entertainment for other sectors of the population (Astell, Alm, et al., 2014).

1.3.1 Stigma

One factor that may contribute to the relative lack of technology designed for use by people with dementia to provide recreation and entertainment is stigma. Stigma has been described as the discrediting or discounting of a person based on attributes that differentiate them from a larger population (Goffman, 1964). It can incorporate stereotypes (collective judgements), prejudice (emotional responses) and discrimination (behavioural responses; Benbow & Jolley, 2012). Stereotypical preconceptions of the needs, requirements and abilities of people living with dementia drive the forms of technology developed specifically for them (S. K. Smith & Mountain, 2012). Examples of such preconceptions include the notion that people with dementia cannot learn new skills because of their cognitive impairment (Mountain, 2006), and that a diagnosis of dementia prevents quality of life and reduces an individual's capacity for pleasure (Garand, Lingler, Conner, & Dew, 2009). These negative perceptions may be a consequence of measuring skills and performance against pre-diagnostic levels, that inevitably focus on loss (Naue & Kroll, 2009). If technological solutions instead focus on the retained abilities of people living with dementia, the potential for experiences that promote enjoyment and pleasure can be realised (Astell, 2013). This notion is congruent with the concept of positive psychology.

1.3.2 *Flow and positive psychology*

Positive psychology is a field concerned with wellbeing and optimal functioning (Duckworth, Steen, & Seligman, 2005). Essentially, positive psychology focuses on the things that make life worth living. Research in this field has increased significantly over the last fifteen years (Bolier et al., 2013). This increase has been demonstrated in its application to the older adult population (Astell, 2013), to the field of technology (Astell, 2013; Botella et al., 2012) and to the field of dementia (Wolverson [Radbourne], Clarke, & Moniz-Cook, 2010), where it has been highlighted as a theoretical basis for de-stigmatising the condition (de Vugt & Dröes, 2017). Positive psychology offers a holistic understanding of psychological health (Riva, Baños, Botella, Wiederhold, & Gaggioli, 2012), which, as discussed above (see 1.2.2), can be an effective approach to supporting people with dementia. At an individual level, positive psychology is about valued subjective experiences of one's past, present and future (Seligman & Csíkszentmihályi, 2000). Given the impact dementia has on a person's orientation to time and memory (see 1.1), it is perhaps the experience of one's present that is the most pertinent for people with dementia. In positive psychology theory, the present is characterised by the theory of flow (Seligman & Csíkszentmihályi, 2000). Flow explains why people enjoy activities that do not necessarily have an end product or any extrinsic good as an outcome, but that are simply rewarding in and of themselves (Nakamura & Csíkszentmihályi, 2001). Flow is a subjective state that seamlessly unfolds as the activity progresses, characterised by the following; intense and focused concentration; merging of action and awareness; loss of reflective self-consciousness; sense of control over the activity; distortion of temporal experience; and intrinsic reward (Nakamura & Csíkszentmihályi, 2001). While positive psychology has been adopted as a theoretical framework for improving understanding of dementia, there have been no reported examples of flow being applied to people with dementia.

1.3.3 *Engagement*

Any activity can become engaging if its core elements meet the requirements of flow (Murphy, Chertoff, Guerrero, & Moffitt, 2014). However, opportunities for engagement decrease for people living with dementia, and a prolonged absence of engagement can be detrimental to life quality (Cohen-Mansfield, Dakheel-Ali, & Marx, 2009). Consequently, engagement has been identified as the most important component of psychosocial interventions for people living with dementia (Cohen-Mansfield et al., 2009; Low et al., 2013; Trahan, Kuo, Carlson, & Gitlin, 2014). The potential for technology to provide opportunities for engagement with people with dementia through enjoyable leisure activities has been highlighted (S. K. Smith & Mountain, 2012). Measuring or assessing people with dementia's engagement in activities requires tools that sensitively and appropriately capture the elements of flow. Existing measures of engagement developed for dementia (e.g., Cohen-Mansfield et al., 2009; Orsulic-Jeras, Judge, & Camp, 2000) do not address flow. As such, finding ways to identify elements of flow in people with dementia, especially when engaged with an independent activity, are currently lacking. Exploring these in the context of touchscreen activities provides an opportunity to further knowledge on this topic. Furthermore, by ignoring stigmatising preconceptions and applying positive psychology and flow theory to the use of technology with people living with dementia, many possibilities arise for facilitating engagement through entertainment.

1.4 Thesis outline

The main hypothesis of this thesis is that touchscreen technologies have the potential to provide meaningful and stimulating activities for people with dementia. Guided by the principles of positive psychology and flow, this hypothesis is explored through a series of studies developed to examine how people with dementia respond to and interact with touchscreen devices and applications (apps) presented on them.

A literature review was conducted (Chapter 2) to examine (i) in what contexts touchscreen technology has been applied with people living with dementia, (ii) for what reason the technology was selected, (iii) what forms of hardware and software were used, and (iv) what evidence has been reported that people living with dementia could use touchscreen technology independently. The findings of the literature review were used to form the specific research questions. Study 1 (Chapter 3) examined what types of touchscreen games or leisure activities were most suitable for people living with dementia, and involved a thorough examination of how participants interacted with two touchscreen gaming apps. This led to the identification of multiple design barriers that affected the gameplay experience for participants. These were discussed with the developers of the two apps who subsequently incorporated adaptations into future software releases to address these barriers. The adapted apps were assessed in Study 2 (Chapter 4) following the same procedure as in Study 1, and the results were compared to evaluate the effectiveness of the app adaptations. Further analysis of participants' behavioural responses to the apps during gameplay sessions in Studies 1 and 2 was conducted (Chapter 5) to examine what indicators of engagement look like when people with dementia are using gaming apps independently. The results of Studies 1 and 2 led to the final empirical study (Chapter 6), which examined prompt features in the design of touchscreen games. Eye-tracking technology was used to analyse how people with dementia were using prompts when they played games. Chapter 7 describes a method of identifying accessible apps for people with dementia, and an online resource to share the outputs with other researchers, clinicians and people living with and affected by dementia. The overall results are discussed in relation to the original research questions in Chapter 8.

1.4.1 Method

An exploratory approach (Stebbins, 2001) was adopted to investigate the potential of touchscreen technology to create opportunities for independent activity with people living with dementia. This approach was considered to be appropriate given how relatively little is yet known about the use of everyday technology products by people living with dementia (Jiancaro, Jaglal, & Mihailidis, 2017), particularly in the context of facilitating leisure or entertaining activity (Astell, Alm, et al., 2014). Observing behaviour through the use of video recordings is a method that has been used in studies involving people living with dementia as users of technology (Astell, Alm, et al., 2014; C. Jones, Sung, & Moyle, 2017; Moyle et al., 2013; Purves, Phinney, Hulko, Puurveen, & Astell, 2014; Riley, Alm, & Newell, 2009). Benefits of this method include the depth of analysis possible (Astell, Alm, et al., 2014), the reduction of the effect of observer presence (C. Jones, Sung, & Moyle, 2015), and the ability to measure concepts such as engagement that can otherwise be methodologically challenging in dementia research (Moyle et al., 2014). Studies 1, 2 and 3 each employed video recordings as a method of data collection, to allow the researcher to capture two separate streams of data (iPad-facing and participant-facing recordings) whilst encouraging independent interaction by retreating from participants' line of sight. Quantitative video analysis using purpose-designed coding schemes was later conducted when all of the data had been collected.

Chapter 2. The use of touchscreen technology with people living with dementia: a review of the literature

2.1 Introduction

The increased availability of touchscreen technology devices in everyday life, such as smartphones and tablets, has led to an increased consideration by health care professionals and researchers of their potential suitability for people living with dementia (Malinowsky, Nygård, & Kottorp, 2014). This trend is set to continue as people are being diagnosed with dementia at a younger age, and coming generations will be more familiar with computer technology (Astell, Malone, Williams, Hwang, & Ellis, 2014). It has been suggested that the touchscreen format is a more effective solution as it makes less demand of hand-eye co-ordination when compared with a desktop computer using a mouse and cursor (Wandke et al., 2012). Therefore, the intuitive nature of touchscreen devices presents an opportunity for their application with people with dementia as the intended users of the technology, and for whom the benefits may be experienced directly. For this potential to be realised, the design of simple and accessible software should be considered a priority.

This review presents an overview of the ways touchscreen technology has been used with people living with dementia since its invention to the present generation of touchscreen devices, addressing the questions listed in Table 2.1.

Table 2.1. Questions addressed by the literature review

Q1.	In what contexts has touchscreen technology been used with people living with dementia?
Q2.	For what reason was touchscreen technology chosen?
Q3.	Which forms of hardware and software were used?
Q4.	Was there any evidence reported that people with dementia were able to use touchscreen technology independently?

2.2 Methods

A systematised review (Grant & Booth, 2009) of the literature was conducted on the topic of touchscreen technology used with people living with dementia.

The following search terms, including Boolean operators (e.g., AND, OR) and truncation symbols (denoted by *), were used for this review: (dementia) OR (Alzheimer*) AND (touchscreen) OR (touch screen) OR (tablet computer) OR (tablet device) OR (smartphone) OR (smart phone) AND (app*) OR (activit*) OR (game*) OR (gaming).

The following electronic databases were accessed for this review, selected due to their content being relevant to the subject area: Medline via Web of Science; PsychINFO via Ovid SP; ProQuest; PubMed; CINAHL via EBSCO; Cochrane. The search was extended to include references of relevant articles and existing articles in the researcher's reference management database. The literature search was conducted between the 20th July and the 7th August 2015. The results of this review were published in November 2016[1].

For the purpose of this thesis the literature search was repeated on the 12th September 2017 to update the search results by identifying any articles published since the original search was undertaken.

During screening, records were included/excluded based on the criteria in Table 2.2.

Table 2.2. Inclusion/exclusion criteria used for the literature search

Language	English
Participants	Human; living with dementia
Technology	Any featuring a touchscreen interface
Article type	Original research; not reviews, study protocols or opinion/commentary

The search protocol described above resulted in 257 references being returned through the database searches and 18 additional references through other sources/hand searching. Duplicate articles were removed resulting in a figure of

[1] Joddrell, P. & Astell., A. J. (2016). The use of touchscreen technology with people living with dementia: A review of the literature. JMIR *Rehabilitation and Assistive Technologies* (JRAT), 3(6) e10, http://doi.org/10.2196/rehab.5788

205. Subsequently, articles were removed having been reviewed against the inclusion and exclusion criteria, based on their title (97) and/or abstract (34). This resulted in 74 articles being obtained as full-text documents. Having read all of these articles, a further 12 were excluded due to them not meeting the inclusion and exclusion criteria; either because the studies did not actually involve people living with dementia or because a touchscreen interface was not featured. In total 62 articles were included for the final review (see Figure 2.1 below). It should be noted that in the second search phase in 2017, six articles were returned that met the above criteria but were not included due to them having been published by the author of the present review during the research project (see p.iii).

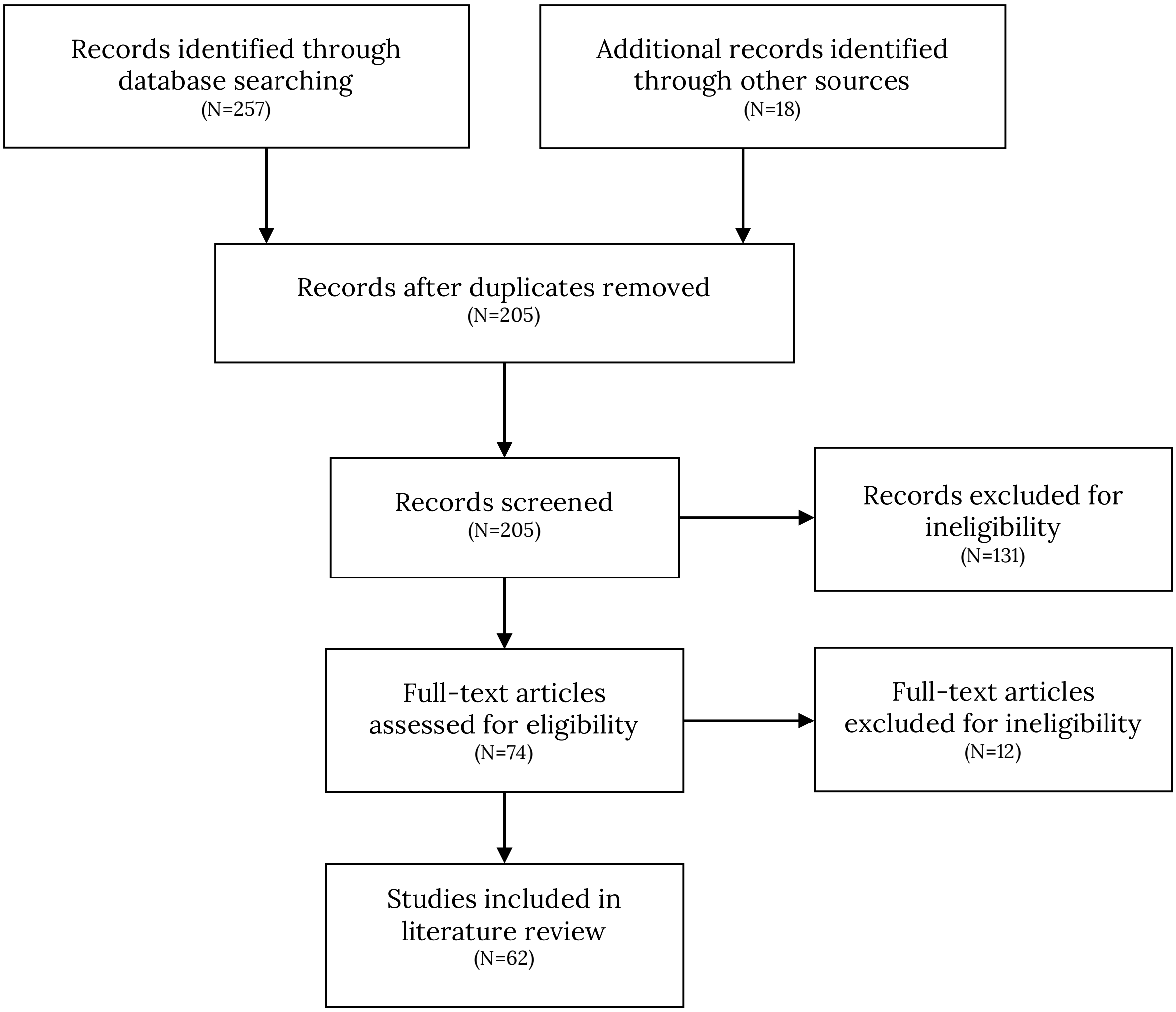

Figure 2.1. Flow diagram of search procedure (adapted from Moher, Liberati, Tetzlaff, & Altman, 2009)

2.3 Results

Sixty-two articles met the described criteria and were included for this review. Appendix A presents the summarised results of the review, and information from these articles has been synthesised to provide an overview on this topic, organised according to the questions outlined in Table 2.1.

2.3.1 *Contexts of use* (Q1)

Three broad categories of touchscreen technology utilisation were identified during the review; (i) **Assessment and screening** (15 articles); (ii) **Assistive technology and cognitive rehabilitation** (38 articles); and (iii) **Leisure activities** (12 articles). Three papers contained information pertaining to both an assistive device and a leisure activity and were counted in both categories (Alm et al., 2009a, 2009b; Kerkhof, Bergsma, Graff, & Dröes, 2017). Multiple papers within both the assistive and leisure categories described the same devices or software, which is highlighted. Each of these categories are now discussed in detail. It is worth noting that the majority of papers in the 'assessment and screening' category mostly describe the touchscreen device as a piece of equipment used to deliver a test, and rarely discuss the impact of selecting the specific technology.

2.3.1.1 Assessment and screening

The first reported use of touchscreen technology with people with dementia was in 1986 by Carr, Woods, & Moore, who compared the use of a touch-sensitive screen with a peripheral response device connected to a conventional computer monitor, to deliver two cognitive assessment or screening tests. In the early 1990s, two articles describe the incorporation of touchscreen technology into cognitive assessments: the Cambridge Neuropsychological Test Automated Battery (CANTAB; Sahakian & Owen, 1992); and the French-language Examen Cognitif par Ordinateur (ECO; Ritchie et al., 1993). Touchscreens have continued to be used for these purposes, evidenced by more recent examples delivering tests of global cognition (Ishiwata et al., 2014) or batteries of cognitive tests (Fukui et al., 2015; Inoue, Jimbo, Taniguchi, & Urakami, 2011; Inoue, Jinbo, Nakamura, Taniguchi, & Urakami, 2009; Weir et al., 2014) for the detection of dementia or mild cognitive impairment.

In addition to global cognitive assessment, several articles reported the use of touchscreen technology to deliver tests of specific cognitive functions; visual attention (Pignatti et al., 2005); working memory (Satler, Belham, Garcia, Tomaz, & Tavares, 2015); executive functioning (Manera et al., 2015) and visuomotor skills (Tippett & Sergio, 2006; Verheij et al., 2012). The remaining article in this theme (Ott et al., 2008) used computerised maze tests presented on a touchscreen computer to predict driving performance.

The vast majority of these articles developed original tests for the touchscreen format, such as the Edinburgh Dementia App (Weir et al., 2014) and the Touch Panel-type Dementia Assessment Scale (Inoue et al., 2011). Only one study reported the adaptation of an existing test; the sparse-letter display test (Pignatti et al., 2005), which had previously been presented on a computer but not using the touchscreen format.

2.3.1.2 Assistive technology and cognitive rehabilitation

The majority of articles describe the use of touchscreen technology to provide an assistive function for the person with dementia and/or their caregivers, or to present interactive cognitive exercises.
Seven of the reviewed papers discussed the Computer Interactive Reminiscence and Conversation Aid (CIRCA), a communication support tool using digital reminiscence materials to stimulate conversation between the person with dementia and a conversation partner (Alm et al., 2004, 2009a, 2009b; Alm, Dye, et al., 2007; Astell et al., 2009, 2010; Purves et al., 2014). Only one other article featured communication as the primary focus (Ekström, Ferm, & Samuelsson, 2017), but several studies also used reminiscence materials presented on a touchscreen interface to provide other assistive functions (Critten & Kucirkova, 2017; Kerssens et al., 2015; Kikhia, Hallberg, Bengtsson, Savenstedt, & Synnes, 2015; Nezerwa et al., 2014; Pang & Kwong, 2015; Pringle & Somerville, 2013; Yamagata, Coppola, Kowtko, & Joyce, 2013). The use of touchscreen technology to support therapists was also evident in the context of art therapy and occupational therapy (Hoey, Zutis, Leuty, & Mihailidis, 2010; Leuty, Boger, Young, Hoey, & Mihailidis, 2013; Tomori et al., 2015). Several articles reported the use of touchscreen technology to address multiple activities of daily living (ADL) and self-management for people with dementia (Armstrong et al., 2010; Boyd, Evans, Orpwood, & Harris, 2017; Davies et al., 2009; Imbeault, Langlois, Bocti, Gagnon, & Bier, 2016; Kerkhof et al., 2017; Meiland et al., 2012; Nijhof, Gemert-Pijnen, Burns, & Seydel, 2013), including calendars, diaries, video calling and location tracking. Two recently conducted studies investigated the use of touchscreen apps as an intervention intended to reduce the reporting of behavioural expressions that professional carers interpret as 'challenging' (Loi et al., 2017; Vahia et al., 2017). Although different terminology was used to describe their focus, the remaining 11 articles categorised in this section used touchscreen technology to present cognitive exercises to people with dementia, either using originally designed software (González et al., 2013; Hackner & Lankes, 2016; Hofmann et al., 2003; Hofmann, Hock, Kühler, & Müller-Spahn, 1996; Hofmann, Hock, & Müller-Spahn, 1996; Kim, 2016; Tziraki, Berenbaum, Gross, Abikhzer, & Ben-David, 2017; Zaccarelli, Cirillo, Passuti, Annicchiarico, & Barban, 2013; Zmily et al., 2014) or existing apps (Kong, 2015, 2017).

2.3.1.3 Leisure activities

Several of the aforementioned articles have featured games or leisure activities, however these have been designed to assess cognition (Fukui et al., 2015; Manera et al., 2015), provide cognitive stimulation (Hackner & Lankes, 2016; Kim, 2016; Kong, 2015, 2017; Nijhof et al., 2013; Pang & Kwong, 2015; Tziraki et al., 2017;

Zaccarelli et al., 2013), or to assist in the delivery of therapeutic interventions (Hoey et al., 2010; Leuty et al., 2013; Loi et al., 2017; Vahia et al., 2017). Very few studies focused on games or activities purely for entertainment or leisure purposes.

Four of the reviewed articles described ‘Living In the Moment’ (LIM; Alm et al., 2007, 2009a, 2009b; Astell, Alm, et al., 2014), a suite of touchscreen games and activities that at various stages of the project included virtual environments, skill games, games of chance and creative activities; the common factor being that they were all designed in partnership with people living with dementia. Original design was also utilised in four articles; two focusing on musical creativity (Riley, 2007; Riley et al., 2009); one on the experience of viewing art (Tyack, Camic, Heron, & Hulbert, 2015); and one to provide enjoyable activity either independently or in a group setting (Yamagata et al., 2013). The remaining articles included in this section investigated the use of existing touchscreen activities (Astell, Malone, et al., 2014; Cutler, Hicks, & Innes, 2016; Kerkhof et al., 2017; Leng et al., 2014; Lim, Wallace, Luszcz, & Reynolds, 2013), rather than those developed specifically for people with dementia.

2.3.2 *Touchscreen technology selection* (Q2)

Many, although not all, of the reviewed articles reported why they had chosen touchscreen technology. The reasons can be summarised into the following categories: intuitive control method (10 articles); practicalities of administration (16 articles); ability to customise and adapt (seven articles); and the multi-functional nature of the devices (12 articles). These reasons will now be explored further.

2.3.2.1 Intuitive control

The touchscreen control method is widely regarded as intuitive (Carr et al., 1986; González et al., 2013; Leng et al., 2014; Lim et al., 2013) and easy to use (Hackner & Lankes, 2016; Inoue et al., 2009; Satler et al., 2015; Tziraki et al., 2017; Yamagata et al., 2013), making it highly advantageous for people with dementia. Eliminating the need for external input devices (e.g., a keyboard and mouse) is beneficial as it reduces the cognitive load required to input information (Carr et al., 1986; González et al., 2013; Hackner & Lankes, 2016; Lim et al., 2013; Pignatti et al., 2005; Tziraki et al., 2017). This was addressed directly in Tippett & Sergio (2006), where the performance of people with dementia on a visuomotor test was highest when the touch-sensitive interface was placed directly over the computer monitor as opposed to in front or to the side. A similar method was used in the study by Carr, Woods & Moore (1986), who reported that participants in the group using an external response board would sometimes intuitively reach out to touch the screen. An alternative example can be seen in Ott et al. (2008), where participants were required to use a stylus to trace a path through the maze in order to replicate the 'natural' method of using a paper and pen.

2.3.2.2 Practicalities

In administering cognitive tests or cognitive rehabilitation, touchscreen computers are seen as a more practical solution for a number of reasons. These include increased accuracy of data input (Inoue et al., 2009; Ott et al., 2008; Sahakian & Owen, 1992; Satler et al., 2015), flexible but also standardised administration (Inoue et al., 2009; Satler et al., 2015), reduction in administration bias by avoiding experimenter effects (Inoue et al., 2009; Ishiwata et al., 2014), financially efficient implementation (Inoue et al., 2011; Ott et al., 2008; Satler et al., 2015; Tziraki et al., 2017), improved connectivity between patients and professionals (Kim, 2016), and the wide availability of this technology in healthcare settings (Weir et al., 2014).
Additionally, the use of touchscreen computers reduces the practical requirement for members of staff to prepare and manage multiple materials, such as reminiscence materials (Alm et al., 2004; Astell et al., 2010; Kong, 2015; Pringle & Somerville, 2013; Tomori et al., 2015). This is highlighted as a potential time-saving measure for often busy clinical staff (Leuty et al., 2013). The reduction of physical materials was also the motivation for researchers to recommend the use of a touchscreen diary and calendar app as opposed to a paper-based diary for a person living with dementia, as reported in the case study by Imbeault et al. (2016).

2.3.2.3 Customisation

Programs and apps presented on touchscreen devices can be designed to facilitate customisation, which allows for easy adaptation and consequently they can be responsive to the needs of the users (Astell, Malone, et al., 2014; Hoey et al., 2010; Leuty et al., 2013; Pang & Kwong, 2015; Satler et al., 2015). Presenting customisation options within programs in an accessible format allows a caregiver or therapist to tailor the program to each individual (Critten & Kucirkova, 2017; Hoey et al., 2010; Leuty et al., 2013). This is particularly beneficial for people with dementia as programs can become responsive to change to an individual's cognitive functioning and abilities over time. For example with games, it is important to include difficulty options so that each player can find a suitable entry point (Kerkhof et al., 2017; Pang & Kwong, 2015). Another benefit to customisation highlighted in the literature is with regards to administering cognitive assessments; that being able to easily manipulate experimental parameters allows for repeat testing whilst avoiding learned responses (Satler et al., 2015).

2.3.2.4 Multi-functional use

A further advantage of touchscreen devices such as tablets and smartphones is that they can provide a wide range of functions for the user. As is reflected in the literature, these devices can address the multiple needs of people with dementia, such as increasing socialisation, providing memory prompts, facilitating activities, and delivering educative tools (Astell, Malone, et al., 2014; Ekström et al., 2017; Lim et al., 2013; Meiland et al., 2012; Nezerwa et al., 2014; Pang & Kwong, 2015; Vahia et al., 2017). During reminiscence activities, for example, photographs and music can be accessed simultaneously, increasing their potential to trigger memories (Critten & Kucirkova, 2017; Pringle & Somerville, 2013). The fact that a wide variety of downloadable apps can be added to such devices (Critten & Kucirkova, 2017; Kong, 2015, 2017; Leng et al., 2014), and they are Internet accessible (Critten & Kucirkova, 2017), only increases the range of these functions. It is also reported that built-in and attachable accessories, such as cameras (Critten & Kucirkova, 2017; Kikhia et al., 2015), microphones (Critten & Kucirkova, 2017) and sensors (Zmily et al., 2014), can even further increase the functionality available through these devices.

2.3.3 *Hardware and software* (Q3)

Where stated in the literature, information related to the hardware and software used in the reviewed studies is now discussed. The information that was considered to be most relevant was screen size and the model of tablet devices or smartphones and their operating system (OS). To allow for easier comparison, all screen sizes have been converted to inches (diagonal) if not already presented in this unit.

2.3.3.1 Screen size

The touchscreen devices used in the reviewed articles range in size, largely determined by whether a monitor (largest), tablet or smartphone (smallest) was used. Sixteen articles reported and specified using a touchscreen monitor, or a touch-sensitive interface in combination with a monitor (Alm et al., 2004; Alm, Astell, et al., 2007; Astell et al., 2010; Carr et al., 1986; Davies et al., 2009; Fukui et al., 2015; Hoey et al., 2010; Hofmann et al., 2003; Inoue et al., 2011, 2009; Ott et al., 2008; Pignatti et al., 2005; Purves et al., 2014; Satler et al., 2015; Tippett & Sergio, 2006; Weir et al., 2014). Screen size in these studies ranged from 14 inches to 32 inches, with a mode size of 20 inches. Seven articles reported and specified using a tablet device (Hackner & Lankes, 2016; Imbeault et al., 2016; Kong, 2015; Leng et al., 2014; Lim et al., 2013; Tomori et al., 2015; Yamagata et al., 2013), five of which featured a screen size of 9.7 inches. Three articles reported and specified using a smartphone, with sizes of 2.8 inches (Davies et al., 2009), 3.5 inches (Astell, Malone, et al., 2014) and 3.8 inches (Armstrong et al., 2010).

With regard to size, a larger screen can be advantageous for people with cognitive impairment, particularly when there is the addition of a visual impairment (Hackner & Lankes, 2016; Riley et al., 2009). This would support the use of monitors, however the portability of tablet devices and smartphones is also seen as advantageous (Hackner & Lankes, 2016; Satler et al., 2015; Tziraki et al., 2017), as is the availability and ease of access to downloadable apps (Kerkhof et al., 2017; Kong, 2015; Leng et al., 2014).

There should be consideration for the suitable placement of tablet devices during interactions, given their size and weight, with the recommendation of placing the device on a surface (e.g., table) and raising the height to a comfortable level for the user to reduce muscle stress (Satler et al., 2015; Tziraki et al., 2017). Natural light is beneficial to aid vision, but the position of the tablet should be such to prevent screen glare (Tziraki et al., 2017). Finally, the small size of smartphone screens has been highlighted as a potential issue for people with dementia during user testing (Armstrong et al., 2010).

2.3.3.2 Models and systems

Eleven of the studies that reported using tablets (and specified which device) used an Apple iPad (Critten & Kucirkova, 2017; Cutler et al., 2016; Hackner & Lankes, 2016; Kong, 2015, 2017; Leng et al., 2014; Lim et al., 2013; Loi et al., 2017; Tomori et al., 2015; Vahia et al., 2017; Yamagata et al., 2013). In discussing the reason for selecting an iPad, and therefore the Apple OS (iOS), Lim et al. (2013) and Kerkhof et al. (2017) both commented on its ease of use when compared with Android OS or Windows OS, a factor that is particularly important where the intended users are people with dementia. However, three studies did use tablets with Android OS, although they did not discuss their reason for this selection (Hackner & Lankes, 2016; Imbeault et al., 2016; Tyack et al., 2015). Android (Zmily et al., 2014), Windows (Armstrong et al., 2010) and Apple (Astell, Malone, et al., 2014) were each used as the OS in studies that specified smartphone use. Zmily et al. (2014) used near-field communication (NFC) technology, and selected the Android OS primarily because, at the time, the majority of mobile devices with NFC functionality used Android. Commenting on app development, Pang & Kwong (2015) stated that apps designed for people with dementia should be developed for both Apple and Android to allow people the choice of which device to purchase, particularly in relation to cost.

2.3.4 *Independent use* (Q4)

The use of touchscreen technology in the reviewed articles involved a range of interaction levels between the people with dementia and the devices. Supported use was common, where the person with dementia interacts with the technology in the presence of a clinician or carer, where input may be encouraged or shared (Astell et al., 2010; Ekström et al., 2017; Kerkhof et al., 2017; Kim, 2016; Leuty et al., 2013; Pringle & Somerville, 2013; Purves et al., 2014; Riley et al., 2009; Tomori et al., 2015; Tyack et al., 2015; Weir et al., 2014). Many studies involved devices that were designed for independent use, or used existing devices that were utilised independently by the person with dementia (Alm, Astell, et al., 2007; Armstrong et al., 2010; Astell et al., 2009; Astell, Alm, et al., 2014; Astell, Malone, et al., 2014; Critten & Kucirkova, 2017; Cutler et al., 2016; González et al., 2013; Imbeault et al., 2016; Inoue et al., 2011; Ishiwata et al., 2014; Kerssens et al., 2015; Kikhia et al., 2015; Lim et al., 2013; Manera et al., 2015; Meiland et al., 2012; Nijhof et al., 2013; Pang & Kwong, 2015; Pignatti et al., 2005; Tippett & Sergio, 2006; Tziraki et al., 2017). In some cases, independent use was successful. For example, Lim et al. (2013) reported that half of their participants were able to use an iPad independently for leisure activities, and a quarter were able to store and charge the device without support.

Participants using the LIM games were left alone to interact with the touchscreen and the majority were able to navigate the system independently, even at the prototype stage (Alm, Astell, et al., 2007). Two-thirds of participants were able to use the Companion system independently, although the remaining third were not, with the authors citing personal motivation and physical impairment as potential factors (Kerssens et al., 2015). Although the "COGKNOW" system was designed for independent use by people with dementia, in practice it was found that those people who lived with a partner tended to rely on them for support (Meiland et al., 2012), a factor that was also reported in two other articles (Ekström et al., 2017; Tyack et al., 2015). Several articles reported positive factors for people living with dementia associated with independent use of the touchscreen devices, including relaxation (Kerssens et al., 2015), enjoyment (Astell, Alm, et al., 2014; Cutler et al., 2016; Kerssens et al., 2015; Nijhof et al., 2013; Tziraki et al., 2017), autonomy (Astell, Alm, et al., 2014; Cutler et al., 2016; Imbeault et al., 2016; Kerssens et al., 2015; Nijhof et al., 2013), motivation (Manera et al., 2015), socialisation (Astell et al., 2009; Cutler et al., 2016) quality of life (Imbeault et al., 2016), reduced stigma (Cutler et al., 2016) and engagement in the activity (Astell, Alm, et al., 2014; Cutler et al., 2016).

In reviewing the articles for evidence of independent touchscreen use by people with dementia, several key factors emerge relating to the potential for successful outcomes, namely: training; use of prompts; integrated feedback; and visual design. Each of these factors will now be discussed.

2.3.4.1 Training

There were many examples of studies using a training or demonstration phase before participants were expected to use a device independently (Astell, Malone, et al., 2014; Boyd et al., 2017; Cutler et al., 2016; Ekström et al., 2017; Hackner & Lankes, 2016; Imbeault et al., 2016; Kim, 2016; Kong, 2017; Manera et al., 2015; Pignatti et al., 2005; Sahakian et al., 1993; Satler et al., 2015; Tippett & Sergio, 2006; Zaccarelli et al., 2013; Zmily et al., 2014). In several cases this involved the researcher or clinician demonstrating or instructing device use, followed by a familiarisation phase where the participant would be observed using the device so that their understanding could be verified (Imbeault et al., 2016; Pignatti et al., 2005; Sahakian et al., 1993; Satler et al., 2015; Tippett & Sergio, 2006). In one example employing this method, the familiarisation phase would only end once the clinician was satisfied that the participant could use the device independently, up to a maximum of eight trials (Tippett & Sergio, 2006). In another example, a simplified version of the actual trial test was used during this phase to prevent learning bias (Pignatti et al., 2005). Zmily et al. (2014) predicted that a demonstration would be necessary given that the target population is generally less experienced using computer devices, which was supported in their results. Imbeault, et al. (2016) highlight the importance of a supported training phase to ensure that errors are not adopted from such an early stage. In their case study, Astell, Malone, et al. (2014) concluded that the participant's successful adoption of several forms of new technology was achieved because of the high level of appropriate training and support delivered by the researcher, but they also stress that this will not always be feasible to deliver.

2.3.4.2 Prompts

Many of the articles described the use of integrated prompts within their software to direct or regain the attention of the user, although the outcomes are varied. In developing the LIM games, the research team considered and experimented with many different forms of prompts including text boxes, animations, the spoken voice and an avatar (Alm, Astell, et al., 2007; Astell, Alm, et al., 2014). The idea of an avatar was rejected due to the potential for it to be overly distracting, whilst the spoken voice prompt was implemented but often ignored (possibly due to its synthetic nature being unrecognisable), or relied upon too heavily resulting in a passive experience where the user would just wait until they next received an instruction. In contrast, the text boxes and animations were found to be more successful, with the conclusion being that

overly intrusive prompts were unnecessary (Astell, Alm, et al., 2014). Other studies reported using spoken prompts in their programs (Boyd et al., 2017; Inoue et al., 2011; Ishiwata et al., 2014; Kikhia et al., 2015; Zmily et al., 2014), either through human recording or synthesised text-to-speech. Inoue et al. (2011) reported that participants were more likely to find hints useful in the earlier stages of dementia. In Meiland et al. (2012), the use of visual and audio prompts was reported to be largely unsuccessful, with users either not noticing the prompt or ignoring it. Combining visual and audio information was found to be the most successful formula for effective prompting in the study by Boyd et al. (2017).
There was also variety between the studies in how prompts were triggered: following a period of inactivity (Alm, Astell, et al., 2007; Astell, Alm, et al., 2014); following a pre-determined number of errors (Manera et al., 2015); or using AI to detect a reduction in engagement, measured through eye-tracking and screen touches (Leuty et al., 2013).

2.3.4.3 Feedback

The importance of feedback in response to user input when designing or selecting touchscreen software for use by people with dementia was discussed in several articles (Astell, Alm, et al., 2014; Pignatti et al., 2005; Riley et al., 2009; Tziraki et al., 2017). Feedback should involve either an animation or sound effect (or both) contextual to the input and should be immediate, to acknowledge the user interaction (Astell, Alm, et al., 2014).

2.3.4.4 Visual design

When designing interfaces specifically for people with dementia on touchscreen devices, the reviewed literature recommends the avoidance of complexity (Hoey et al., 2010; Kerkhof et al., 2017; Kikhia et al., 2015; Pang & Kwong, 2015; Riley et al., 2009). The number of steps to navigate or achieve goals should be kept to a minimum (Kerkhof et al., 2017; Kikhia et al., 2015; Nezerwa et al., 2014; Pang & Kwong, 2015; Riley et al., 2009), with uncluttered interfaces (Kerkhof et al., 2017; Riley et al., 2009) and the consistent use of colours and icons so that users have a sense of context (Boyd et al., 2017; Kerkhof et al., 2017; Kikhia et al., 2015; Nezerwa et al., 2014; Pang & Kwong, 2015). Common design features within apps may be problematic for people with dementia (e.g., drop-down menus and ambiguous icons without text), and therefore should be avoided (Nezerwa et al., 2014; Pang & Kwong, 2015). Icons, text and graphics should be appropriately sized for people who may have visual impairment (González et al., 2013; Hackner & Lankes, 2016; Kerkhof et al., 2017; Nezerwa et al., 2014; Pang & Kwong, 2015) and the interactive elements should be of a large enough size to allow for less precise motor control (González et al., 2013). In software featuring motion, such as games, a slow pace of movement, or the ability to control the pace, is recommended (Cutler et al., 2016; Kerkhof et al., 2017).

The multi-touch control method (i.e., tap, drag-and-drop, pinch, etc.) popular on market-leading touchscreen devices has the potential to allow for easier and more engaging interactions for people with dementia (Leuty et al., 2013). However, with multi-touch there is the risk of accidental gestures caused by users resting their hand on one part of the screen whilst interacting with another (Carr et al., 1986; Riley et al., 2009), although considered programming can prevent this (Carr et al., 1986; Leuty et al., 2013). Using familiar imagery to cue users into their activity can be helpful for people with cognitive impairment (Astell, Alm, et al., 2014), and offering activities that are familiar to people (Cutler et al., 2016; Kerkhof et al., 2017; Kong, 2017), such as virtual representations of everyday environments to explore (Alm, Astell, et al., 2007), or digital versions of existing games to play (Lim et al., 2013), has also shown to be favourable with this population.

To support the design process, Astell et al. (2010) recommended educating all members of the research and development team on dementia, and enabling everyone to spend time talking with people with dementia and seeking their input. An iterative design process in collaboration with users is also recommended (Alm, Astell, et al., 2007; Astell et al., 2009; Hackner & Lankes, 2016; Tyack et al., 2015). This can reduce the risk of releasing products that have poor performance, stability issues or are not fit for purpose, which is highlighted as being crucial in order to achieve acceptance and adoption by people living with dementia, their families and services supporting them (Meiland et al., 2012).

2.4 Discussion

Whilst the use of touchscreen technology with people with dementia is in its infancy across the board, of the three main contexts (assessment, ADL, leisure) highlighted in the results, the most apparent gap in the literature is in the application of these devices for leisure activities. Only 12 articles were returned from the literature search that could be categorised in this area, and within these only eight projects are featured, as multiple articles focused on the same work. This is all the more unusual given that worldwide the most popular app category in the market leading app store for smartphones and tablets is games (Chapple, 2016). There is no reason to believe that a diagnosis of dementia should alter people's interests and hobbies. Moreover, one of the biggest challenges for people living with dementia and those who care for them is finding ways to provide stimulating and meaningful activities for them to engage with (Alzheimer's Society, 2012).

2.4.1 *Application of knowledge*

Understanding why touchscreen technology has been used with this population in the past can help to make decisions as to how it might be used in the future. This is particularly pertinent given the speed with which this technology evolves, and the availability of new design features both internally (software) and externally (hardware). Having reviewed the literature, clearly what has attracted researchers, clinicians and designers working with people living with dementia to touchscreen technology is the intuitive control method. Whilst not entirely new technology (Carr et al., 1986, heralded its use more than 30 years ago), the increase in availability, popularity and affordability of touchscreens in recent years has perhaps provided a new entrance into personal computing for people with dementia. The practicalities, customisation and multi-functional abilities discussed in the literature could to a certain extent also be applied to non-touchscreen computing devices. However, in combination with the intuitive control method, it is no surprise this technology is gaining the interest of those working with people with dementia. Areas that might require further consideration include how customisation can best be employed to improve the accessibility of this technology and how, with such a vast number of apps available, to identify which ones might be suitable for people with dementia. Perhaps the most difficult outcome to analyse relates to the hardware, as there is a potential disparity between what is most available and popular on the market (and therefore presents the most opportunity) and what might be the most appropriate for this population. The majority of studies featured in this review used larger touchscreen devices (20 inches being the most common). In comparison with the Apple iPad, which was the single most used device in the remaining studies, this is almost four times the size. It is likely that in some of these cases there was no choice to be made, as tablet devices with 'acceptable' hardware have only been widely available since 2010 (Walker, 2011). Given the knowledge gained on software design, a larger sized interface would certainly be beneficial for this population. However, with tablet devices like the iPad offering so many easily accessible, low-cost apps, and their (comparatively) smaller size offering more portability, there are advantages to this technology too. There is perhaps not enough information currently to definitively answer this question, and it is unlikely that there will be a 'one-size-fits-all' solution given the variety of contexts and individual variations (e.g., individual or group activity, age, presence of physical impairment, etc.). If the principles of interaction derived from the earlier studies featuring larger touchscreens could be achieved with tablets, then this might provide an accessible, economically viable approach going forward. It would also be sensible to consider the specific target population and context in advance of each study, and consult with people with dementia and people in a caregiving role before making a decision.

2.4.2 *Evolving evidence base*

The second phase of the literature review, conducted two years after the original search, returned articles that for the most part were consistent with the earlier studies (articles returned in the second phase are clearly labelled in the table of results presented in Appendix A). However, several trends did emerge to indicate that the evidence base is evolving. The most obvious difference was the absence of any new articles detailing the use of touchscreen technology for assessment and screening. In the original search, 15 papers described the use of devices with touchscreen interfaces to assess cognition or screen for dementia severity, published between 1986 and 2015. This could simply be due to chance, an explanation made more likely by the fact that there was no indication that the use of touchscreen devices for assessment and screening was waning over the original search period (five of the original 15 articles were published between 2014 and 2015), and the fact that there have been other years with no articles published on this topic (e.g., 2010, 2013).

A more unsurprising and easily explainable difference is that 10 of the 11 articles incorporated into the review from the second search phase featured tablet computers as the selected touchscreen format. This is in comparison with only five of the original 51 articles, and reflects the ubiquity of tablet computers on the market (Tziraki et al., 2017). It is also possible that these newer studies were picking up on the potential of tablets that was demonstrated in some of the earlier studies reporting their effectiveness with people with dementia (e.g., Kong, 2015; Leng et al., 2014; Lim et al., 2013).

However, one of the key findings that remained consistent from the original to the repeated search, was the relatively low number of studies investigating the use of touchscreen technology to deliver entertainment or leisure for people with dementia.

2.4.3 *Limitations*

It became apparent during the review that many articles did not report all of the information that might be considered pertinent to the completion of a comprehensive overview of this topic. This absence, combined with the relatively modest number of articles identified, is a limiting factor in applying the findings. For example, if the studies that reported trials of apps/devices consistently included information about the age and severity of cognitive impairment experienced by people living with dementia, this would advance knowledge about how the technology could be used at the various stages of the

condition. This is not to assume that there would necessarily be a correlation, for as Kerssens et al. (2015) reported; independent use was related more to personal motivation or curiosity for the technology than level of cognitive function.
Another potential limitation is that the review may not have uncovered all articles that have used touchscreen technology with people who have dementia. The decision was made to include only articles that directly referred to the use of a 'touchscreen' (or 'touch screen') interface. Every effort was made to investigate alternative terminology but nothing consistent was found, therefore the presence of the term 'touchscreen' (or 'touch screen') dictated the search results. It also highlights the small amount of direct research touchscreens have received with this population beyond being an alternative to pen and paper cognitive tests.

2.5 Conclusion

The reviewed literature can be seen as an emerging body of evidence that people who have dementia can independently use touchscreen technology. Certainly, there are caveats here involving the appropriate level of support needed, both on a human and a technological level, but there is clearly enough reason to warrant continued research into this area. The results have highlighted numerous learning outcomes whilst also identifying areas that are currently under-researched. It is clear that touchscreen devices are not only usable by people living with dementia, but the wide array of functions available offer great potential to improve their lives in many different contexts. This knowledge and understanding of the literature formed the basis of all decisions made in this thesis, beginning with the formation of the following research questions.

2.6 Research questions

1. What types of touchscreen games or leisure activities are most suitable for people living with dementia?
2. Can people with dementia play touchscreen games independently?
3. How can suitable apps for people living with dementia be identified?
4. How can touchscreen apps be customised to improve their accessibility for people living with dementia?

Chapter 3. Investigating the potential of touchscreen games for independent leisure activity for people living with dementia (Study 1)

3.1 Introduction

For people with dementia, there is currently a lack of satisfying and enjoyable forms of entertainment with which to meaningfully engage that does not place huge demands on caregivers (Clissett, Porock, Harwood, & Gladman, 2013). Identifying independent activities for people with dementia that are both stimulating and safe would benefit both the individual and their caregivers (Alm et al., 2009b). Touchscreen devices, such as smartphones and tablets, are increasingly available, affordable and accessible (Marceglia, Bonacina, Zaccaria, Pagliari, & Pinciroli, 2012), and as highlighted from the reviewed literature on this topic (see Chapter 2); they have the potential for providing entertainment for people with dementia with which they can engage and enjoy independently (Astell, Malone, et al., 2014).
Previous research addressing the use of touchscreen interfaces with people with dementia for entertainment purposes has identified that activities that require constant interaction and an element of challenge can hold the user's attention and be enjoyable (Astell, Alm, et al., 2014). This work, along with more recent projects (Burdea et al., 2014; Manera et al., 2015), focused on the development of original touchscreen games designed specifically for people with dementia. Whilst the advantages of this method are clear, there could also be value in looking at existing touchscreen apps that have not been designed specifically for people with cognitive impairment. This would bring a vast range of readily available choice and, by utilising apps that are available to the wider population, reduce stigma (S. K. Smith & Mountain, 2012). These two approaches (bespoke and off-the-shelf) need not be considered mutually exclusive as any outcomes learned from one can serve to benefit the other. Evidence for this can be found in similar work involving the development of games for older adults without dementia or cognitive impairment, where existing games were used initially to collect design recommendations (Marston, 2013). If suitable 'off-the-shelf' games could be identified for people living with dementia, and a model for selecting them developed, this could provide users with a greater variety of choice whilst reducing the possibility of stigmatisation, as well as potentially informing the development of new games in the future.

3.1.1 *App preferences and familiarity*

An evaluation of available touchscreen apps on the Apple iPad carried out in 2012 offered people living with dementia a choice of 10 apps classified into two types: 'competitive games' (e.g., Checkers) and 'sensory activities' (e.g., Pocket Pond; Groenewoud, Schikhof, Astell, Goumans, & de Lange, 2014). The research, conducted in the Netherlands, had a researcher either sitting with or near to the participants to help them navigate the tablet. One app, 'Sjoelen' (translated as Shuffleboard), was by far the most popular, accounting for 77% of all 82 selections, with the second most popular accounting for only 23%. Sjoelen is a representation of a popular Dutch board game (Algemene Nederlandse Sjoelbond, 1988) that requires players to slide pucks along a playing board into any of four compartments that carry point values of one to four. The app's title and icon, and the design of the board and playing pieces, are accurate to the original 'real-world' game, which may have provided the necessary cues for the participants to recognise the game. The finding that people living with dementia consistently chose this game suggests that familiarity with the 'physical' version of the game could have influenced their selection. However, because the participants were free to choose which app they used, it is not known whether familiarity affected their ability to use the app or how much they enjoyed using it, compared with unfamiliar, or novel, apps.

The current study therefore investigated the effect of familiarity on usability and enjoyment by people with dementia, focusing on apps identified as games (as opposed to sensory experiences). A series of selection parameters were devised on which to base decisions about the selections of apps, developed using the evidence synthesised from the literature review (see section 2.3). These criteria were used to select two games designed for individual play that were deemed the most accessible for people with dementia when compared with all available apps of their type - one 'familiar' and one 'novel'.

3.1.2 *Research questions*

The following research questions were addressed: (1) Are people living with dementia able to play games on the iPad independently (without a researcher or caregiver on hand); (a) does the familiarity of the game affect their ability to play it on the iPad, and (b) does their performance on the game improve over time? (2) Do people living with dementia enjoy playing games on the iPad independently; (a) does the familiarity of the game affect their enjoyment of it? (3) What can be learned about how people living with dementia interact with touchscreen apps through detailed observation of their gameplay sessions?

3.1.3 *Patient and Public Involvement (PPI)*

A member of the research team attended the South Yorkshire Dementia Research Advisory Group on 20th March 2014 to discuss the planned project and demonstrate the two selected iPad games. Attendees of the group were given the opportunity to play these games and they approved their selection as being potentially suitable for people living with dementia. They also provided feedback on their experience and on other aspects of the planned research, which was used to inform various elements of the protocol, as indicated in the relevant sections below.

3.2 Method

3.2.1 *Design*

Given that the evaluation of digital technology interaction by people living with dementia is a relatively innovative research topic (see 1.4.1), an exploratory research design was used employing quantitative analysis of video recorded gameplay sessions. Thirty participants were recruited and alternately assigned to one of two groups: Group 1 played the familiar game and Group 2 played the novel game. Each participant was asked to play the same game at three different time-points over the course of a five-day period, with each gameplay session being video recorded.

3.2.2 *Participants*

Thirty people living with dementia were recruited from residential, specialist dementia and day services. Twenty-five of the participants were female and five were male. Their mean age was 87 years (range 78-100; SD 8.3). The presence of cognitive impairment was confirmed using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), with a score of <26 required to distinguish between dementia and healthy controls. The participants' mean score on the MoCA was 13.4 out of 30 (range 8-21; SD 5.5).

The study received a favourable ethical opinion from the School of Health And Related Research (ScHARR) Ethics Committee at The University of Sheffield (see Appendix B). A member of the research team obtained consent from each participant. Members of staff from the care services supported the consent process as gatekeepers by identifying potential participants and providing them with an information sheet (see Appendix C). The researcher only approached individuals if they were agreeable to finding out more information about the study. Those who consented were visited individually within their care service and the study was explained to them in full. A member of the research team assessed each person's capacity to consent to participate in the research based on the criteria set out in the Mental Capacity Act (England & Wales; 2005), and following recommended guidelines published by the British Psychological Society (Dobson, 2008). On receiving verbal consent to take part in the study, and with satisfaction that the person had the capacity to make this decision, signed consent was obtained from the individual (see Appendix C). As decisions are time-specific, the researcher reviewed this procedure at every point of contact with each participant. All participants were made aware that they were free to leave the study at any time. The input of relatives was not required as all participants demonstrated the capacity to consent to participate, however it was agreed with the service managers and participants that relatives would be informed that the study was taking place.

3.2.3 *Materials*

3.2.3.1 Games

Familiar game. In selecting a familiar game, an app was sought that was a digitised version of an existing game that is sufficiently popular to have a high chance of being known to the target population (in the UK). 'Solitaire' (or 'Patience') is a one-player card game that has been played in England since the late 19th century (Parlett, 1979) and that saw an increase in popularity during the 1980s through its inclusion on early personal computers (CleverMedia, 1999). The decision by Microsoft to include a version of the game as preloaded software on Windows 3.0 in 1990 was an attempt to initiate people to the new 'point-and-click' technology, used throughout the operating system, through an activity that would be familiar and "soothing" to them (Levin, 2008). Its inclusion in the current study can be viewed as an attempt to replicate this experience for users who might be unfamiliar with touchscreen technology. The selection of Solitaire as a 'familiar' game was supported by members of the PPI group, who had all either previously played the game or were aware of the format and basic premise.

Novel game. A second game was sought with the requirement that it was not a computerised version of an existing game. The aim was to find a game with novel rules that is conceptually modern to minimise the chance of it being known by the target population. An exploration of the Apple iTunes Store revealed a plethora of games that can be categorised in the 'matching tile' game subtype, where players manipulate tiles in order to make them disappear, according to a set of matching criteria (Juul, 2007). There are many conceptual variations of these games with different objects representing the 'tile' element (e.g., fruit, candy, jewels, etc.), which are all categorised in the broader 'puzzle' game genre within the Apple iTunes Store, thus making searching difficult. However, further exploration revealed that the term ‘bubble’ is often used in games of this subtype and, having sampled several examples within the genre, these games were deemed to have the greater potential for the target population, as their elements typically require less manipulation by the player.

A search of the Apple iTunes Store was conducted to select the most appropriate version of the games compatible with the Apple iPad, using the search terms ‘Solitaire’ and ‘Bubble’. Each search returned 500+ results, arranged according to a combination of relevance to the search term and popularity. As it would have been unrealistic to review each of these apps individually, the first 10 apps judged appropriate from their title and icon were downloaded and reviewed according to the set of parameters (see Table 3.1; further described in Chapter 7).

Table 3.1. The parameters used to identify the most appropriate versions of Solitaire/Patience and a 'bubble' based matching tile game for people living with dementia

Items	Category	Definition and justification
1. Tap 2. Drag-and-drop 3. Multi-touch	Interaction	Apps with more interaction methods were favoured *No guidance from the literature was found for people with dementia, however it was hypothesised that more available methods of interaction would allow users more freedom to intuitively control the apps*
4. Audio 5. Animation 6. Text	Feedback	Apps providing multiple forms of feedback were favoured *The importance of feedback in response to user input was highlighted in several articles* (Astell, Alm, et al., 2014; Pignatti et al., 2005; Riley et al., 2009)
7. Object size 8. Text size	Visual design	Apps featuring interactive objects and text of a larger size were favoured *This was advocated as users may have visual impairment* (González et al., 2013; Nezerwa et al., 2014; Pang & Kwong, 2015) *or find precise motor control difficult* (González et al., 2013)
9. Prompts 10. Hints 11. Customisation	Game design	Apps featuring automated prompts, hints and customisation options were favoured *Several articles recommend the use of prompts and hints to direct or regain the attention of the user* (Alm, Astell, et al., 2007; Astell, Alm, et al., 2014; Leuty et al., 2013; Manera et al., 2015), *and customisation to tailor the experience is highlighted as beneficial* (Astell, Malone, et al., 2014; Hoey et al., 2010; Leuty et al., 2013; Pang & Kwong, 2015; Satler et al., 2015)
12. Portrait 13. Landscape	Orientation	Apps that operated in either orientation were favoured *No guidance from the literature was found for people with dementia, however it was hypothesised that apps that functioned in both portrait and landscape mode would allow users more choice*
14. In-app 15. Menu	Obstacles	Apps without adverts or pop-up messages were favoured *No guidance from the literature was found for people with dementia, however it was hypothesised that intrusive obstacles could distract and confuse users*

The selected version of Solitaire was considered the most suitable for people living with dementia as it contains the largest range of accessibility options (e.g., background colour, size and style of the card face design), and was the only version reviewed to feature an automatic prompt system if the player was inactive for 15 seconds. A possible limitation was that the game did not automatically notify the player if there are no further moves possible (i.e., that the game is 'lost'). However, this was considered a surmountable issue for the purposes of this study, as the researcher would be in a position to view the participants' progress and intervene if necessary. The selected version of a matching tile game, 'Bubble Explode' also had the largest range of accessibility options allowing the player to control, for example, the speed of gameplay and the size of the bubbles.

3.2.3.2 Equipment

An Apple iPad (fourth generation) running iOS 7 was used in all data collection. The selection of the iPad over other tablet devices for this research was due to the greater availability of regulated apps in the Apple iTunes Store in comparison with other platforms (Ashwini, 2017; Ranger, 2015), and the fact that other researchers have recommended its use in similar contexts (Kerkhof et al., 2017; Lim et al., 2013; see 2.3.3.2). Operating system settings were set to provide an optimal experience for the user and to prevent unnecessary or accidental interference during gameplay: brightness and volume were both set to maximum; app notifications were all turned off; and multitasking gestures were turned off. The free version of the app Solitaire (by *MobilityWare*) was the game presented to participants in Group 1 (see Figure 3.1). The game was presented in landscape mode as members of the PPI group (see 3.1.3) suggested that this provided the clearest presentation of the game.

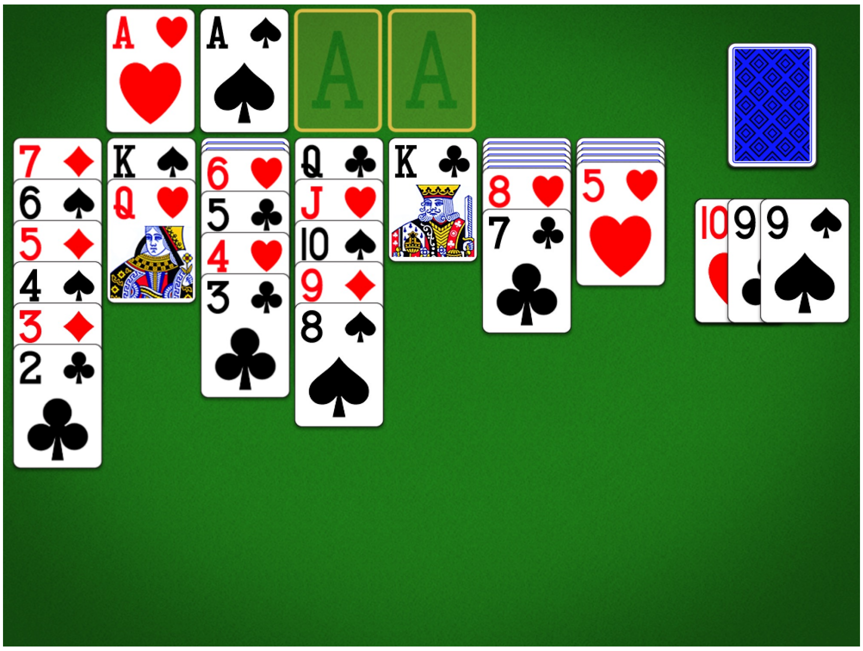

Figure 3.1. Screenshot of Solitaire

The premium version of the app Bubble Explode (by *Spooky House Studios*) was presented to participants in Group 2 (see Figure 3.2). Within the app, the '*Classic*' game mode was chosen.

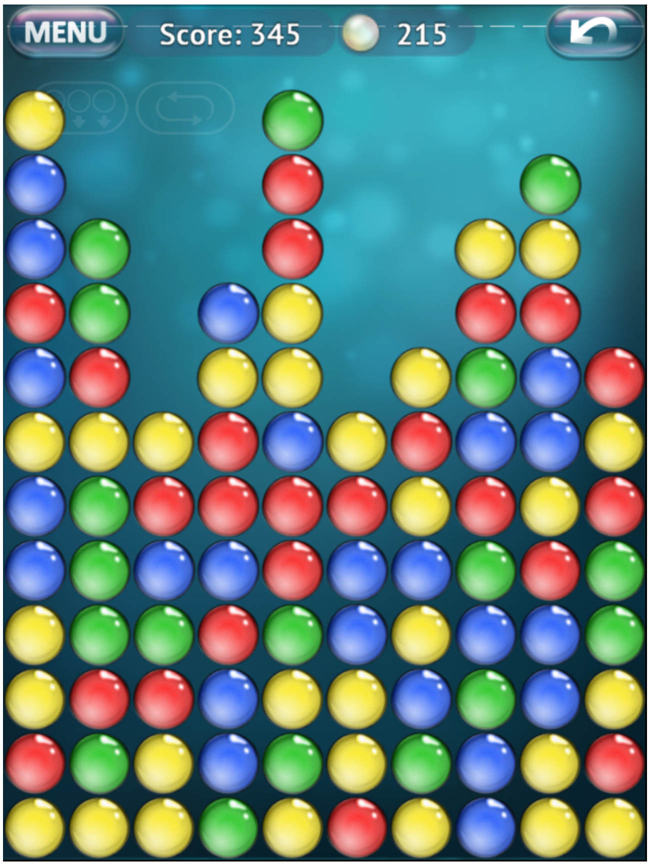

Figure 3.2. Screenshot of Bubble Explode

The iPad was presented in a purpose-designed case for people living with dementia, created as part of the international InTouch research project (see Figure 3.3; further details available at http://proud-toplay.com). The case provides protection for the iPad, prevents accidental interactions with the physical buttons and allows for portrait or landscape presentation of the device at a comfortable viewing angle.

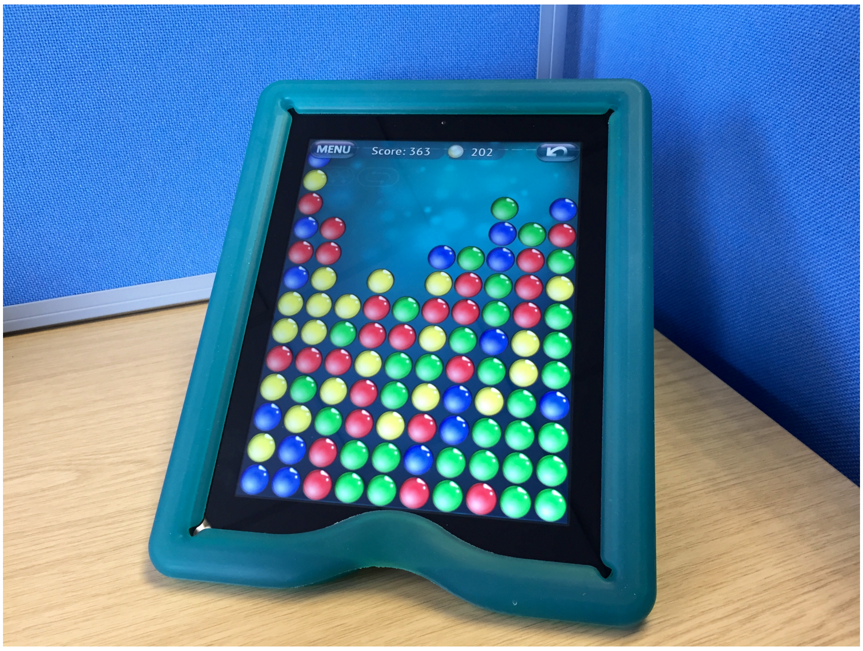

Figure 3.3. iPad presented in purpose-designed case

Two Sony HD Handycam digital video recorders with tripods were used to record all data collection sessions.

3.2.4 Environment

A suitable environment to conduct the activity sessions was identified within each care service prior to the first data collection session. This was achieved through discussion with members of staff working at the care service. A room was chosen that could provide privacy to minimise distraction, prevent interruption and maintain confidentiality during the session, and with enough space for the participant to sit comfortably at a desk or table with two video cameras on tripods set up close to them (see Figure 3.4). The first video camera was positioned facing the participant to capture a recording of their face whilst they played the game. The second video camera was positioned on a tripod in a position allowing a view of the iPad screen over the participant's shoulder (this was over the left shoulder for a right-handed participant and vice-versa, to capture the clearest view of the screen).

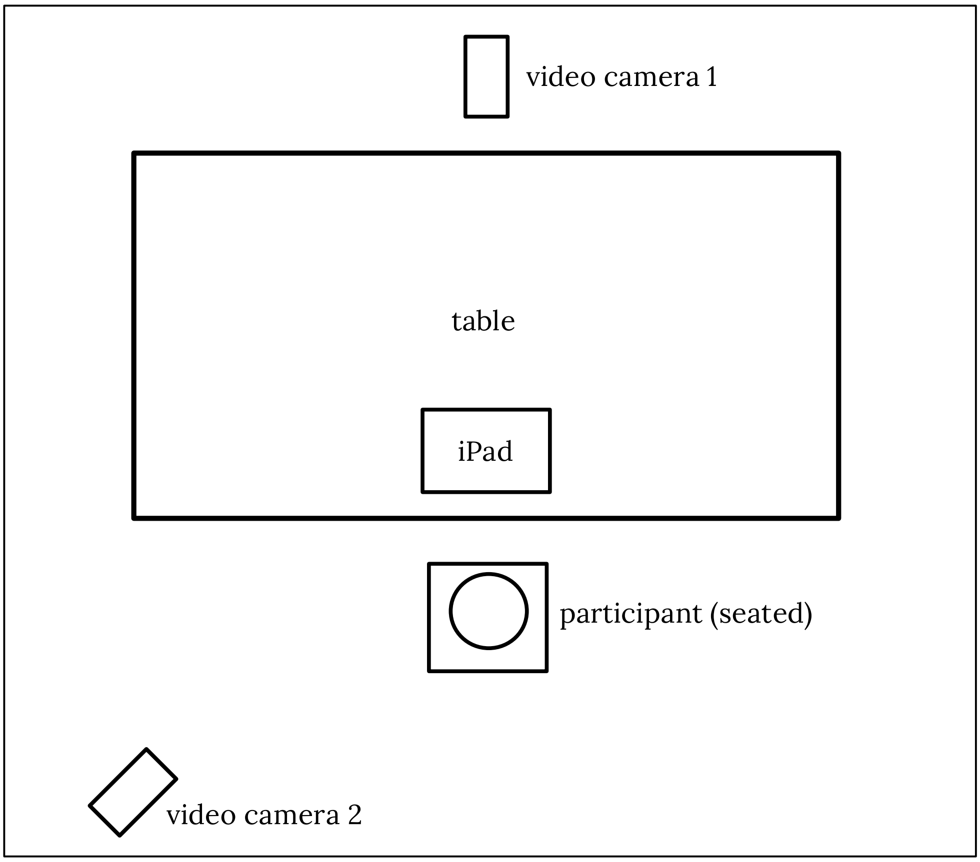

Figure 3.4. Diagram of the ideal environment setup

3.2.5 *Outcome measures*

Research questions 1 and 2, regarding gameplay initiation, progression and enjoyment, were addressed by the primary outcome measures. Research question 3, regarding gameplay behaviour, was addressed by the secondary outcome measures.

3.2.5.1 Primary outcomes

Independent gameplay initiation. This was measured through the observation of whether the participants attempted to begin playing the game independently, once the rules had been explained to them and they were invited to start. *Checkpoint attainment.* This was measured through observation of whether the participants advanced through the game independently to a pre-determined 'checkpoint'. In the case of Solitaire, this was determined by whether the participants played through one cycle of the card deck whilst placing cards as the moves become available. In the case of Bubble Explode, this was determined by whether the participants played through until the first 'regenerated' row of bubbles falls (this occurs when the top two levels of bubbles are empty and the participant subsequently eliminates five bubble combinations).

Enjoyment. This was measured using an item from a modified version of an existing questionnaire used to assess game experience. The Game Experience Questionnaire (GEQ; Ijsselsteijn, de Kort, & Poels, 2008) comprises three modules – (i) the core questionnaire, (ii) the social presence module, and (iii) the post-game module – of which (iii), the post-game module, was used to inspire the design of a simple checklist to assess seven areas of gameplay: game involvement, challenge, responsiveness, control, game rules, concentration and enjoyment. The questions are designed to illicit closed responses ('yes' or 'no') and were delivered in an interview format at the end of each gameplay session (see Appendix D). The item relating to enjoyment was the only item measured for the purposes of the present study. The researcher received permission from the authors of the GEQ prior to modifying and using the questionnaire, and also followed guidance published from the Eldergames project (Gamberini et al., 2009) during the modification process.
Improved gameplay performance over time. This was measured by timing how long it took the participants to reach the checkpoint, as described above, and comparing with each of their subsequent gameplay sessions to see if their times decreased (to be eligible for this outcome, participants must have attended and reached the checkpoint in all three of their gameplay sessions).

3.2.5.2 Secondary outcomes

Screen interactions. A video coding scheme (see Table 3.2) was designed to measure user-led screen interactions and game features in either app (and to be generalisable to other apps with minimal adaptation). The coding scheme was designed to measure objective elements of gameplay by quantifying comparable elements of each participant's unique sessions, allowing for a comprehensive evaluation of each app. The coding scheme was developed through observation of volunteers interacting with both apps to provide a list of all possible screen interactions that were subsequently categorised into five groups.
Prompts. The activation of a prompt, its duration on screen and the outcome (i.e., whether the participant's next move after a prompt is displayed takes advantage of the suggestion) were all measured. This game feature is present only in Solitaire (described in 3.2.3.1).

Table 3.2. Summary of coding scheme designed for the purposes of the present study to observe all user-led screen interactions and the presence of certain app features

Screen interactions	**Definition**
Game advancing move	*An intentional game move that is valid and successfully completed*
Unsuccessful move	*An intentional game move that is valid but not successfully completed*
Invalid move	*An intentional game move that is invalid (i.e., does not comply with the rules of the game)*
Unintentional interaction	*An interaction with the screen that was not intended by the participant*
Non-game interaction	*An interaction with the screen that is intentional but not directly related to the game (i.e., a menu item)*
Gameplay	**Definition**
Gameplay initiated	*Player begins gameplay (first screen interaction after demonstration)*
Checkpoint reached	*Checkpoint of the game is reached independently by the player*
Checkpoint not reached	*Checkpoint of the game is not reached by the player*
Prompts	**Definition**
No prompt	*No prompt is displayed on the screen*
Prompt	*Prompt is displayed on the screen*
Prompt utilised	*Next intentional screen interaction attempts highlighted move*
Prompt not utilised	*Next intentional screen interaction does not attempt highlighted move*

3.2.6 *Procedure*

For each participant at each data collection session the following procedure was used. At the beginning of each session, the researcher spoke with the participant and reiterated the purpose of the research project, using their signed consent form as a reference. If the participant provided verbal consent to continue and the researcher was satisfied that they had the capacity to do so, the session proceeded.

The iPad within the purpose-designed case was presented to the participant with the start of the game (Solitaire [Group 1] or Bubble Explode [Group 2]) ready on the screen. The researcher provided a rehearsed physical demonstration of the game, consisting of three ‘game moves’ (three card moves in Solitaire or three bubble groups eliminated in Bubble Explode), in combination with verbal instructions describing the process. This method of presentation; combining physical demonstration with verbal instruction, was suggested by members of the PPI group (see 3.1.3) and was also supported by the reviewed evidence-base (see 2.3.4.1). The researcher then reset the game to the beginning and invited the participant to begin in his or her own time.

Participants were given the opportunity to play the game through to completion unless they indicated that they wanted to finish earlier or if their gameplay session exceeded 10 minutes. As the focus of the research was on independent gaming, the researcher retreated out of the participant’s line of sight and resisted any initial requests for advice or support from the participant during gameplay by politely encouraging them to try and continue themselves. However, if the participant requested support more than twice, or was deemed to be in any discomfort or distress, then the researcher responded to the participant and offered support. In these cases, for the purposes of the data collection, the result would be recorded as having not met the criteria for advancement through the game (assuming they had not already reached the checkpoint prior to the researcher’s intervention).

After the participant had finished playing the game, the researcher immediately conducted the post-gameplay interview whilst the game was still on the screen in front of the participant, to maximise their ability to recall their experience of playing the game (E. R. Smith et al., 2011). After the interview had been completed, the participant was thanked and reminded of when their next session would be.

3.2.7 *Observation of video recordings*

Using the ‘over-the-shoulder’ video recordings of the participants interacting with the tablet computer, each gameplay session was analysed after all data had been collected. The coding scheme used to analyse each of the ‘over-the-shoulder’ videos is summarised in Table 3.2.

Analysis was conducted using The Observer® XT (version 12.0.825) software by Noldus Information Technology on a Dell Precision T3610 computer running Windows 7 Professional. Videos were first transferred from the recording equipment to an encrypted external hard drive and uploaded to The Observer®

software for analysis. The researcher viewed each video at half-speed and entered codes chronologically within the monitored duration of gameplay (from the end of the demonstration until either the checkpoint was reached or the gameplay session ended). All videos from Group 1 of participants playing Solitaire were analysed first, followed by the videos from Group 2 of participants playing Bubble Explode. Once all video sessions had been coded, data for each group were exported from The Observer® software into Microsoft Excel.
Analysis of the 'participant-facing' video recordings of the participants faces was also conducted and this is reported separately (see Chapter 5).

3.3 Results

Participant characteristics (age, gender and cognitive score; see Table 3.3) were comparable between the two groups, indicating that the alternate sampling method had successfully yielded equal samples. Of the 30 participants recruited to the study, 23 engaged with the study at all three time-points; five engaged at two time-points; and two engaged at just one time-point. This resulted in a total of 81 sessions out of a possible 90 (see Table 3.3). The missing data were accounted for by: participants being judged as having shown signs of discomfort at a previous session (four occasions); participants declining to participate on the day of the session (three occasion); or participants missing a session/s through ill health (two occasions).

Table 3.3. Characteristics of participants and their contributions to Study 1

	Female	Male	Mean age (SD)	Mean MoCA score /30 (SD)	Total no. of sessions	Sessions in which gameplay was initiated
Group 1 (Solitaire)	12	3	87.53 (5.89)	13.07 (2.84)	38	28
Group 2 (Bubble Ex.)	13	2	87.13 (4.93)	13.73 (3.22)	43	43

3.3.1 *Primary outcomes*

3.3.1.1 Independent gameplay initiation

Gameplay was initiated independently in 71 of the 81 (87.65%) attended sessions. In Group 1, participants initiated gameplay in 28 of the 38 (73.68%) attended sessions, compared with 43 out of 43 (100%) sessions in Group 2 (see Table 3.3). In total, 27 of the 30 (90%) participants in the study attempted to play the game assigned to them independently on at least one occasion.

3.3.1.2 Checkpoint attainment

The checkpoint was reached in only six out of the 28 (21.43%) Solitaire sessions initiated, and it was the same two people who demonstrated this progression on each of the three occasions they played. None of the remaining participants (86.67%) reached the checkpoint in any of their sessions. This was due to them repeatedly requesting some form of help or support (nine sessions), reaching the time limit for the session (six sessions), opting to end the session (four sessions), or not attempting gameplay for 60 seconds (three sessions).

Checkpoint attainment occurred in 33 of the 43 (76.74%) initiated gameplay sessions of Bubble Explode. Of the 15 participants in the group, 14 (93.33%) reached the checkpoint on at least one occasion and nine (60%) did so in all of the gameplay sessions they attended. On the occasions that the checkpoint was not reached during Bubble Explode gameplay sessions, the reason was either that the participant opted to end the session (seven sessions) or they did not attempt gameplay for 60 seconds (three sessions).

3.3.1.3 Enjoyment

In 70 of the 71 sessions where the participant attempted to play the game, the post-gameplay interview was conducted (one participant in Group 1 declined to answer on one occasion). In total, participants reported enjoyment following 60 (85.71%) of these gameplay sessions. Out of the 26 participants who initiated gameplay and agreed to the interview, 23 (88.46%) reported having enjoyed playing their game in at least one of their gameplay sessions, with 20 (76.92%) reporting enjoyment in all their sessions.

In Group 1, participants playing Solitaire reported having enjoyed playing their game in 24 (88.89%) of the 27 gameplay sessions after which the interview was conducted. Ten (90.91%) of the 11 participants who initiated gameplay and completed the post-gameplay interview reported enjoyment on at least one occasion, with eight (72.73%) reporting enjoyment in all gameplay sessions they attempted.

In Group 2, participants assigned to play Bubble Explode reported having enjoyed playing their game in 36 (83.72%) of the 43 gameplay sessions. Thirteen (86.67%) of the 15 participants reported enjoyment on at least one occasion, with 12 (80%) reporting enjoyment in all gameplay sessions they attempted.

Figure 3.5 depicts reported enjoyment in all gameplay sessions by assigned group compared with gameplay initiation and checkpoint attainment.

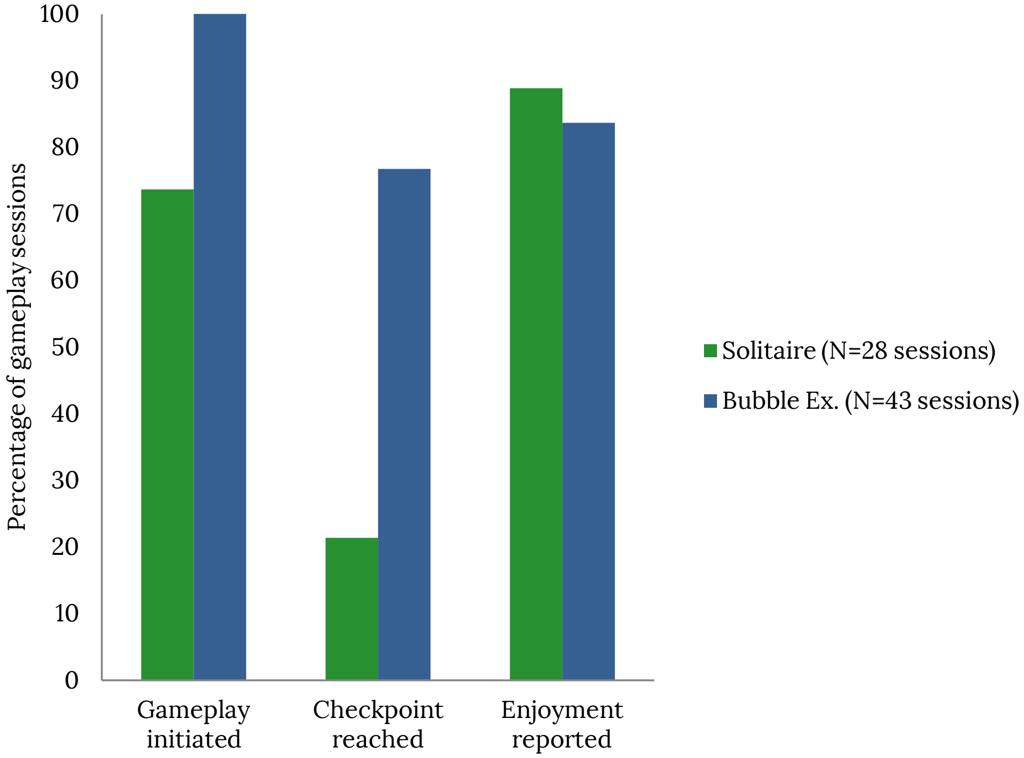

Figure 3.5. Comparison of gameplay initiation, checkpoint attainment and reported enjoyment in all gameplay sessions between groups

3.3.1.4 Improved gameplay performance over time

For the 10 participants who reached the checkpoint of their assigned game in all three sessions, their times were examined for evidence of improved performance, through a reduction in the time taken to reach the checkpoint at each subsequent session.

Of the two participants who played Solitaire through to the checkpoint on all three occasions, participant 1-01's performance showed evidence of improvement, as their time taken to reach the checkpoint decreased on each subsequent gameplay session (see Table 3.4). By contrast, participant 1-15, who had a much quicker baseline time, was far more consistent across the three sessions.

Table 3.4. Indicators of improved performance for each participant who reached the checkpoint in Group 1 in all three gameplay sessions

	Time taken to reach checkpoint (seconds)		
Participant	T1	T2	T3
1-01	475.09	343.20	280.42
1-15	183.24	185.56	184.08

Among the eight participants in the novel group who played Bubble Explode through to the checkpoint on all three occasions (see Table 3.5), only two (1-06 and 1-24) recorded decreasing times between each of the three time-points. The remaining six participants displayed less consistent patterns.

Table 3.5. Indicators of improved performance for each participant who reached the checkpoint in Group 2 in all three gameplay sessions

	Time taken to reach checkpoint (seconds)		
Participant	T1	T2	T3
1-02	118.16	133.20	- *
1-06	99.12	83.64	54.12
1-10	108.88	49.84	148.52
1-16	160.88	91.44	217.56
1-18	237.15	145.80	187.48
1-20	146.16	180.00	46.84
1-24	210.52	126.96	122.24
1-26	134.24	211.92	108.88

*Unable to record exact time due to equipment failure

3.3.2 *Secondary outcomes*

All of the secondary outcomes were obtained through the video analysis procedure described in 3.2.7. Due to equipment failure, the recording of one gameplay session in Group 1 and one session in Group 2 could not be analysed. Therefore, the number of analysed sessions for the secondary outcomes is 27 in Group 1 and 42 in Group 2.

Table 3.6 presents the total counts of all screen interactions made by participants in Groups 1 and 2. The secondary outcomes described in the proceeding sections are all derived from the figures in this table, calculated as proportions according to the definitions described in 3.2.5.2.

Table 3.6. Total counts of screen interactions from all sessions involving both Solitaire and Bubble Explode, where gameplay was initiated

Category of interaction	Solitaire (N=27 sessions)	Bubble Explode (N=42 sessions)
Total touches	2137	1507
Game advancing moves	279	737
Unsuccessful moves	227	71
Invalid moves	719	652
Unintentional touches	812	39
Non-game touches	100	8
Total intentional gameplay moves (game advancing moves + invalid moves)	998	1389
Total moves indicative of usability problems (unsuccessful moves + unintentional touches + non-game touches)	1139	118
Prompts generated†	44	-
Prompts used†	9	-

†Prompt feature not present in Bubble Explode

3.3.2.1 Screen interactions

The figures presented in Table 3.7 present a broad overview of the gameplay experiences (defined in Table 3.2) for each group of participants. In Solitaire, most screen interactions were coded as unintentional interactions (38%) or invalid moves (33.65%). In Bubble Explode, game advancing moves (48.91%) and invalid moves (43.26%) formed the majority, with each of the remaining coded interactions accounting for less than 10% of the total screen interactions in Group 2.

Table 3.7. Summarised screen interactions from gameplay sessions involving Solitaire and Bubble Explode

Coded label	Total (%) Solitaire (N=27 sessions)	Bubble Explode (N=42 sessions)
Game advancing moves	13.06	48.91
Unsuccessful moves	10.62	4.71
Invalid moves	33.65	43.26
Unintentional interactions	38	2.59
Non-game interactions	4.68	0.53

Further investigation into the results of the video analysis revealed that each app had specific design features that were identifiably causing many of the problematic screen interactions (unsuccessful moves, unintentional touches and non-game interactions).

In Solitaire, 227 of the 2137 (10.62%) screen interactions were coded as unsuccessful moves (see Tables 3.6 and 3.7). An unsuccessful move is a move that was valid (i.e., within the rules of gameplay) but was not successfully completed. In this version of Solitaire, by default, users have the option of whether to make moves using a ‘drag-and-drop’ method of control (where the finger touches a card and slides it to its desired location in one continuous motion) or a ‘tap’ method (where the finger briefly touches the card and the computer automatically moves it to a valid location). In total, of these 227 unsuccessful moves, 95 (41.85%) were due to participants having attempted to use one method of control, only for the computer to have interpreted it as another method. For example, in attempting to ‘tap’ a card, the finger is held on the screen too long resulting in the computer interpreting it as the commencement of the continuous sliding motion required for a ‘drag-and-drop’ move; consequently, when the finger is lifted, the card does not automatically move as expected. The remaining 131 unsuccessful moves were also due to breakdowns between the human-computer interaction, such as participants’ using their nails instead of their finger-pads, or not touching the card precisely enough.

Non-game interactions, defined as intentional touches not directly related to the game, accounted for 100 of the total 2137 (4.68%) screen touches in Solitaire (see Tables 3.6 and 3.7). All of these interactions were with items on the toolbar of the app; an integrated graphic providing access to further features (see Figure 3.6), which was hidden at the beginning of each gameplay session. To toggle (switch from one state to another) the presence of the toolbar the user is required to touch anywhere in the background of the app (the green area in Figure 3.6). Participants in the study were not made aware of this design feature, as the toolbar was not directly relevant to the gameplay under observation. However, the toolbar was frequently toggled during gameplay through unintentional interactions by the participant. There were 812 unintentional interactions across all gameplay sessions of Solitaire, accounting for 38% of the total screen touches (see Tables 3.6 and 3.7). Of these 812 interactions, 775 (95.44%) were caused by a resting palm or trailing finger, where a user is either making or contemplating a move, and another part of their hand accidentally touches the screen. 647 of these 775 (83.48%) accidental touches toggled the presence of the toolbar, or interacted with items on the toolbar itself.

Figure 3.6. Screenshot of Solitaire depicting the toolbar at the bottom of the screen

In Bubble Explode, there were only eight non-game interactions, accounting for 0.53% of the 1507 screen interactions (see Tables 3.6 and 3.7). However, they affected four of the 43 (9.3%) gameplay sessions, and were caused by the overlaying of interactive menu buttons on the top two rows of bubbles (see Figure 3.7). If a participant was to attempt to pop any of the bubbles underneath these items, they would inadvertently interact with the superfluous buttons instead.

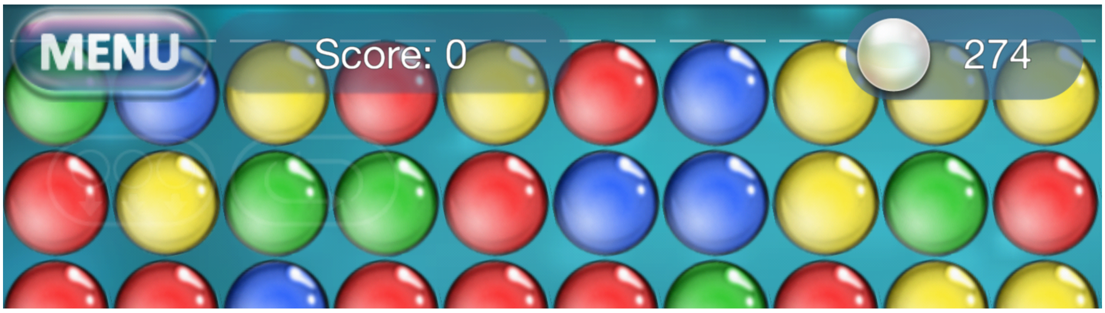

Figure 3.7. Screenshot of Bubble Explode depicting the 'menu' and 'store' (white ball) buttons overlaying the top row of bubbles, and the faded option buttons overlaying the four bubbles on the left side of the second row (which become active later in the game)

Unlike Solitaire, Bubble Explode could only be controlled using the 'tap' method, therefore the 71 unsuccessful moves, accounting for 4.71% of all screen interactions (see Tables 3.6 and 3.7) were all caused by the same human-computer interactions that were also evident in Solitaire (i.e., participants not using the tab of the finger or lacking precision when attempting to tap bubbles). Similarly, the 39 screen interactions of the total 1,507 (2.59%) that were coded as unintentional moves (see Tables 3.6 and 3.7), were due to trailing fingers and resting palms.

3.3.2.2 Prompts

The app Solitaire includes a prompt feature that highlights a potentially valid move if the user is inactive (i.e., does not interact with the screen) for 15 seconds. The prompt is displayed on screen for eight seconds, or until the user interacts with the screen again, at which point the prompt disappears.
Across all 27 gameplay sessions in Group 1, 44 prompts were generated, of which 35 (79.5%) were not used (see Table 3.6). A prompt was presented on screen for an average of 13.28% of participants' total independent gameplay time. However, the average proportion of prompts used in each gameplay session was only 12.54%. Depending on their individual gameplay experience (i.e., whether there was a 15 second period of inactivity during their session), not all participants received a prompt. Of the nine who did, seven (77.78%) did not respond to the prompt feature at all. There was no correlation between prompt utilisation and checkpoint attainment, as the two participants who responded to the prompt feature were not the same two who progressed through to the checkpoint.

3.4 Discussion

When presented with a touchscreen game and left to play independently, the majority (27) of the 30 participants in the study attempted to play the game. Only three participants made no attempt to interact with the iPad independently in any of their sessions. This indicates the potential that touchscreen tablet devices have in providing independent activity for people living with dementia. None of the participants involved in the study had ever used a touchscreen device before and the researcher only spent a couple of minutes explaining the game assigned to them before leaving them on their own, yet this was enough for most participants to attempt gameplay independently. This is demonstrative of the fact that people living with dementia, with cognitive scores as low as eight on the MoCA, are able to learn to interact with a technology that they have never used before.

Participants' progression within the game was more varied, with just over half advancing through their assigned game to the pre-determined checkpoint on at least one occasion. However, this result highlighted the importance of selecting appropriate apps, as only two participants who played Solitaire reached the checkpoint, compared with Bubble Explode where all but one participant reached the checkpoint at least once. This is echoed within the summaries of the coded screen interactions for each group of participants, where game advancing moves comprised just 13% of all screen interactions in Solitaire, compared with 49% in Bubble Explode.

3.4.1 *Familiarity versus novelty*

Although Solitaire was familiar to all participants (when asked, all participants said that they recognised the game and the majority said that they could remember having played it before), it is evident from the observations and the results that most participants could not retain, or could not understand, the rules of the game sufficiently to advance through it. This is in contrast with Bubble Explode, which was a game that none of the participants in the novel group were familiar with (when asked nobody recognised or had played the game before), yet all but one participant were able to progress to the checkpoint on at least one occasion. These results suggest that familiarity is not sufficient on its own when selecting appropriate games that might be suitable for people with dementia.

To participants of the present UK study, Solitaire was felt to be comparable with Sjoelen (Shuffleboard), the most selected app in the study in the Netherlands (Groenewoud et al., 2014; see section 3.1.1), in terms of its familiarity within the respective countries. Also, like Sjoelen, the selected version of Solitaire was a 'classic' representation of the original game in name, icon and the design of the game components. However, it is apparent that Solitaire was not comparable with Sjoelen in terms of its difficulty level. In this respect, the Sjoelen app is more similar to Bubble Explode, where both apps have a 'pick-up-and-play' design, requiring players to repeat an input (Sjoelen: slide puck; Bubble Explode:

pop bubbles), with minimal options (Sjo; which compartment to target; BE: which colour bubbles to target) and only two outcomes (Sjo: score or miss; BE: explode or remain). Contrastingly, Solitaire is much more complex, with players needing to concentrate on multiple aspects of the game concurrently (i.e., suit colour, card number/picture, the deck, the draw pile, descending card sequences, ascending card sequences, etc.). Familiarity may have been the factor that led participants to choose Sjoelen in the original Dutch study, but once playing a game, the present research suggests that familiarity with the physical version of the game by itself, does not promote usability. This distinction between familiarity and usability is important for guiding choice of apps for people with dementia, as familiarity is an obvious criterion when trying to select from the thousands of apps on offer, but this may not be the most useful method of identifying usable ones.

3.4.2 Problematic design features

It is also possible that the digital representation of Solitaire was a barrier, in that participants may have struggled with the mechanics of the app as opposed to the actual rules of gameplay. There is supporting evidence for this theory in that 'unsuccessful moves', 'unintentional interactions' and 'non-game interactions' (defined in Table 3.2) comprised just over half of all screen interactions by participants playing Solitaire, compared with fewer than 10% in Bubble Explode. Whereas screen interactions coded as 'game advancing moves' or 'invalid moves' provide indicators of how well the participant performed in the game, those coded as 'unsuccessful', 'unintentional' or 'non-game' are more indicative of the participants' ability to use the app.

Through analysis of the video recorded gameplay sessions, several common problems were identified that caused most of these types of game interactions. In Solitaire, the presence of two optional control methods ('drag-and-drop' and 'tap') concurrently, and the confounding presence of a toolbar, toggled via a simple tap mechanism, were both highly problematic for many participants. Furthermore, the prompt feature that was such an influential factor in the selection of this version of Solitaire as the most suitable app for people living with dementia, was rarely utilised by the participants. From the available data, it is unknown whether the reason for such low utilisation is because participants did not notice the prompt, or if they did not know how to respond to it. Therefore, with reference to Solitaire, it is not possible to conclude with any certainty whether the lack of progression by people living with dementia in this study was solely due to the complexity of the game, or due to inaccessible design features, or whether the factors are combined.

Usability problems were less of a factor in Bubble Explode, although there was an issue with the placement of interactive buttons (superfluous to gameplay) over the top row of bubbles at the beginning of a game (see Figure 3.7). Instead, the most prominent issue affecting Bubble Explode gameplay, highlighted by the video analysis, was related to the high proportion of invalid moves (43% of all screen interactions). The only invalid move that can be made in Bubble Explode is attempting to remove a bubble that is not grouped with other bubbles of the same colour (see Figure 3.8). This gameplay rule is explained to participants during the brief demonstration of the game at the begininng of each session, but the evidence would suggest that it is not being retained or that it is not being understood. Users can repeatedly 'tap' an isolated bubble without the game providing any feedback that the move is invalid, which may account for the high proportion of this type of move. In Solitaire, an invalid move attempt triggers an animated and audible response, which at the very least conveys to the user that their input has been acknowledged, and maybe informs them that they should try something different. The fact that Bubble Explode does not include this design feature may cause frustration, as without any feedback to confirm their interaction, users may believe that they had not made the move correctly, or that the tablet or app were not functioning effectively.

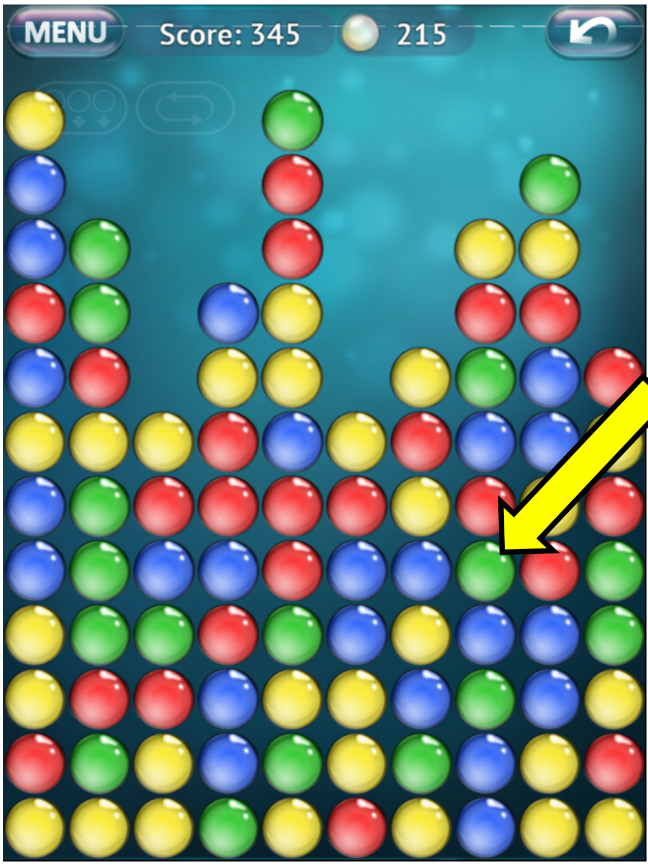

Figure 3.8. Screenshot of Bubble Explode illustrating an example of an invalid move (indicated by arrow); in this case a green bubble without any matching coloured bubbles in contact with it horizontally or vertically

3.4.3 *Enjoyment*

Irrespective of these difficulties, the findings revealed that people living with dementia enjoyed playing touchscreen games independently. Further, despite the contrasting results in reaching the checkpoint between the groups, the type of game played or whether a person had managed to advance through the game to the checkpoint did not affect their reported enjoyment (illustrated in Figure 3.5). It is possible that the novel experience of playing any game on a touchscreen tablet, whether familiar or not, was enough to facilitate enjoyment. This result further demonstrates the potential in touchscreen tablet devices for providing opportunities for independent activity that is also enjoyable (Alm et al., 2009b; Astell, Malone, et al., 2014).

3.4.4 *Application of results*

The Apple iPad and iOS platform are individual examples within a wide range of touchscreen tablet devices and operating systems available on the market. Whilst there are differences in both the hardware and software of all these devices (and given the regular release schedules of new models and operating systems, this is an unavoidable issue), the touchscreen technology remains consistent with the majority of devices using projected capacitive touchscreens (Poor, 2012). The applicability of the findings of this study to other devices is therefore dependent on the apps themselves and their availability within the different app stores (for example, MobilityWare's Solitaire is available on both Apple and Android systems, whilst Spooky House Studio's Bubble Explode is available on Apple and Windows). It would be reasonable to assume that if an app is found to be playable by a user on one device, then that same app should also be playable on a comparable yet different device.

It is conceivable that anyone in a position of support or care for a person living with dementia might be responsible for setting up a new technological device such as an iPad. Therefore, it will be these people, both family and formal caregivers, who are most likely to make decisions as to which apps to download for the person they are supporting. In these circumstances, the people who know the person with dementia and know their hobbies might assume that a good starting point would be to download apps that recreate their hobbies and previous interests or games played in a digital format. Whilst an individual's hobbies and interests will of course be a factor in the selection of games and activities for touchscreen devices, the results of this study suggest that it should not be the only factor. Apps should be carefully reviewed beforehand to assess their suitability, as a negative experience with an activity in the early stages of using a new technology such as this could lead to its abandonment (Zhang et al., 2014). To address this issue, one of the outcomes of the present study was to create a resource offering guidance to people who might be selecting apps for people living with dementia to use (see Chapter 7). The aim of this resource is to provide a smaller pool of apps to select from, whilst still being able to make person-centred choices based on the hobbies and interests of the user.

3.4.5 *Limitations*

The selection of a checkpoint in each game that players had to reach for the researcher to categorically answer the question of whether they had demonstrated progression could be viewed as arbitrary, thereby undermining the validity of this aspect of the study. However, this was felt to be a necessary step to compare the performance of participants within each group playing the same game, where each time the game is started the layout of elements is random. This issue has been previously reported when using games in research (McCallum, 2012), but without a solution. It would not have been sufficient to simply use whether a player finished their game as a way of categorising whether they were able to play the game, because Solitaire is not always winnable from the outset. As neither game was designed with a checkpoint or level system, the solution was to identify a checkpoint within both games to which participants would naturally progress if they continually made valid moves, thereby achieving the goals of the game. Therefore, it is possible to surmise that if a player did not reach the identified checkpoint of the game, they did not achieve the goals of that game.

Another issue that became apparent with hindsight was the use of gameplay duration as an indicator for whether participants had demonstrated improved performance over time. This is because, as stated above, in both games the initial setup is randomised and therefore some games might require more moves to reach the checkpoint than others. In such a case, a player could play equally well on consecutive games, yet take a longer amount of time to reach the checkpoint on their second play because the game was setup differently, and this would be interpreted as a decline in performance. Furthermore, many puzzle games can be played casually or strategically (Levin, 2008), and this applies to both Solitaire and Bubble Explode, although to varying extents. In Solitaire, a player may place cards as they become available, or they may be more considerate of the order in which they place cards to increase the likelihood of uncovering more of the cards that are not available from the outset. In Bubble Explode, there is less of an opportunity for strategy, but if a player is interested in the point scoring mechanism, they may try to strategically manipulate the layout of the bubbles into large or particularly shaped groups of colours, in order to score more points. With either of these approaches, it could be argued that to play more strategically is a demonstration of improved skill, yet this might increase the length of gameplay as each move requires more thought. Therefore, the use of time would again be invalid as an indicator for gameplay improvement. When formulating the protocol for this research, time was intuitively considered as an indicator of performance. However, clearly performance is a more complex concept for which time is not a sensitive enough measure. If the notion of gameplay improvement in touchscreen games for people living with dementia is to be investigated further, it is recommended that an alternative methodological approach is employed.

3.5 Conclusion

This study has provided evidence that people living with dementia can play touchscreen games independently, and in this instance with minimal instruction or support. It has also demonstrated the importance of game selection, and that prior familiarity with a game, particularly a non-digital version, is not a guarantee of suitability. The ease of use and playability of Bubble Explode highlights the importance of looking beyond familiar names to explore different games types, such as tile matching games. It has also shown that people can enjoy playing touchscreen games regardless of the level of progression achieved. Whilst both tested apps were originally selected for this research due to them being the most suitable representations of their type for people living with dementia, the results demonstrate that it will be unlikely that any existing app will be perfectly suited for people with dementia, as they as a population were not considered during the design process.

Chapter 4. Evaluating the effectiveness of tailored accessibility settings for people living with dementia in touchscreen games (Study 2)

4.1 Introduction

Study 1 established that people living with dementia can independently play touchscreen games on tablet computers. Two apps were tested (Solitaire and Bubble Explode), selected due to the presence of certain design features identified in the literature as being suitable for people living with dementia. These included a wide range of accessibility options and minimal impact of advertising in each app, and an auto-prompt feature in Solitaire (see 3.2.3.1). In Study 1, independent initiation of gameplay was high for both apps, but independent progression was much higher for Bubble Explode. It appeared that the majority of participants were unable to progress through Solitaire due to its complexity as a game, particularly in comparison with Bubble Explode. However, the video analysis of participants using the app (reported in 3.3.2) revealed large numbers of usability problems with Solitaire (e.g., confusion between optional control methods and the disruptive mechanics of a pop-up toolbar), again in comparison with Bubble Explode where usability problems were much less frequent. This suggested that app design could underlie some of the difficulties people experienced playing Solitaire. Consequently, further investigation of the different patterns of results for the two apps selected in Study 1 is warranted to advance understanding of how to increase accessibility of apps for people with dementia.

4.1.1 Addressing usability problems

When considering how to approach such an investigation, two potential strategies were considered. The first was to address the usability problems observed in the performance of participants directly by amending the design of the apps to better accommodate their cognitive impairment, and then repeating the study to investigate whether such amendments were effective in improving the gameplay experience for people with dementia. This strategy would require collaboration with the app developers to implement such amendments in their apps, as original development of new apps is problematic on multiple levels, namely: (i) time and resources would almost certainly restrict the potential of developing apps of a high enough quality to match (and improve upon) the existing apps; (ii) comparison with the results of Study 1 would be more tenuous given the inevitable increase in variables; and (iii) developing specifically for people living with dementia could be stigmatising (see Section 3.1).

The second strategy considered was to focus only on Solitaire (as this was the app where usability problems and progression were more prominent), and compare the performance of people living with dementia on the digital adaptation presented in the app with that of the physical card game. This approach would seek to answer the question of whether the observed usability and progression issues, in what was a familiar game to all participants, was due to the complexity of the game itself or to its recreation on a digital format. Of these two strategies, the former was selected for the continuity this would offer in learning about accessibility of apps and dementia. Also, the investigation of making adaptations to touchscreen software for people living with dementia and evaluating their effectiveness presents an opportunity to build upon the evidence base reviewed in Chapter 2 and further develop the framework that was created to select Solitaire and Bubble Explode (described in 3.2.3.1). Furthermore, despite the comparative success participants experienced playing Bubble Explode in Study 1, usability problems and the potential for improvements to the design of the app for people with dementia were still evident from the video analysis. Therefore, it was felt that continuing with both Bubble Explode and Solitaire was warranted.

To achieve this, the researcher contacted the development studios of Solitaire (MobilityWare) and Bubble Explode (Spooky House Studios) via email, briefly explaining the motive for the contact and requesting further discussion at their convenience. Replies were received from personnel within both studios indicating a willingness to open a dialogue and meetings were arranged using online videotelephony service Skype (as the developers were based in the USA and Germany respectively). During these meetings, the developers confirmed that they would collaborate with the research project and implement app adaptations for people living with dementia in future software updates. Adaptations were proposed, discussed and agreed in these and subsequent correspondence (further meetings or emails), following a rough format of the researcher describing the observed usability problems and suggesting potential solutions (using images to support the explanation, if necessary), and the developers responding either with affirmation or alternative solutions if what was proposed was unfeasible (described in 4.1.2). Once the adaptations were agreed, the developers assigned estimated timeframes to the release of the software updates which was, in both cases, within three months. As it happened, MobilityWare released the update for Solitaire in just under four months, whereas Spooky House Studios were more significantly delayed (due to issues arising with a concurrent update to the app's user interface), and released the update for Bubble Explode in just over eight months.

4.1.2 *App adaptations*

Design features within the two original apps that were highlighted as being the cause of some of the most common gameplay barriers were identified (see Table 4.1), and potential solutions were posited prior to any discussions with the app developers. These barriers and proposed solutions are presented along with the implemented solutions, with an explanation if necessary/available of why there was a discrepancy between what was proposed and what was implemented.

Table 4.1. Summary of barriers identified for each app

Solitaire	Bubble Explode
1. Optional control methods	1. Screen layout at the start of gameplay
2. Confounding presence of toolbar	2. Presence and content of text feedback
3. Ineffectiveness of the prompt feature	3. No prompt feature
	4. No feedback for incorrect moves

4.1.2.1 Solitaire

Barrier 1: Optional control methods.
By default, users of Solitaire are given the option during gameplay as to whether they employ a 'drag-and-drop' method of control or a 'tap' method. To 'drag-and-drop', the user touches the card they want to move and drags their finger across the screen in a continuous motion to the desired location before removing their finger to 'drop' the card in place. To 'tap', the user briefly touches the card that they want to move and the card is automatically moved to an available location. It was hypothesised that the choice of control methods would be beneficial to participants as it would allow them to employ whichever method came the most naturally to them. However, through analysis in Study 1, it became apparent that just over 40% of interactions coded as unsuccessful moves (see 3.3.2.1) were caused by a misalignment between the intentions of the participant and the interpretation of the software regarding the control method. For example, participants who intended to use the 'tap' method might hold their finger down too long when touching a card, which the software would interpret as them beginning a 'drag-and-drop' motion, causing the card to remain in position despite their being a viable location to which the card could be moved. Contrastingly, participants who intended to use the 'drag-and-drop' method would sometimes not press firmly enough when beginning the drag motion,

which would consequently be interpreted as a ‘tap’ motion by the software, causing the card to move automatically.
Proposed solution: Introduce option to remove ‘drag-and-drop’ control method. Within the app’s Settings, it was already possible to turn off the ‘tap’ control method, leaving ‘drag-and-drop’ as the only method of control during gameplay. However, as most participants employed the ‘tap’ method in Study 1, it was felt that it would be more beneficial to play with just this method and turn off ‘drag-and-drop’ in the settings menu. This would also allow for users to select between the two methods of control and not become confused by the potentially confounding presence of an additional method.
Implemented solution: As above.
An option to turn off the ‘drag-and-drop’ control method was added to the app’s Settings menu, under a newly designed ‘Accessibility’ heading to include all the implemented options from this collaboration (see Figure 4.1).

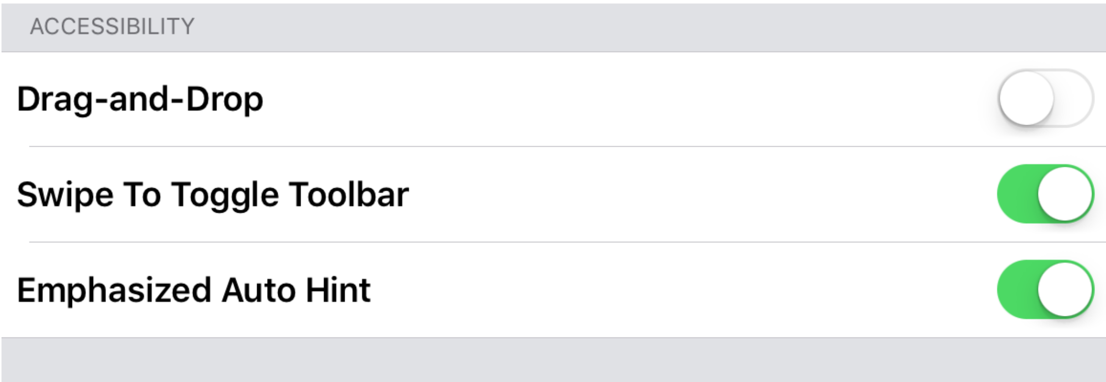

Figure 4.1. Accessibility options implemented in Solitaire to address identified barriers to gameplay for people living with dementia

Barrier 2: Confounding presence of toolbar.
Solitaire featured a toolbar at the bottom of the screen that could be hidden from sight during gameplay (see Figures 4.2a and 4.2b). When introducing the app to participants in Study 1, the menu bar was hidden as its presence was not necessary for gameplay. To toggle the presence of the toolbar, users are required to tap any part of the background (i.e., anywhere on screen where there is not a card present or space for a card to be present). It was hypothesised that the absence of a toolbar would be beneficial to participants as it would limit unnecessary distraction or confusion and allow them to concentrate solely on the required elements of the game. However, as the interaction required to toggle the toolbar was so simple, and could be triggered within such a large proportion of the screen, 30% of all screen interactions in Study 1 unintentionally toggled the presence of the toolbar. Consequently, 5% of all

screen interactions were with elements present on the toolbar that were superfluous, and often contrary, to successful gameplay.

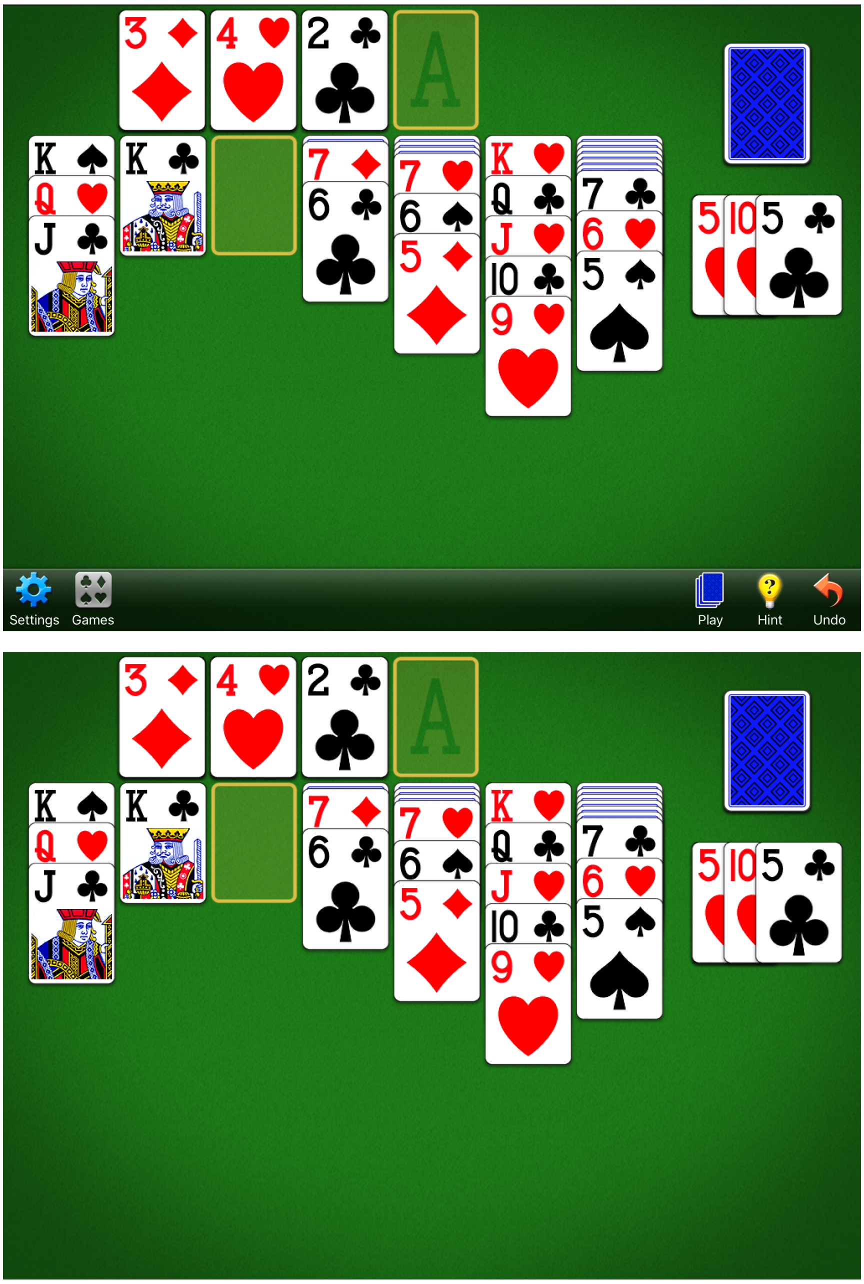

Figure 4.2a (above) and 4.2b (below). Screenshots from Solitaire depicting the presence (4.2a) and absence (4.2b) of the toolbar.

Proposed solution: Preventing interaction in the lower portion of the screen. As the majority of unintentional interactions toggling the presence of the toolbar were located in the lower portion of the screen, if touches to the background area in this location were not registered, these unintentional interactions would be inconsequential.

Implemented solution: Change the interaction method required to toggle the toolbar.

MobilityWare stated that to prevent an area of the screen from registering touches would be fraught with potential issues, particularly as later in the game the lower portion of the screen becomes so integral to gameplay (see Figure 4.3). They did, however, offer an alternative solution; to introduce an option within the newly designed 'Accessibility' section of the settings menu (see Figure 4.1) where users could opt for a slightly more complex interaction method required to toggle the presence of the toolbar. When turned on, this would require users to swipe (touch the screen and move their finger in an upwards motion or downwards motion) to reveal or hide the toolbar.

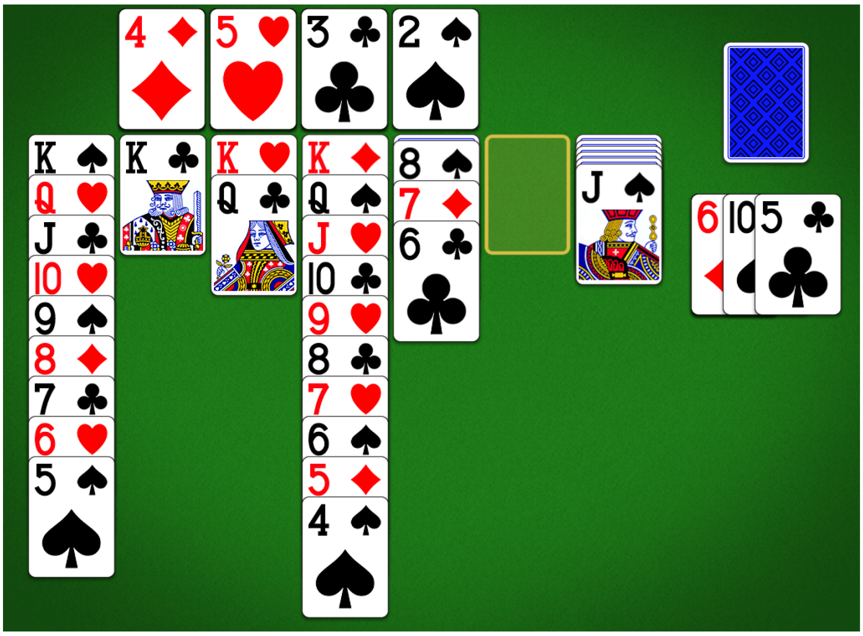

Figure 4.3. Screenshot from Solitaire demonstrating the use of the lower portion of the screen area during advanced gameplay

Barrier 3: Ineffectiveness of the prompt feature.

The prompt (referred to in-app as an 'auto-hint') feature within Solitaire, that alerts users to a viable gameplay move if they are inactive (do not touch the screen) for 15 seconds, was only used in 20% of cases when it was presented to participants in Study 1 (see Figure 4.4a). When identifying this version of Solitaire as the most accessible for people living with dementia prior to the study, it was hypothesised that this feature would act as a facilitator for gameplay. Its ineffectiveness could have been due to participants not noticing the hint or not knowing how to respond.

Proposed solution: Introduce a text hint in addition to the visual hint.
By including a text-based hint (e.g., "try this move") in addition to the existing visual animation, participants might be both more likely to notice the hint and have more of an idea as to how to respond.
Implemented solution: Emphasise the prompt's existing visual animation.
MobilityWare stated that the inclusion of text with the prompt could be problematic as it would often have to overlay other gameplay elements which could be aesthetically undesirable and confusing. As an alternative, they suggested including an option within the newly designed 'Accessibility' section of the settings menu (see Figure 4.1) for an emphasised prompt whereby the entire card is animated (instead of just the edges) with an arrow beneath the card (see Figures 4.4a and 4.4b for a comparison of the original and adapted prompts).

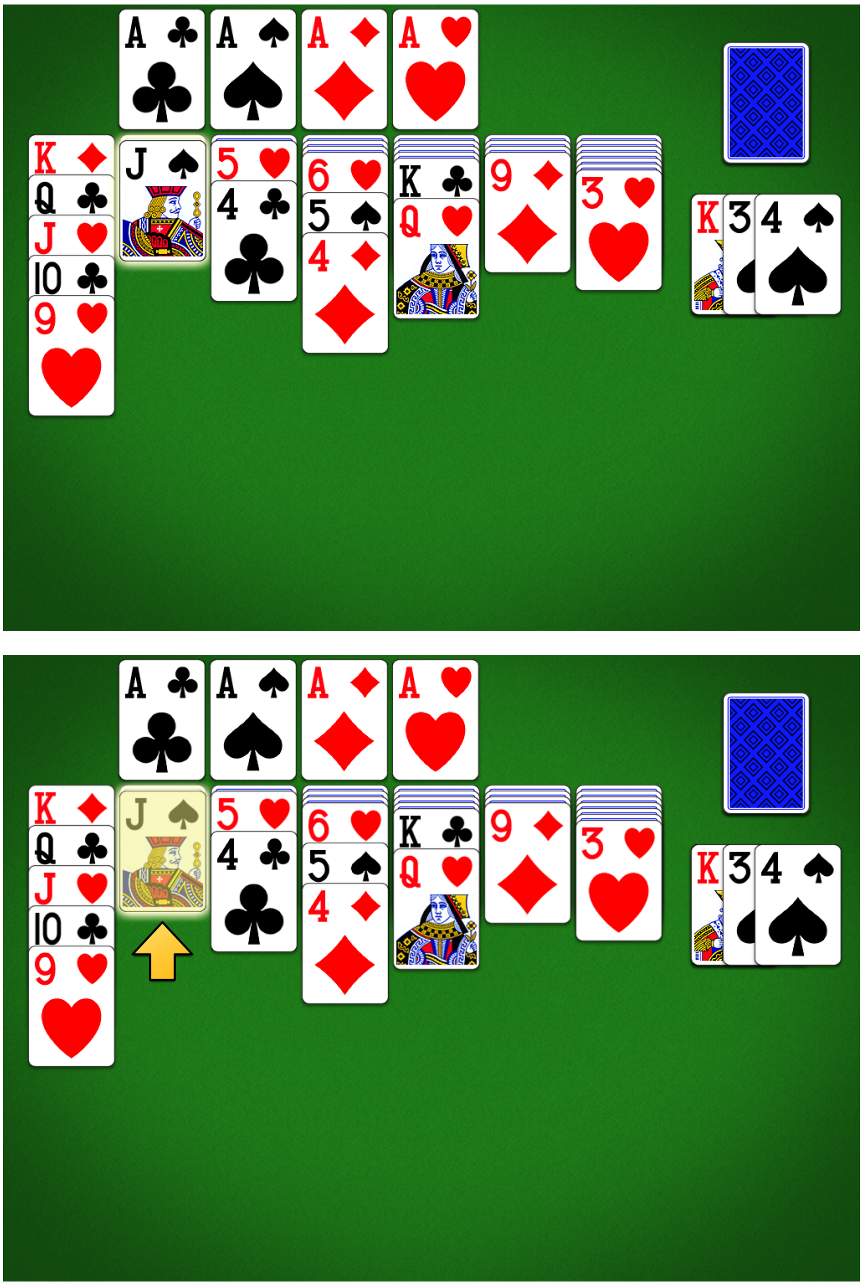

Figure 4.4a (above) and 4.4b (below). Screenshots of Solitaire illustrating a comparison of the prompt feature prior to (4.4a) and post (4.4b) adaptation to make the app more accessible for people living with dementia

4.1.2.2 Bubble Explode

Barrier 1: Screen layout at start of gameplay.

When a new game of Bubble Explode is started, the layout of the screen features interactive elements superfluous to gameplay overlaying the top two rows of bubbles (initially, the two buttons overlaying the four bubbles on the left side of the second row are very faint, but still visible, and their visibility is increased later in the game; see Figure 4.5). Participants in four gameplay sessions in Study

1 were observed to attempt to begin the game by targeting the top row which led to them inadvertently selecting menu items and disrupting gameplay.

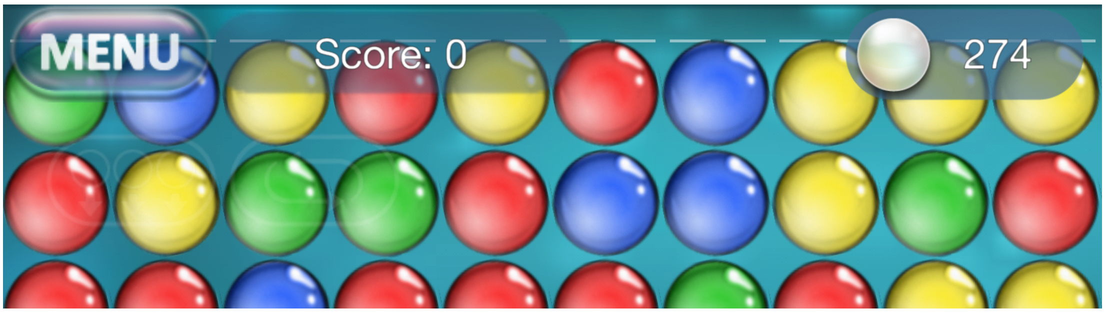

Figure 4.5. Screenshot of Bubble Explode illustrating the problematic placement of the menu items overlaying the top two rows of bubbles

Proposed solution: Adjust the displayed layout.
Versions of Bubble Explode designed for other technology formats feature a different layout with more optimal placement of these items so they are not interfering with gameplay (see Figure 4.6). A layout identical or similar to this whereby each interactive element on screen can be easily distinguished would minimise the risk of inadvertent interactions that do not advance gameplay.

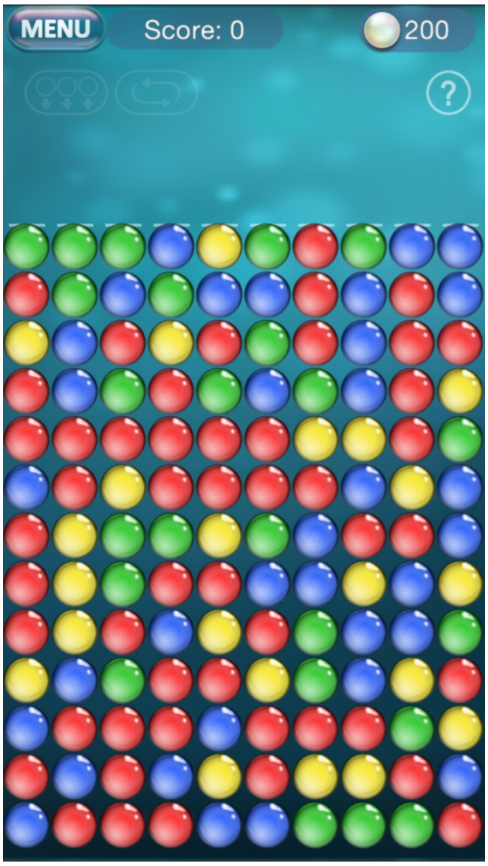

Figure 4.6. Screenshot of Bubble Explode for the Apple iPhone, illustrating an optimal positioning of interactive elements where none overlap

Implemented solution: Partially adjusted layout.
When discussing the issues verbally and through written communication with Spooky House Studios, it was thought that an understanding had been reached as to the problem, and the proposed solution agreed upon. However, possibly due to a misunderstanding or possibly due to the proposed solution being too complex to implement, only some of the superfluous items were removed (those overlaying the second row). Consequently, the top row of bubbles was still obscured by other elements which could be inadvertently selected (see Figure 4.7).

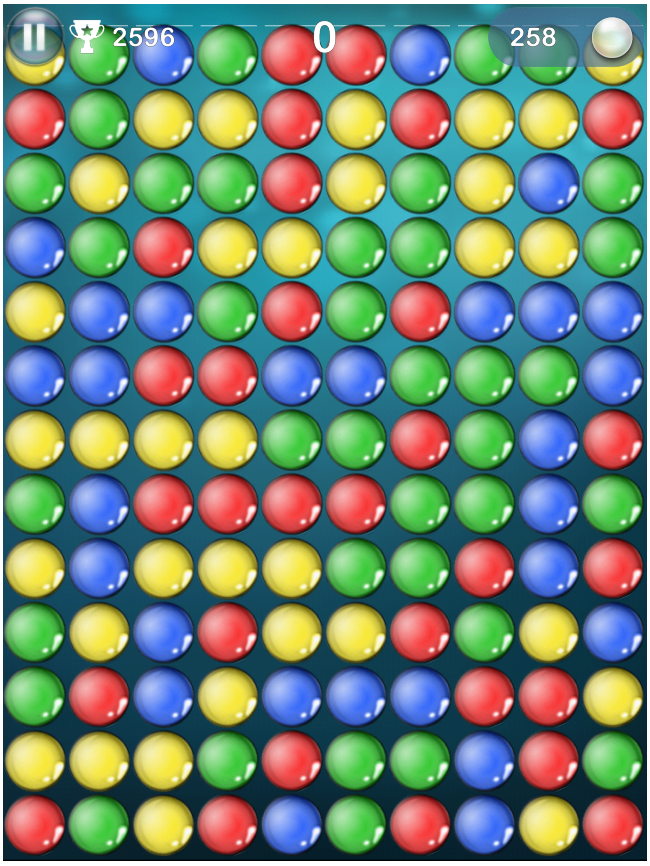

Figure 4.7. Screenshot from Bubble Explode depicting the newly designed opening layout which still features interactive elements overlaying the top row of bubbles

Barrier 2: Presence and content of text feedback.

Following a successful move on Bubble Explode, in addition to animated and audio feedback, text feedback also appears on screen. As a minimum, the associated score for that specific move is displayed, but often further text is displayed relating to certain shapes of the bubble groups and/or bonus items accrued (see Figure 4.8). Analysis of the participants' gameplay sessions from Study 1 revealed that some were being distracted by the text; attempting to read what it said before it faded and sometimes asking what it meant.

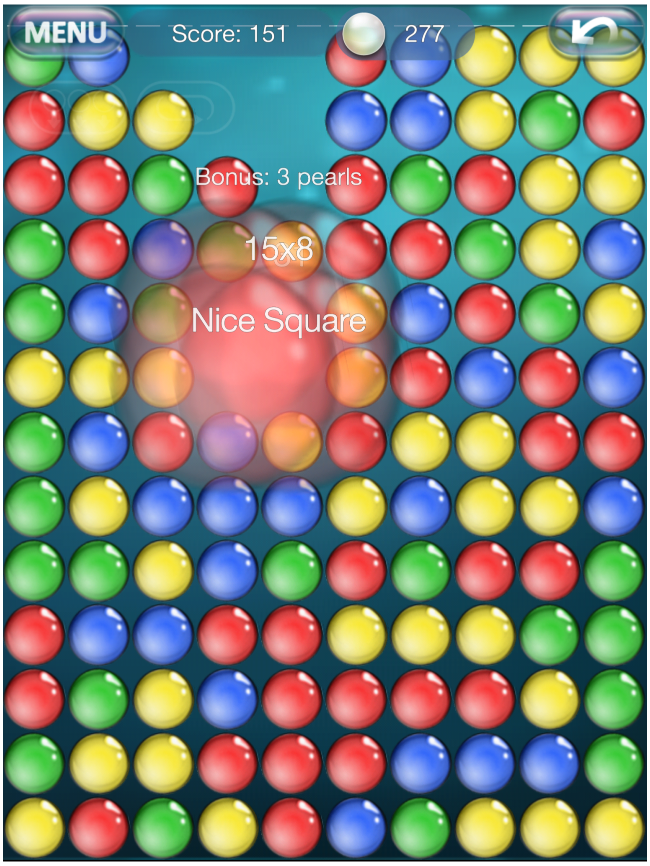

Figure 4.8. Screenshot of Bubble Explode illustrating three examples of text feedback after a single gameplay move

Proposed solution: Option to remove text feedback.
Whilst it was hypothesised that multiple forms of feedback would be beneficial, the evidence from Study 1 indicated that this text feedback in Bubble Explode was distracting some users. If it were possible to turn off the text feedback in the Settings, this would provide a customised experience where text was not generated after successful moves.
Implemented solution: Text feedback fades more slowly.
Spooky House Studios were reluctant to add more options within the Settings as they did not want to over-complicate the menu. Instead, they suggested that the speed by which the text fades could be linked to the existing animation speed option (i.e., slower animation speed would include slower fading of text). This would provide those participants who are trying to read the information with more time to do so.

Barrier 3: No prompt feature.
Bubble Explode does not feature a prompt to direct users to an available move if they are inactive for a certain period (as in Solitaire). In Study 1, when

participants became stuck or distracted, they relied on their own motivation and initiative to continue playing.

Proposed solution: Introduce prompt feature when inactive.

As with Solitaire, an animated prompt highlighting a potential move to be automatically triggered if the user is inactive for 15 seconds could reengage users who have become stuck or distracted. The animation for this already exists within the Bubble Explode software, as when the app is first downloaded, a gameplay guide assists the user on their first game (see Figure 4.9). This animated prompt shares some similarity with the redesigned prompt feature in Solitaire which involves both an arrow pointing toward a potential move with the move itself being highlighted using a glow effect (see Figure 4.4b).

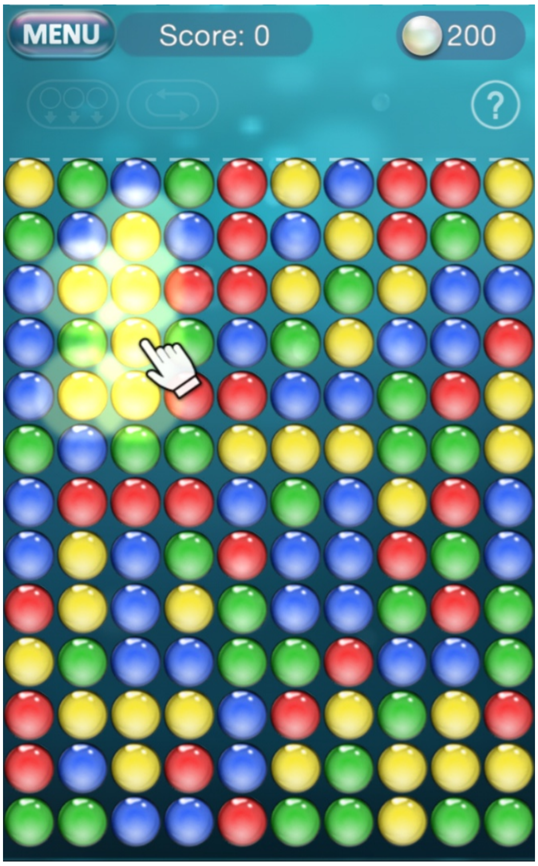

Figure 4.9. Screenshot of Bubble Explode during the tutorial mode which features a prompt animation that had the potential to be reimplemented as a prompt feature during gameplay

Implemented solution: Prompt feature introduced.

A prompt feature was implemented that is triggered when the user is inactive for 10 seconds. The animation used for this feature was not the same as the one already featured in the tutorial mode (see Figure 4.9), as it did not include the 'pointing hand' animation; just the illuminated bubbles (see Figure 4.10).

Figure 4.10. Screenshot of Bubble Explode depicting the newly implemented prompt feature that is triggered when a user is inactive for 10 seconds or attempts an invalid move

Barrier 4: No feedback for incorrect moves.

After game advancing moves, the most common screen interaction observed in the analysis of Bubble Explode gameplay sessions in Study 1 was invalid moves (43% of all screen interactions); the attempt by participants to remove isolated bubbles from the game (i.e., those not grouped with other bubbles of the same colour; see Figure 3.8). The game does not provide any feedback to users when they attempt these invalid moves, therefore it is unclear whether their attempt has been registered. This may lead to repeat attempts at the same invalid move, which was informally observed during the video analysis of gameplay sessions in Study 1.

Proposed solution: Introduce feedback for invalid moves and trigger a prompt. The use of animation, audio and text (or any combination of these) in response to an invalid attempt would provide confirmation to the user that their interaction had been registered and may lead them to seek an alternative move. If users repeatedly attempt the same invalid move, the previously implemented prompt could be triggered whereby a valid move is suggested instead, after, for example, three invalid attempts.

Implemented solution: No feedback for invalid moves; prompt feature triggered. With regards to the bubble that the participant attempts to remove invalidly, no feedback was implemented by Spooky House Studios. However, a different adaptation was made; immediately when an invalid move is attempted, a prompt feature is triggered to suggest an alternative, valid move (matching the prompt feature following inactivity).

4.1.3 Research questions

The design and methodology used in Study 1 was repeated replacing the original versions of Solitaire and Bubble Explode with the newly adapted apps. The following research questions were addressed: (1) Are the tailored accessibility options in touchscreen games for people living with dementia effective in (a) increasing the potential for progression, (b) reducing usability problems and (c) increasing the utilisation of a feature designed to prompt gameplay? (2) Does adapting touchscreen games affect any of the original findings from Study 1 relating to (a) gameplay initiation, (b) independent progression, and (c) enjoyment?

4.2 Method

To facilitate direct comparison of the adaptations with the original apps, the method from Study 1 was replicated as closely as possible. This section is therefore a summarised account of the method described in section 3.2, with more detailed description provided for the unique elements of this study.

4.2.1 Design

The same research design was used as in Study 1 (see 3.2.1). Due to the release schedule of the two app updates being several months apart, 15 participants were recruited to play Solitaire (Group 1) in the first wave of data collection, followed by a further 15 participants in the second wave to play Bubble Explode (Group 2).

4.2.2 Participants

Thirty people living with dementia were recruited from residential and specialist dementia services in Sheffield, UK. Twenty-two of the participants were female and eight were male. Their mean age was 84.17 years (range 66-102; SD 8.35). The presence of cognitive impairment was confirmed using the Montreal Cognitive

Assessment (MoCA; Nasreddine et al., 2005), with a score of <26 required to distinguish between dementia and healthy controls. The participants' mean score on the MoCA was 12.97 out of 30 (range 4-24; SD 4.9).
The study received a favourable ethical opinion from the School of Health And Related Research (ScHARR) Ethics Committee at The University of Sheffield (see Appendix B). A member of the research team obtained consent from each participant, following the same consent procedure as used in Study 1 (described in 3.2.2).

4.2.3 *Materials*

4.2.3.1 Apps

Solitaire (described in 3.2.3.1). MobilityWare released version 4.7 of Solitaire to the Apple App Store on 17th February 2016. This version contained a 'hidden' menu featuring accessibility options for people living with dementia (described in 4.1.2.1), with the developers granting the researcher access via a web link to allow for evaluation of the new settings in the present study. The same in-app settings were used as in Study 1 (described in 3.2.3.1), with the addition of the three new settings (see Figure 4.1): 'Drag-and-Drop' (OFF); 'Swipe to Lock Toolbar' (ON); and Emphasised Auto-Hint (ON).
Bubble Explode (described in 3.2.3.1). Spooky House Studios were unable to release the updated version of Bubble Explode containing the adaptations for people living with dementia (described in 4.1.1.2) to the Apple App Store in time for the present study. They were, however, able to release this version to the Google Play Store for Android devices on 11th July 2016. Having received confirmation from the developer that the Android version of Bubble Explode provided an equivalent user experience to the iOS version, this version was obtained for the present study. The same in-app settings were used as in Study 1 (the newly implemented adaptations were not part of the settings menu and therefore no further adjustments were necessary).

4.2.3.2 Equipment

An Apple iPad (fourth generation) running iOS 9 was used for all participants in Group 1 playing Solitaire. The same OS settings were used as in Study 1 (described in 3.2.3.2). A Samsung Galaxy Tab (S2) running Android 7.0 (Nougat) was used for all participants in Group 2 playing Bubble Explode. This tablet was selected as it was the closest in specification to the Apple iPad; providing a multi-touch capacitive touchscreen with the same screen size (9.7 inch), resolution (1536 x 2048) and pixels per inch (264). Hardware and software settings were matched as closely to the iPad settings, with brightness and

volume maximised and all notifications turned off. The Galaxy Tab was compatible with the specially designed case used in Study 1 (described in 3.2.3.2), and therefore this case was used to present both the iPad for Solitaire (see Figure 3.3) and the Samsung Galaxy Tab for Bubble Explode (see Figure 4.11) in the present study. The researcher recorded and observed footage testing Bubble Explode on both the iPad and Galaxy Tab within the case. No discernible differences in gameplay were observed (aside from the newly implemented adaptations), and therefore it was decided that there would be minimal risk of bias on the results by using a different tablet for Bubble Explode in the present study.
Two Panasonic HD digital video recorders (models HC-X900 and HC-V110) with tripods were used to record all data collection sessions.

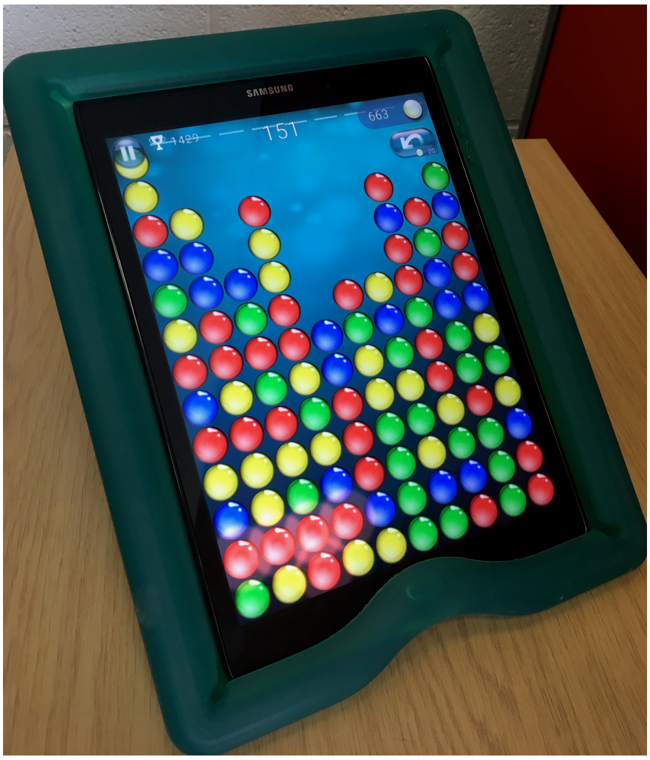

Figure 4.11. Samsung Galaxy Tab presented in purpose-designed case

4.2.4 Environment

A suitable environment to conduct the activity sessions was identified within each care service prior to the first data collection session, as in Study 1 (described in 3.2.4).

4.2.5 *Outcome measures*

4.2.5.1 Primary outcomes

The primary outcomes were all measured through the post-analysis of the video recorded data. The coding scheme used for this analysis was replicated from Study 1. For the convenience of the reader, this coding scheme is repeated in the present section (see Table 4.2).

Game advancing moves. The percentage of screen interactions that were coded as advancing the gameplay was calculated from the total number of intentional screen interactions in each gameplay session. Game advancing moves are defined as drawing cards from the deck or placing cards in viable locations in Solitaire, and removing coloured groups of bubbles in Bubble Explode.

Usability problems. The percentage of screen interactions that were coded as being indicative of an issue relating to usability was calculated from the total number of screen interactions in each gameplay session. Usability problems for both apps are defined as attempted but unsuccessful viable moves, unintentional screen interactions or interactions with on-screen elements not directly related to gameplay (e.g., menu icons).

Utilised prompts. The percentage of prompts to which participants responded was calculated from the total number of displayed prompts in each gameplay session. This is to include the inactivity prompts found in both apps as well as the redirection prompt following an invalid move attempt in Bubble Explode. To utilise a prompt is defined as to attempt the highlighted move as the next screen touch.

Table 4.2. Summary of coding scheme designed for the purposes of this research project to observe all user-led screen interactions and the presence of certain app features

Screen interactions	**Definition**
Game advancing move	*An intentional game move that is valid and successfully completed*
Unsuccessful move	*An intentional game move that is valid but not successfully completed*
Invalid move	*An intentional game move that is invalid (i.e., does not comply with the rules of the game)*
Unintentional interaction	*An interaction with the screen that was not intended by the participant*
Non-game interaction	*An interaction with the screen that is intentional but not directly related to the game (i.e., a menu item)*
Gameplay	**Definition**
Gameplay initiated	*Player begins gameplay (first screen interaction after demonstration)*
Checkpoint reached	*Checkpoint of the game is reached independently by the player*
Checkpoint not reached	*Checkpoint of the game is not reached by the player*
Prompts	**Definition**
No prompt	*No prompt is displayed on the screen*
Prompt	*Prompt is displayed on the screen*
Prompt utilised	*Next intentional screen interaction attempts highlighted move*
Prompt not utilised	*Next intentional screen interaction does not attempt highlighted move*

4.2.5.1 Secondary outcomes

With the implementation of new accessibility features designed to improve the gameplay experience for people living with dementia, it was important to repeat the original primary outcome measures from Study 1 to investigate whether the adaptations had any associated effects. However, given the conclusion drawn

from the previous study that, with hindsight, gameplay duration was not an effective measure of improved performance over time, and the suggestion that this may only be achievable using an alternative method (see 3.4.5), the decision was taken that this would not be included as a measure in the present study. Therefore, the following variables were measured, as replicated from Study 1 (described in 3.2.5.1): *independent gameplay initiation*; *checkpoint attainment*; and *enjoyment*.
Each of the primary and secondary outcomes were compared with the equivalent data from Study 1 (where available) to measure the effects of the newly implemented accessibility options. Where applicable, statistical analyses were conducted. In all cases (except for the comparison of participant characteristics), Mann Whitney tests were identified as being the appropriate test.

4.2.6 *Procedure*

The procedure was directly replicated from Study 1 (described in 3.2.6).

4.2.7 *Observation of video recordings*

Analysis of the video recordings was conducted as in Study 1 (described in 3.2.7). Analysis of the 'participant-facing' video recordings was also conducted and this, along with the equivalent data from Study 1, is reported in the next chapter (Chapter 5).

4.3 Results

To assess the effectiveness of the implemented adaptations for both Solitaire and Bubble Explode, it was necessary to compare the results of the present study with equivalent data from Study 1. Therefore, this section includes data from the participant samples from both studies.

Table 4.3. Characteristics of participants and their contributions to Studies 1 and 2

		Female	Male	Mean age (SD)	Mean MoCA score /30 (SD)	Total no. of sessions
Group 1 (Solitaire)	Study 1	12	3	87.53 (5.89)	13.07 (2.84)	38
	Study 2	13	2	85.4 (6.61)	12.8 (4.78)	43
Group 2 (Bubble Ex.)	Study 1	13	2	87.13 (4.93)	13.73 (3.22)	43
	Study 2	9	6	82.93 (9.87)	13.13 (5.18)	43

Participant characteristics from both studies are presented in Table 4.3. In comparison with Study 1, the mean age in both groups is slightly lower, whereas the MoCA scores are closer by comparison. Two independent samples *t*-tests were conducted between the population samples in studies 1 and 2 based on their age and MoCA score. There was no significant difference between the age of the participant sample in Study 1 (M = 87.33, SE = 0.97) and Study 2 (M = 84.17, SE = 1.52; t (58) = 1.75, p = .09, r = .22), and no significant difference between the MoCA scores of the participant sample in Study 1 (M = 13.4, SE = 0.55) and Study 2 (M = 12.97, SE = 0.9; t (48.06) = 0.41, p = .68, r = .06).
Of the 30 participants recruited to the present study, 26 engaged at all three time-points and four engaged at two time-points. This resulted in a total of 86 sessions out of a possible 90 (see Table 4.3). The missing data were accounted for by: participants missing a session through ill health (two occasions); participants being judged to having shown signs of discomfort at a previous session (one occasion); or participants declining to participate on the day of the session (one occasion). Due to equipment failure, the video recordings of two gameplay sessions could not be analysed. Therefore, apart from gameplay initiation and ratings of enjoyment (that did not rely on the video recordings), the results of all other aspects of the study relate to 84 recorded gameplay sessions (43 for Solitaire and 41 for Bubble Explode). In comparison with Study 1, there were five more sessions attended by participants in Group 1 in the present study, but the same number of sessions attended in Group 2. This is due to fewer participants showing signs of discomfort or declining to participate.

4.3.1 *Primary outcomes (Group 1; Solitaire)*

Table 4.4 presents the total counts of all screen interactions made by participants assigned to play Solitaire, compared between Studies 1 and 2. The primary outcomes for the present study are all derived from the figures in this table, calculated as proportions according to the definitions described in 4.2.5.1.

Table 4.4. Total counts of screen interactions from all sessions involving both original and adapted versions of Solitaire, where gameplay was initiated

Category of interaction	Original version (N=27 sessions)	Adapted version (N=40 sessions)
Total touches	2137	2434
Game advancing moves	279	660
Unsuccessful moves	227	137
Invalid moves	719	1581
Unintentional touches	812	38
Non-game touches	100	18
Total intentional gameplay moves (game advancing moves + invalid moves)	998	2241
Total moves indicative of usability problems (unsuccessful moves + unintentional touches + non-game touches)	1139	193
Prompts generated	44	120
Prompts used	9	73

A summary of the primary outcomes from both groups assigned to play Solitaire, compared between the two studies, is presented in Table 4.5. These outcomes are described fully in the proceeding subsections.

Table 4.5. Summarised primary outcomes from gameplay sessions involving both original and adapted versions of Solitaire

Outcome	Total (%) Original version (N=27 sessions)	Adapted version (N=40 sessions)
Game advancing moves (calculated from total intentional gameplay moves)	27.96	29.45
Usability problems (calculated from total touches)	53.3	7.93
Prompts utilised (calculated from total prompts generated)	20.45	60.83

4.3.1.1 Game advancing moves

The proportion of screen interactions coded as game advancing was calculated from the total number of intentional screen interactions in each gameplay session of Solitaire in Studies 1 and 2. The results revealed that game advancing moves in Solitaire gameplay sessions were marginally higher in the adapted version of the app in comparison with the original (see Table 4.5). Histograms depicting the results from each game version were inspected. As these data were skewed, the most appropriate statistical test was Mann-Whitney, which confirmed that there was not a significant difference in the proportion of game advancing moves between the adapted version and the original version (U = 59, $z = -1.51$, $p = .14$, $r = -.29$).

4.3.1.2 Usability problems

For each Solitaire gameplay session, the proportion of unsuccessful viable moves, unintentional screen interactions and non-game interactions were collated as usability problems. Their proportion in each session was calculated from the total number of screen interactions made by the participant. The results indicated that the total percentage of interactions indicative of usability problems in Solitaire sessions was considerably higher for the original version of the app when compared with the adapted version (see Table 4.5). Histograms depicting the results from each game version were inspected. As these data were skewed, the most appropriate statistical test was Mann-Whitney, which revealed a significant difference in the proportion of usability problems between the adapted version and the original version (U = 23.5, $z = -3.25$, $p < .001$, $r = -.63$).

These results suggest that the adaptations made to Solitaire improved the app's usability for people living with dementia.

4.3.1.3 Utilised prompts

The proportion of inactivity prompts to which participants responded was calculated from the total number of prompts generated in each Solitaire gameplay session in Studies 1 and 2. The results revealed that almost three times the percentage of prompts were utilised in gameplay sessions with the adapted version of Solitaire in comparison with the original app (see Table 4.5). Histograms depicting the results from each game version were inspected. As these data were skewed, the most appropriate statistical test was Mann-Whitney, which confirmed a significant difference in the proportion of utilised prompts between the adapted version and the original version ($U = 22$, $z = -2.63$, $p = .01$, $r = -.56$). These results indicate that the redesigned prompt feature in Solitaire was utilised more often by people living with dementia than the original design.

4.3.2 Primary outcomes (Group 2; Bubble Explode)

Table 4.6 presents the total counts of all screen interactions made by participants assigned to play Bubble Explode, compared between Studies 1 and 2. The primary outcomes for the present study are all derived from the figures in this table, calculated as proportions according to the definitions described in 4.2.5.1.

Table 4.6. Total counts of screen interactions from all sessions involving both original and adapted versions of Bubble Explode, where gameplay was initiated

Category of interaction	Original version (N=42 sessions)	Adapted version (N=41 sessions)
Total touches	1507	1971
Game advancing moves	737	857
Unsuccessful moves	71	82
Invalid moves	652	964
Unintentional touches	39	62
Non-game touches	8	6
Total intentional gameplay moves (game advancing moves + invalid moves)	1389	1821
Total moves indicative of usability problems (unsuccessful moves + unintentional touches + non-game touches)	118	150
Prompts generated†	-	665
Prompts used†	-	68

†New feature not present in original version of the app

A summary of primary outcomes from both groups assigned to play Bubble Explode, compared between the two studies, is presented in Table 4.7. These outcomes are described fully in the proceeding subsections.

Table 4.7. Summarised primary outcomes from gameplay sessions involving both original and adapted versions of Bubble Explode

Outcome	Total (%) Original version (N=42 sessions)	Adapted version (N=41 sessions)
Game advancing moves (calculated from total intentional gameplay moves)	53.06	47.06
Usability problems (calculated from total touches)	7.83	7.61
Prompts utilised† (calculated from total prompts generated)	-	10.23

†New feature not present in original version of the app

4.3.2.1 Game advancing moves

The proportion of screen interactions coded as game advancing was calculated from the total number of intentional screen interactions in each gameplay session of Bubble Explode in Studies 1 and 2. The results revealed that the total percentage of game advancing moves in all Bubble Explode gameplay sessions was slightly lower in the adapted version of the app in comparison with the original (see Table 4.7). Histograms depicting the results from each game version were inspected. As these data were skewed, the most appropriate statistical test was Mann-Whitney, which revealed that there was no significant difference in the proportion of game advancing moves between the adapted version and the original version (U = 104.5, z = -.33, p = .75, r = -.06).

4.3.2.2 Usability problems

As with Solitaire, for each Bubble Explode gameplay session, the proportion of screen interactions indicative of usability problems was calculated from the total number of screen interactions. The results indicated that the total percentage of usability problems in Bubble Explode sessions was marginally lower for the adapted version of the app when compared with the original version, although it should be highlighted that this figure was already very low (less than 10%; see Table 4.7). Histograms depicting the results from each game version were inspected. As these data were skewed, the most appropriate statistical test was Mann-Whitney, which confirmed that there was no significant difference in the proportion of usability problems between the adapted version and the original version (U = 99.5, z = -.54, p = .6, r = -.1).

4.3.2.3 Utilised prompts

As the prompt feature was newly introduced for the adapted version of Bubble Explode tested in the present study, there is no comparative data from Study 1. However, the comparison of the new prompt design in Bubble Explode with the original and redesigned prompts in Solitaire may provide further insight into the most effective design of prompt features in digital software for people living with dementia.
The proportion of prompts to which participants responded was calculated from the total number of prompts generated in each Bubble Explode gameplay session in the present study. The results reveal that just over 10% of the prompts that appeared on screen were utilised by participants (see Table 4.7). This figure is lower than for both designs in the adapted and original versions of Solitaire (see Table 4.5).

4.3.3 *Secondary outcomes*

A summary of the secondary outcomes from all gameplay sessions of both apps compared between Studies 1 and 2 is presented in Table 4.8. These outcomes are described fully in the proceeding subsections.

Table 4.8. Summarised secondary outcomes from gameplay sessions involving both original and adapted versions of Solitaire and Bubble Explode

	Total (%) in Solitaire gameplay sessions		Total (%) in Bubble Ex. gameplay sessions	
Outcome	Original version	Adapted version	Original version	Adapted version
Independent initiation of gameplay	73.68	93.02	100	100

	Total (%) in initiated Solitaire gameplay sessions		Total (%) in initiated Bubble Ex. gameplay sessions	
Outcome	Original version	Adapted version	Original version	Adapted version
Independent advancement to checkpoint	15.79	20.93	76.74	87.8
Enjoyment	88.89	77.5	83.72	95.35

4.3.3.1 Independent gameplay initiation

The proportion of sessions where gameplay was initiated increased for participants playing Solitaire in the present study when compared with Study 1, and remained at 100% in Bubble Explode (see Table 4.8). There were three sessions in the present study where participants did not initiate gameplay, compared with 10 sessions in Study 1. This means that participants attended those sessions but did not attempt any gameplay moves after the demonstration by the researcher was completed.

4.3.3.2 Checkpoint attainment

The checkpoint was reached more frequently in gameplay sessions of the adapted versions of both Solitaire and Bubble Explode in comparison with sessions involving the original versions of the apps in Study 1 (see Table 4.8). This is despite the slight decrease in the proportion of gameplay advancing moves in the adapted version of Bubble Explode reported in 4.3.2.1.

Of the 15 participants who were assigned to play Solitaire in the present study, three reached the pre-determined checkpoint, and did so in each of their three gameplay sessions, which is a 50% increase over the number of participants in Study 1. The remaining 12 participants were unable to reach the checkpoint in any of their sessions. This was due to them reaching the time limit for the session (12 sessions), opting to end the session (12 sessions), not attempting gameplay for 60 seconds (three sessions), or repeatedly requesting some form of help or support (two sessions). The explanations as to why participants who initiated gameplay did not reach the checkpoint in the present study contrast with those from Study 1, as illustrated in Table 4.9. The most common reason in sessions involving the adapted app; that the participant reached the time limit for the session (set in the protocol as 10 minutes; see 3.2.6), was reported half the number of times in sessions with the original app. Contrastingly, the most common explanation in sessions involving the original version; multiple requests for help, was much less prevalent with the adapted version. The explanation of inactivity was equal between the two versions, whereas opting out was three times as high for the adapted version of Solitaire.

Table 4.9. Comparison of explanations for why participants who initiated gameplay did not reach the checkpoint in sessions of Solitaire between those who played the original version and those who played the adapted version

Explanation	Total no. of sessions Original version (N=22 sessions)	 Adapted version (N=29 sessions)
Time limit	6	12
Opting out	4	12
Inactivity	3	3
Help requested	9	2

Of the 15 participants who played the adapted version of Bubble Explode in the present study, 14 reached the pre-determined checkpoint on at least one occasion with only one participant not reaching the checkpoint in any of their gameplay sessions, as in Study 1 for participants playing the original version. Twelve participants reached the checkpoint in all of their gameplay sessions, an increase from the nine participants in Study 1, with the remaining two participants failing to do so in their third and final session. On the occasions that the checkpoint was not reached during Bubble Explode gameplay sessions, the reason was always that the participant reached the time limit (5 sessions). As with Solitaire, this contrasts with the reasons reported in Study 1, where nobody reached the time limit but instead either opted to end the session (7 sessions) or did not attempt gameplay for 60 seconds (3 sessions).

4.3.3.3 Enjoyment

Descriptive statistics indicate that reported enjoyment was slightly lower in the group of participants playing Solitaire and slightly higher for the participants playing Bubble Explode in the present study compared with Study 1 (see Table 4.8). All but one participant playing the adapted version of Solitaire in the present study responded positively on at least one occasion, which was the same as reported in Study 1. All participants playing the adapted version of Bubble Explode reported enjoyment on at least one occasion, whereas two participants in Study 1 reported no enjoyment in any of their three sessions.

4.4 Discussion

Implementing tailored accessibility settings in touchscreen games for people living with dementia improved several aspects of gameplay in an initially difficult game (Solitaire), with smaller benefits to an initially easier game (Bubble Explode). Also, further evidence for independent gameplay, progression and enjoyment was reported, and, in several areas, these were improved in comparison with the findings in Study 1. This suggests that the adaptations were generally successful, with no notable negative consequences. In addition, there were many things to be learned from their implementation.

4.4.1 Solitaire accessibility

The results from Group 1 of participants assigned to play adapted Solitaire revealed that the inclusion of tailored accessibility settings significantly reduced the number of usability problems experienced by people with dementia, and that the redesign of a proven ineffective prompt feature significantly increased its utilisation during gameplay. Furthermore, there was a slight but non-significant increase to the proportion of game advancing moves, and a 50% increase to the number of participants who were able to progress through the adapted version of the app to the game's checkpoint. This suggests that the implemented adaptations – a simplified control method, a less disruptive method of activating the toolbar and a redesigned prompt feature – were effective in improving the accessibility of the app for people living with dementia; removing or at least minimising the barriers identified in Study 1 (described in 4.1.2.1).
Further investigation into the individual categories that comprise usability problems (unsuccessful moves, unintentional touches and non-game interactions) revealed that the total count of each had substantially decreased (see Table 4.4) in comparison with the results of Study 1 (and this despite there being more initiated gameplay sessions and therefore more overall touches). This is important because several of the individual barriers identified from the data in Study 1 were attributed to specific categories of touch. Consequently, whilst the overall reduction in usability problems indicates improved accessibility generally, the fact that all three of these categories reduced provides evidence that the individual adaptations were effective.
Considering unsuccessful moves; just over 40% of these in the original version of Solitaire (see 3.3.2.1) were attributed to the concurrent presence of two control methods ('tap' and 'drag-and-drop') and the fact that participants' intentions of which control method they were attempting was not always recognised by the computer (see 4.1.2.1; Barrier 1). In the present study, the overall number of unsuccessful moves reduced from 227 to 137 (see Table 4.4) as this misinterpretation was no longer possible given that the option to play with only the 'tap' method was introduced as part of the adaptations. The remaining 137 moves coded as unsuccessful (and the remaining proportion of unsuccessful moves in Study 1) were due to other types of breakdowns between the

participants' interactions and the computer's response (e.g., using nails instead of finger-pads, or not quite touching the card when attempting a move); breakdowns that could not easily be addressed through software adaptions. It is possible that these would reduce as users become more experienced with the technology, and this would be an interesting topic for future research taking a more longitudinal approach to investigating touchscreen tablet use by people with dementia.

The combination of just over 80% of the unintentional touches and all of the non-game touches reported in Solitaire in Study 1 (see 3.3.2.1) were attributed to the toolbar and the method by which its appearance was toggled (see 4.1.2.1; Barrier 2). The toolbar was hidden at the beginning of gameplay sessions and could only be revealed by touching part of the background. However, the video analysis conducted in Study 1 revealed that his happened frequently (775 interactions), due to participants unintentionally touching the screen, often due to a trailing finger or resting their palm on the screen when attempting to make other moves. Once the toolbar was activated, participants sometimes interacted with the menu buttons on it, which constituted all of the non-game touches in Study 1 (100). In the present study, the number of unintentional touches reduced considerably (from 812 to 38; see Table 4.4), because whilst participants may have still been resting their palm on the screen or trailing a finger whilst attempting moves, there was no response from the software due to the method by which the toolbar was raised being adapted to require a slightly more complex touch gesture (swiping in an upwards direction). Consequently, with the toolbar now rarely activated, the number of non-game touches also reduced (from 100 to 18; see Table 4.4).

4.4.2 Bubble Explode accessibility

In contrast with the improved accessibility evident in Solitaire, the results from Group 2 of participants assigned to play Bubble Explode in the present study indicated that the adaptations had less impact. Game advancing touches actually decreased slightly (from 53% to 47%), and there was only a marginal decrease in usability problems (from 7.8% to 7.6%), although both these results were non-significant. Interestingly, the effectiveness of the newly introduced prompt feature was low, with just 10% of all generated prompts being utilised, even though this was identified in the gameplay analysis of Study 1 as something that could be helpful.

Two possible explanations for the lower impact of the Bubble Explode adaptations are considered. Firstly, in comparison with Solitaire, the original Bubble Explode was already a highly accessible game, evidenced from the results of Study 1 (see 3.3.2.1); where participants recorded very low proportions of usability problems (fewer than 8% of all screen interactions) and high proportions of game advancing moves (just over 50% of their intentional interactions). This, in combination with the high levels of enjoyment, checkpoint attainment and independent gameplay initiation (at 100% ceiling) using the original version of the app suggest that marginal improvements were perhaps all that could have been realistically achieved. However, many of the observed barriers (described in 4.1.2.2) to gameplay in Study 1 on which the implemented app adaptations were based – interaction with menu buttons, confusion with text feedback, and repeated invalid move attempts – were again observed in the present study. Consequently, the second explanation proposed is that the adaptations implemented in Bubble Explode – a slightly adjusted screen layout, text feedback that fades more slowly, and an alternative move prompt in response to invalid move – were less consistent with what was proposed as solutions and less consistent than those implemented in Solitaire.

For Solitaire, once the collaborative discussion phase with the developers was completed, the three agreed adaptations were all implemented as expected in the app update. However, with Bubble Explode, of the four agreed solutions, three were only partially implemented: (i) the app layout still featured some interactive elements superfluous to the core gameplay overlapping the top row of bubbles at the beginning of the game (see Figure 4.7); (ii) the newly introduced prompt feature did not include an animated 'pointing hand' (only a subtle glowing behind the bubbles, similar to the glowing effect used for a prompt in the original version of Solitaire; see Figures 4.9 and 4.10); and (iii) there was no audible or animated feedback assigned to an invalid move attempt (other than the instigation of the aforementioned prompt feature; see Figure 4.11). The fourth adaptation – for text feedback to fade more slowly allowing users a chance to read it (see Figure 4.8) – was implemented as discussed although this was a compromised solution as the recommendation to include an option to hide all text feedback was not considered viable.

It is unknown whether the effectiveness of the adaptations in Bubble Explode would have been greater if all proposed solutions had been implemented in full. In concluding this aspect of the discussion, it is important to state that there is no intention to apportion blame or criticise the developers when considering these issues. Rather, this process highlights some of the challenges and tensions encountered when attempting to achieve accessibility for *all* players without compromising gameplay. It is also important to emphasise that the developers were under no obligation to collaborate with this research project and were doing so to improve the accessibility of their app for their users. This is also a useful lesson when considering how to incorporate accessibility features for people with dementia into existing apps.

4.4.3 *Prompt features*

Further comment on the prompt features adapted or introduced in the updated versions of Solitaire and Bubble Explode is warranted given the observed difference in prompt utilisation between the two studies and the two apps. In considering the ineffectiveness of the feature in the original version of Solitaire (only 20% of all generated prompts were utilised), it was proposed that participants may either not be noticing the prompt, or they may not know how to respond to it. The implemented adaptation of the prompt in Study 2 increased the brightness and surface area of the pulsating light and added an animated moving arrow pointing directly to the prompted card (see Figure 4.4b). By emphasising the prompted card to this extent, this conceivably increased not only its potential to be noticed, but also the likelihood of the prompt being utilised. This suggestion is based on the distinction between implicit and explicit prompts (Wherton & Monk, 2010), whereby an implicit prompt is merely designed to draw attention to an element, whilst an explicit prompt is designed to provide instruction. For example, for some participants, a subtle pulsating light (the design of the original Solitaire prompt; see Figure 4.4a) may be too implicit, in that it may be noticed but then dismissed as a purely aesthetic feature. On the other hand, whilst not being a fully explicit prompt, an emphatic pulsating light with an animated arrow moving beneath it may convey its instruction more effectively, in addition to being more visible. From the results of the present study, it is evident that the redesigned prompt feature in Solitaire was utilised significantly more often than the original design (61% compared with 20%), but it is not known whether this was due to it becoming more implicit or explicit. In other words, whilst the effectiveness of the adaptation has been established, the reason behind its effectiveness has not.

This discussion is also applicable to the newly introduced prompt feature in Bubble Explode, which was rarely utilised and, from a design perspective, shared more in common with the original prompt in Solitaire (see Figures 4.12a and 4.12b). The proportion of utilised prompts in Bubble Explode reported in the present study was actually lower (10%) than for the original design of the prompt in Solitaire reported in Study 1 (20%). As with Solitaire, whether this low utilisation was due to the prompt not being seen or not being understood is unclear.

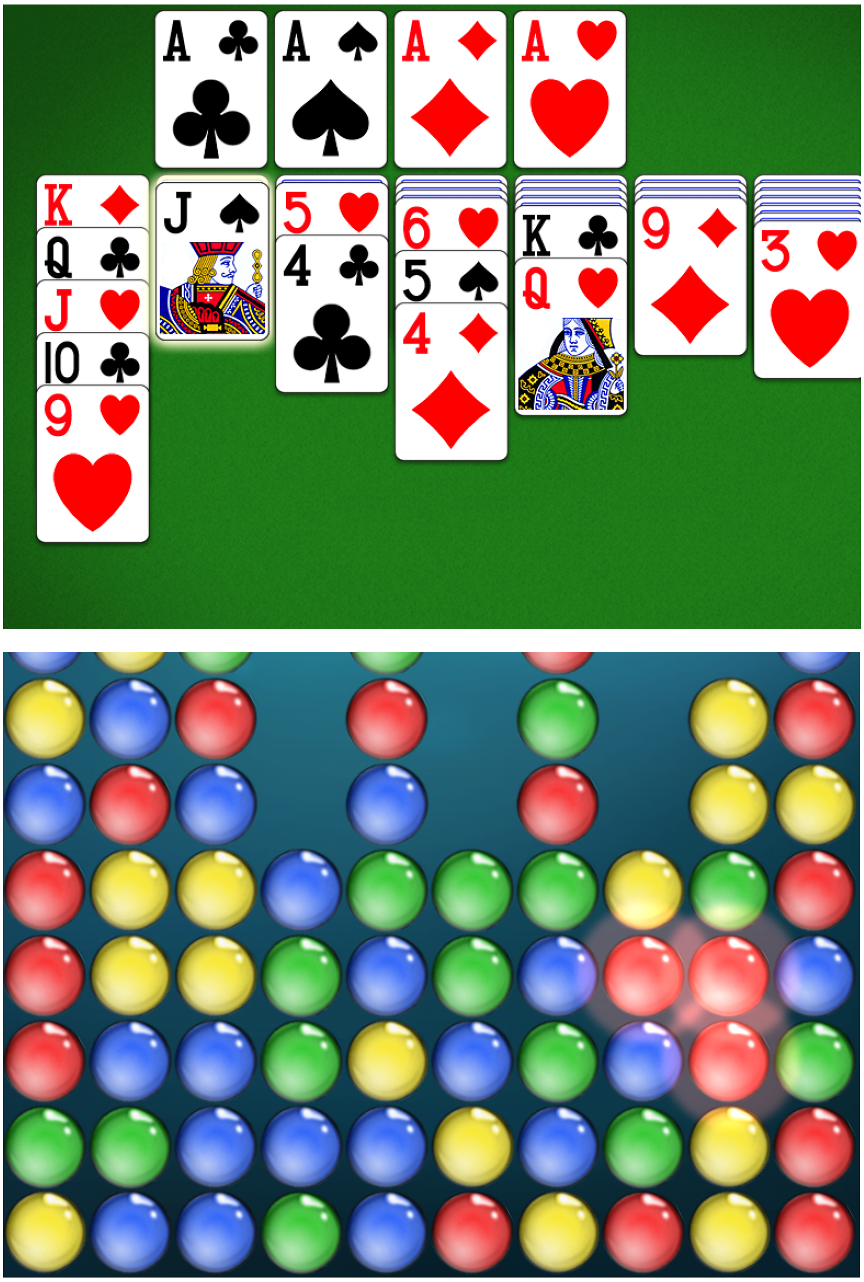

Figure 4.12a (above) and 4.12b (below). Screenshots comparing the original prompt feature in Solitaire (4.12a) with the newly designed feature in Bubble Explode (4.12b)

The potential importance in isolating the reason behind the effectiveness and ineffectiveness of these three prompt designs relates to the recommendations of how prompts should be designed in other gaming apps, as well as other genres of app and other digital formats. It is not possible to solve this issue using the data collected within these two studies, however, and therefore further research is required using an alternative research method (see Chapter 6).

4.4.4 *Independent gameplay*

In comparison with the original versions of both apps, independent initiation of gameplay increased in the adapted version of Solitaire (from 74% to 93%) and was maintained at ceiling level (100%) in Bubble Explode. The most likely explanation for the increase to independent gameplay initiation by participants playing Solitaire is directly linked to the increase in prompt utilisation, in that for a participant who is for whatever reason not interacting with the screen at the beginning of the game, the prompt feature would activate after 15 seconds, and therefore higher prompt utilisation as demonstrated in the present study should logically lead to higher gameplay initiation.

One of the conclusions of Study 1 that motivated the present study, was the uncertainty regarding the cause of the low checkpoint attainment rates. In Study 1, Solitaire was established as being a familiar game to all participants assigned to play it, yet only two progressed through the game to a predetermined checkpoint. The designation of the checkpoint was intended to demonstrate that participants who reached it had understood the rules of the game (either from prior knowledge of the card game or through the researcher's demonstration prior to gameplay on the app). However, with such high rates of screen interactions indicative of usability problems, alongside low rates of game advancing moves and prompt utilisation, it was unclear after Study 1 whether the majority's inability to progress was due to the complexity of the game outweighing any familiarity with the rules, or due to the inaccessibility of the game's digital recreation. When comparing the results from the present study with the results of Study 1, there is evidence to suggest that it is the game's complexity that reduces the likelihood of progression. This conclusion is reached because, despite improved usability, prompt utilisation and gameplay initiation, checkpoint attainment was still low (21% of all gameplay sessions). Therefore, for all that the adapted version of Solitaire has been shown to increase accessibility for people living with dementia, the evidence suggests that the game itself remains overly difficult for many.

Further evidence in support of this suggestion can be seen in the reasons for why checkpoint attainment did not occur in gameplay sessions (see Table 4.9). The number of sessions ended because participants repeatedly requested support was reduced from nine to two between Study 1 and Study 2, whereas the number of sessions ended because participants reached the time limit (10 minutes) without having reached the checkpoint increased from six to 12. This can be interpreted as participants feeling more confident to attempt independent gameplay using the adapted app, but without being able to progress through to the checkpoint due to the game's complexity. Whether prolonged exposure or a more comprehensive demonstration or training process would increase the likelihood of progression is perhaps a topic for future research. What is not clear from the data available is why five participants over the course of both studies were able to progress to the checkpoint in each of their gameplay sessions, whereas none of the other participants managed to reach the checkpoint at all. Performance on the MoCA may be somewhat of an indicator, as the range of cognitive scores for participants assigned to play Solitaire in both studies was between four and 24, and the average score of those who progressed was 16. However, five participants scored higher than 16 and did not manage to progress. An alternative indicator that was not measured may be experience of playing the physical card game of Solitaire (or possibly experience of playing card games in general). All participants confirmed that they were familiar with the game and had played it before, but further exploration of gameplay experience was not ascertained.

The distinction between independent initiation of gameplay and gameplay progression is indicative of the difference between participants learning to use the tablet computer and learning to play the games. As discussed, the use of the checkpoint as a measure for whether participants had learned the basic rules of gameplay to a sufficient extent revealed differences between the apps. However, gameplay initiation was high overall in both studies and for both games (at least 70%). Gameplay initiation was reported if the participant interacted with the app after the demonstration had finished and the researcher had retreated out of view. As presented in Tables 4.4 and 4.6, over 8,000 screen interactions were made by people living with dementia for whom touchscreen interactions were a new concept. Of the 60 participants recruited to the two studies, 57 initiated gameplay on at least one occasion. For people who had never used a tablet computer before, this demonstrates evidence of learning to use a new technology, and with minimal training. This is an important point in the context of understanding indicators of learning for people living with dementia who may be adopting this new technology. If there is evidence of learning to use the tablet, there is the potential for learning to use touchscreen apps; but this requires that appropriate apps are selected for the individual.

4.4.5 *Flow*

Whilst improving the accessibility of Solitaire did not help the majority of participants to progress through the game, those who did reach the checkpoint would have experienced fewer usability issues and therefore may have had a more positive experience. The concept of flow (described in 1.3.2) addresses the reasons that people enjoy activities that do not necessarily offer an end product or any extrinsic good as an outcome, but that are simply rewarding in and of

themselves (Nakamura & Csíkszentmihályi, 2001). It is proposed that the adaptions to Solitaire may have facilitated an experience that creates more opportunity for users to experience flow. The following four conditions of flow are identified as being directly linked with the results of the present study: (i) concentration and focus; (ii) feedback; (iii) clear goals; and (iv) balanced challenge. Concentration and focus requires that a game is designed with minimal distractions (Murphy et al., 2014). The two most prominent distractions observed during the video analysis of Study 1 were the optional 'drag-and-drop' control method and the regular appearance of the toolbar (see 3.3.2.1). By adapting Solitaire to remove or minimise the effects of these elements, the overall proportion of screen interactions indicative of usability problems reduced significantly in the present study. Feedback is necessary in game design to support the user to achieve their short- and long-term goals within the game (Sweetser & Wyeth, 2005). One method to facilitate this is to provide guidance in response to a player's inactivity (Murphy et al., 2014), such as the inactivity prompt featured in Solitaire. By redesigning this feature for the adapted version of the app, prompt utilisation was significantly increased in the present study. Clear goals (that users understand what is required of them) and balanced challenge (that a goal is within the capabilities of the user; Csíkszentmihályi, 1990), are also potentially impacted by the increased effectiveness of this prompt feature. As discussed, one of the possible explanations as to why the prompt feature was utilised more often in the present study is that its increased emphasis improved its capability of conveying meaning (i.e., it more clearly supported users to achieve their short-term goal of finding their next move). The fact that the prompts only support those who need them (i.e., users for whom their flow experience is in jeopardy due to inactivity) avoids the possibility of making the game too easy for users who do not require support, thus contributing toward a balanced challenge (Murphy et al., 2014).
If this hypothesis were true, that for those who were able to progress through Solitaire the adaptations increased the potential for flow; the wider implication is that the likelihood of long-term adoption of the game is increased (Eck, 2010). Further consideration of flow indicators, from the perspective of participant response during gameplay, is examined in the next chapter.

4.4.6 *Enjoyment*

Reported enjoyment was marginally lower among the participants who played the adapted Solitaire compared with the original, whereas there was a slight increase among participants playing adapted Bubble Explode. The variation in reported enjoyment is not so obviously explained, and may in fact be contrary to logical expectation, as of the two apps the one with the more demonstrably improved accessibility was associated with lower reported enjoyment, and vice versa. One possible explanation is that by increasing the accessibility of Solitaire, participants became more aware of the fact that they were not able to progress through the game. With the original version of the app, when participants were unable to progress they could potentially have attributed their difficulty to the design of the game, as opposed to their own capability. This may have had less impact on their opinion of how enjoyable the game was.

In many ways, this is a continuation of the paradox discussed in Study 1 (see 3.4.3), where, again, contrary to expectation, the app associated with less progression and more accessibility issues was rated as enjoyable by marginally more participants. Given that the enjoyment score was only marginally lower, and the fact that generally across all gameplay sessions for each app and in each study enjoyment ratings were relatively high (greater than 75%), the message that enjoyment of touchscreen games is possible for people living with dementia should not be clouded. However, given that the method used to obtain enjoyment ratings was intentionally rudimentary (see 3.2.5), it is recognised that this evidence should only be used as a platform from which to consider other, more thorough methods of analysing enjoyment during independent gameplay. One such method, using video recordings to examine facial responses, is examined in the next chapter.

4.4.7 *Limitations*

The same recruitment strategy was used as in Study 1 to recruit a comparable sample of participants for the present study. Participant characteristics in both studies were reported (see 4.2.2) and the similarity between the samples in terms of gender, age and cognitive score is evident, with no significant differences between the samples in age or cognitive score. However, despite these similarities, it is possible that an unexplored and therefore uncontrolled variable, such as hobbies and interests, or level of gameplay experience, may account for some of the variance in the results.

As highlighted (in 4.2.3.2), due to the unavailability of the updated Bubble Explode app on the iOS platform, participants in Group 2 of the present study used a Samsung Galaxy tablet as opposed to the Apple iPad tablet used in Study 1. Whilst these tablets were closely matched on technical specifications, and showed no differences in performance whilst running Bubble Explode either in pre-testing or during the study, in ideal circumstances this change would not have occurred and, again, the potential for this having affected the results is recognised.

4.5 Conclusion

There is great potential for collaborating with developers to improve the accessibility of touchscreen apps for people living with dementia, although communication is key to ensure that the needs of the target population are understood and are reflected in any design changes. However, desired changes may not always be possible, so compromise or alternative solutions may be required. The adaptations to Solitaire proved to be effective in reducing usability problems and increasing the effectiveness of the prompt feature, whereas those made to Bubble Explode had less of an impact. This may be indicative of the differences in how closely the proposed solutions were implemented. However, whilst this was reflected in the measured outcomes relating to accessibility, there were only marginal increases to the rates of participants' progression through either game; progression in Solitaire was still difficult whereas progression in Bubble Explode was very attainable. These findings reaffirm the conclusions of Study 1 that Solitaire may be too complex a game for many people living with dementia to play independently, despite its familiarity. Also, that familiarity should not be overly relied upon when identifying potential activities on touchscreen tablets. Finally, despite marginal fluctuations between groups in each study, self-reported enjoyment remained high for participants playing both games, again suggesting that game progression was not associated with enjoyment in this context. Further research is warranted into the specific nature of the effectiveness or ineffectiveness of the prompt features within each game (see Chapter 6).

4.6 Summarised findings from Studies 1 and 2

Following a thorough review of the literature on touchscreen technology (see Chapter 2), the potential for touchscreen apps as a source of entertainment that could be enjoyed independently by people living with dementia was proposed. Study 1 sought to investigate how suitable, accessible apps could be identified; considering the concepts of familiarity and novelty when selecting apps and analysing how people with dementia interacted with touchscreen technology. The findings from Study 1 were used to inform the adaptation of two touchscreen games in collaboration with the games' developers. An evaluation of the effectiveness of these adaptations formed the basis of Study 2, which repeated the methodology of the first study to compare the experience of participants using the two newly updated apps. Across the two studies, 60 participants were recruited who contributed a total of 167 gameplay sessions. Each of these sessions were video recorded and analysed, totalling 8 hours and

50 minutes of analysed gameplay and 11,286 coded touchscreen interactions and events. The key findings from these studies are:

- People living with dementia are capable of independent gameplay on touchscreen tablet technology and can learn to interact with the software with minimal training.
- Accessible design can improve the gameplay experience for people with dementia by reducing the number of usability problems.
- Prompt features can be effective to encourage gameplay, but their design must be appropriate.
- There is great potential in collaborating with app developers to improve the accessibility of touchscreen apps, but communication and compromise are essential to the process.
- Familiarity may not always be the most effective indicator when identifying touchscreen apps, and novelty should not be routinely avoided; a game's complexity and usability for the target user should be considered above each of these factors.
- Existing touchscreen apps can be an enjoyable form of entertainment for people living with dementia.
- An investigation of participant engagement during gameplay sessions, using the participant-facing video recordings, will be explored in the next chapter.

Chapter 5. Proposing indicators of engagement for people living with dementia when playing touchscreen games independently

5.1 Introduction

Over the first two studies, 60 people living with dementia participated in gameplay sessions of two pre-existing apps on a touchscreen tablet computer. Chapters 3 and 4 focused on the gameplay experience; to evaluate whether touchscreen apps could be used as independent forms of entertainment for people with dementia, how apps could be identified, and what features of apps are important to facilitate accessibility. To address these questions, video recordings of each gameplay session focusing on the participants' interactions with the tablet computer were analysed. An important concept that was not included in these chapters was that of participant engagement. At the end of each gameplay session, participants were asked whether they enjoyed playing their assigned app, to which responses were generally positive (see 3.3.1.3 and 4.3.3.3). To complement this self-report, objective evidence of engagement with the touchscreen apps was sought. In each session, a second video recording was made focusing on the participant themselves (as opposed to the tablets), and these are examined in the present chapter.

5.1.1 *Engagement*

Engagement has been defined as "the act of being occupied or involved with an external stimulus" (Cohen-Mansfield, Dakheel-Ali, & Marx, 2009, p. 2), and it has been highlighted as the most important element of non-pharmacological interventions for people living with dementia (Cohen-Mansfield et al., 2009; Low et al., 2013; Trahan et al., 2014). The need to quantitatively measure engagement has been emphasised in the context of dementia, in order to assess the effectiveness of activities or interventions (Cohen-Mansfield et al., 2009; C. Jones et al., 2017; Morgan-Brown & Brangan, 2016). This knowledge can be beneficial not only from a research and evaluation perspective, but also to support people in a caring role (Cohen-Mansfield et al., 2009); to recognise the presence or absence of engagement and react accordingly. It is surprising, therefore, that the measurement of engagement has received relatively little focus in comparison with other outcomes (C. Jones et al., 2015; Morgan-Brown & Brangan, 2016).

5.1.2 *Existing measures of engagement*

In a recent systematic review of psychosocial approaches for increasing engagement in activities for people with dementia (Trahan et al., 2014), it was found that only two outcome measures had been used in the reviewed studies to specifically examine engagement; the Observational Measurement of Engagement (OME; Cohen-Mansfield et al., 2009) and the Menorah Park Engagement Scale (MPES; Judge, Camp, & Orsulic-Jeras, 2000). Other, generic measures used to examine engagement directly included frequency counts and time-sampling, but in many cases, measures of other domains (e.g., agitation) were used to infer impact on engagement (C. Jones et al., 2015).
The OME is the most frequently reported measure of engagement in studies with people living with dementia (Trahan et al., 2014). It is based on a conceptual framework of engagement that features five dimensions: rate of refusal, duration, level of attention, attitude, and action (Cohen-Mansfield et al., 2009). The latter three dimensions are measured using Likert scales of between four and seven points. The MPES has been reported less (Trahan et al., 2014), and was developed to measure engagement with a specific intervention (Orsulic-Jeras et al., 2000), although it has been applied in other studies (Jarrott & Gigliotti, 2010). The MPES primarily focuses on four types of engagement: constructive (motor or verbal responses), passive (listening or looking responses), other (purposeless responses) and non-engagement (staring into space or looking away; Camp & Skrajner, 2004). To the best of the researcher's knowledge, and based on a thorough review of the literature (see Chapter 2), the analysis proposed in the present chapter has not been conducted before, with regards to the specific intervention (independent gaming), stimuli (touchscreen tablet apps), population (people with dementia) and measurement (quantitative indicators of engagement). Therefore, whilst the OME and MPES contain relevant information that can be used to inform the selection of outcomes for the present analysis, neither were considered entirely suitable. Also, whether or not participants engaged with the gameplay sessions is not the only question of interest; but what such engagement might look like? This is of equal importance as it will allow the knowledge to be shared with people such as family members and care providers, who may benefit from knowing what external indicators of engagement look like in this context. The assumption that higher levels of expressed emotion equate to higher levels of engagement may not apply, as there is evidence to suggest that demonstrable expressions of emotion might not be a valid indicator of engagement for independent touchscreen gaming (see 5.1.3).

5.1.3 *Independent gaming*

In order to effectively measure how people with dementia engage with touchscreen games independently, it is necessary to first consider what purpose such an activity fulfils. Users without cognitive impairment have previously reported that they play digital games for intellectual stimulation and satisfaction (Ravaja et al., 2004), or for relaxation, fun and to pass the time (Nap, de Kort, & Ijsselsteijn, 2009). It is not usual for players to cite feeling strong emotions as a motivator to play games (Ravaja et al., 2004). The subgenre of casual video games, which includes puzzle games (Russoniello, O'Brien, & Parks, 2009) such as Solitaire and Bubble Explode used in Studies 1 and 2, are less associated with high arousal and excitement, and more with subtle processes such as decision-making, discovery and reward (Gualeni, Janssen, & Calvi, 2012). Independent gaming, where the computer is the opponent, or there is no opponent at all, differs from social gaming in that positive expressions of emotion are less likely without the appetitive motivation to interact with another human (Ravaja et al., 2006). As such, if people with dementia play games in a similar way to those without dementia, it is expected that there will be a lack of expressed emotion during independent gameplay sessions.

Furthermore, the predicted absence of expressed emotion accords with flow theory (described in 1.3.2). When considering the features of flow, Csíkszentmihályi commented that "perhaps the most universal of these [characteristics] is the focused concentration people report whenever an activity is deeply enjoyable" (Csíkszentmihályi, 1988, p. 32). If during engagement with a stimulus the user should enter into a state of focused concentration, this would suggest that positive expressions of emotion would get lower as they become more engaged. Existing measures of engagement (OME and MPES) do not adequately address this directional reverse. Clearly, therefore, an investigation into indicators of engagement when playing touchscreen games requires a non-assumptive measurement of emotional response. This will provide further insight into whether flow theory applies for people living with dementia in this context, and how engagement might be demonstrated.

5.1.4 *Measuring emotional response*

The measurement of facial expression can be conducted using manual coding systems, physiological techniques or computerised automated recognition software (Leppanen et al., 2017). There are pros and cons to each method, for example physiological techniques such as facial electromyography can detect highly specific changes at the muscular level of response, but require invasive sensor placement (Boxtel, 2010; Gualeni et al., 2012) and can be overly sensitive to motor responses unrelated to emotion (Boxtel, 2010; Polman, Calvi, & Janssen, 2011).

For the purposes of the present analysis, the use of automated recognition software was considered. To examine the feasibility of using such software with the data collected in Studies 1 and 2, a test case was conducted using the FaceReader™ software developed by Noldus. The results indicated that the participant in the video was 'angry' for 97% of the gameplay session, which was contrary to the opinion of the researcher who interpreted their facial expression as neither negative nor positive, but indicative of concentration on the task. Previous research utilising FaceReader™ reported similar results, concluding that the software was unable to distinguish between a 'neutral' expression (concentration) and an 'angry' expression when a furrowed brow was displayed (Terzis, Moridis, & Economides, 2010; Zaman & Shrimpton-Smith, 2006). Given the expectation that concentration would feature prominently during the recorded gameplay sessions (as introduced in the previous subsection), automated recognition software was not used for the present investigation. Instead, manual analysis was conducted using an existing coding system.

5.1.5 *Research questions*

The analysis of the participant-facing videos collected in Studies 1 and 2 sought to answer the following questions: (1) Is there further evidence from the participant-facing video recordings to suggest that people living with dementia engaged with the touchscreen apps during gameplay sessions? (2) What observable behaviours indicate engagement during touchscreen gameplay?

5.2 Method

To investigate indicators of engagement for people living with dementia when playing touchscreen games, the video recorded data collected in Studies 1 and 2 was analysed. This included data from 60 participants over a total of 167 gameplay sessions lasting between 4.32 seconds and 10 minutes. As no unique data were collected for this purpose, sections on design, materials, the environment and the procedure are not included as they have been described extensively in Chapters 3 and 4. The present chapter, therefore, includes a truncated method section detailing the outcome measures used and describing the analysis of the participant-facing video recordings. For the convenience of the reader, the diagram detailing the positioning of the video cameras in Studies 1 and 2 is repeated (see Figure 5.1).

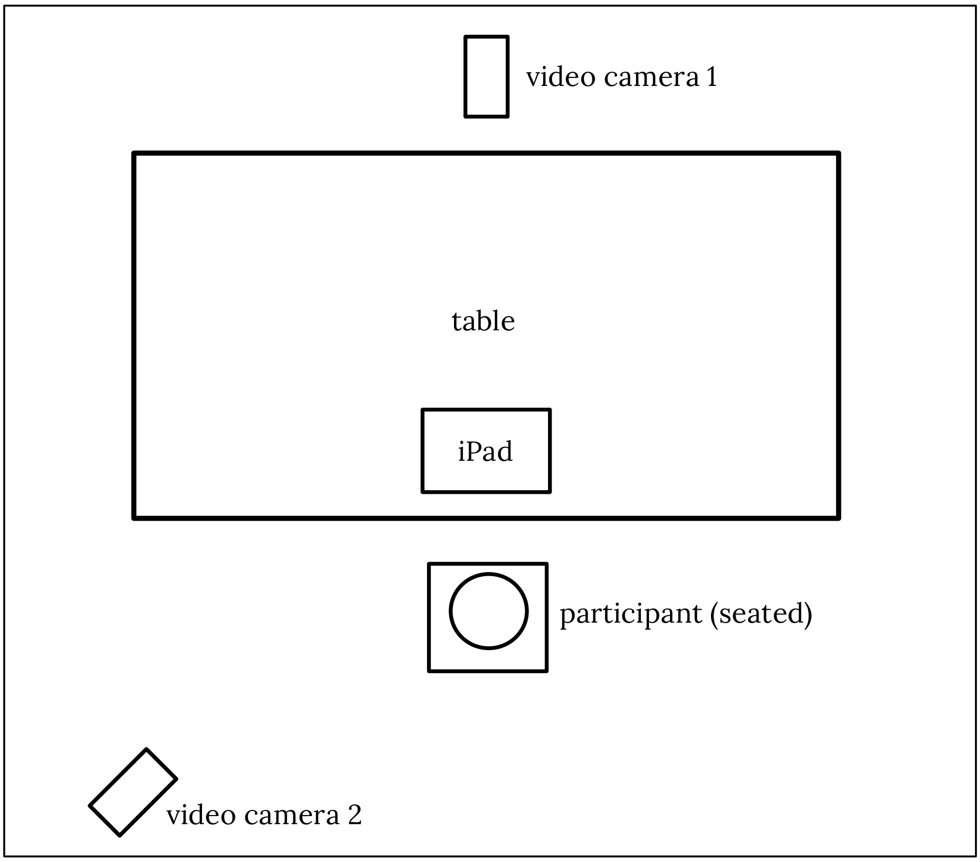

Figure 5.1. Diagram of the ideal environment setup

5.2.1 *Outcome measures*

To measure engagement during independent gameplay on a touchscreen tablet computer, three outcome measures were employed: emotional response, rate of interaction and eye gaze. These were selected based on two dimensions of the OME – attention (interaction and gaze) and attitude (emotional response) – that were reported to be key components by the authors (Cohen-Mansfield et al., 2009).
Descriptive statistics were calculated based on the outcome measures listed in the proceeding subsections. For each outcome measure, statistical analysis was undertaken to assess whether there were any significant differences between gameplay conditions (original Solitaire, adapted Solitaire, original Bubble Explode and adapted Bubble Explode). The presence of outliers in the results of each measure led to the decision to use the nonparametric alternative to the one-way ANOVA; the Kruskal-Wallis H test.

5.2.1.1 Emotional response

In each gameplay session, participants' emotional expressions were analysed and coded using the Facial Expression Coding System (FACES; Kring & Sloan, 1991).

FACES was not developed for use by any specific population, and provides information on the valence of facial expressive behaviour (positive and negative); including the frequency, intensity, and duration of expressions. Expressions are defined either through changes from neutral (i.e., no expression) to non-neutral and back again, or from one non-neutral expression to a different non-neutral expression. Following the advice of the authors of FACES, as included in their user manual and subsequent validation paper, a variation within the scope of the original coding system was made to the use of FACES in the present analysis. They advise investigators to choose from the available variables listed in the user guide (frequency, intensity and duration; Kring & Sloan, 1991) only those which are suitable for the intended purpose, as their inter-correlation has been demonstrated in earlier studies by the authors and colleagues (Kring & Sloan, 2007).

When training to use FACES, the researcher observed that emotional expression during gameplay sessions was minimal, and therefore that the ratings of 'frequency' and 'intensity' would not be necessary (as following the definitions of the intensity range, no expression was ever observed to be greater than the minimum rating of one, defined as 'low'). Instead, each gameplay session would be summarised by the proportions of neutral, positive and negative expressions, using the 'duration' of each expression.

FACES was recreated as a coding scheme (see Table 5.1) in the Observer® software (further described in 3.2.7), with 'neutral' (baseline), 'positive' and 'negative' expressions as mutually exclusive and exhaustive codes (i.e., there was always one active expression, but only one expression could be active at any time).

5.2.1.2 Rate of interaction

Using the coded screen interactions data from Studies 1 and 2 (see sections 3.2.5.2 and 4.2.5.1), a rate of interaction for each gameplay session was calculated from the total number of screen interactions made by participants divided by the total number of minutes they played the game. In order for a gameplay session to be eligible for this measurement, the participant must have made at least five screen interactions and played for at least one minute.

5.2.1.3 Eye gaze

For each gameplay session, the direction of participants' gaze was estimated through observation of the participant-facing video recordings. As more specific measurement of gaze fixation was not possible without the use of specialist equipment, gaze direction was limited to the broad definitions of whether or not the participant was looking at the tablet computer screen. As with the analysis of emotional responses, eye gaze was incorporated into the coding scheme (see Table 5.1) for the Observer software, with eye gaze ‘toward screen’ (baseline) and ‘away from screen’ included as mutually exclusive and exhaustive codes.

5.2.2 Observation of video recordings

Analysis of the video recordings was conducted as in Studies 1 and 2 (described in 3.2.7) using the Observer XT software.
A new coding scheme was developed for the purpose of analysing the participant-facing videos recorded in Studies 1 and 2 (see Table 5.1). The researcher viewed each video at half-speed and entered codes chronologically within the monitored duration of gameplay, that is from the point that the researcher invited the participant to begin to the point the gameplay session ended (see 3.2.6).

Table 5.1. Summary of coding scheme designed for the purposes of the present analysis to observe participants’ facial expressions and eye-gaze

Facial expression	**Definition**
Neutral*	*The participant’s face shows no sign of any emotional expression (Kring & Sloan, 1991)*
Positive	*The participant’s face displays a positive expression, as defined in the FACES training manual (Kring & Sloan, 1991)*
Negative	*The participant’s face displays a negative expression, as defined in the FACES training manual (Kring & Sloan, 1991)*
Eye gaze	**Definition**
Screen*	*The participant’s gaze was directed toward the tablet computer screen*
Away from screen	*The participant’s gaze was directed away from the tablet computer screen, or they closed their eyes (discounting blinks)*

*baseline codes

5.3 Results

Sixty participants attended a total of 167 gameplay sessions in Studies 1 and 2. Gameplay was independently initiated in 154 of these sessions. Due to equipment failure, the participant-facing video recordings of six gameplay sessions could not be analysed. Therefore, the total number of analysed participant-facing video recordings was 148 (see Table 5.2). The mean length of each individual gameplay session was three minutes and 17 seconds.

Table 5.2. Combined characteristics of participants from Studies 1 and 2 (N=60 participants)

Female	Male	Mean age (SD)	Mean MoCA score /30 (SD)	Total no. of analysed participant-facing video recordings
47	13	85.75 (7.13)	13.18 (4.04)	148

5.3.1 *Emotional response*

The facial expressions of participants were analysed during 148 sessions of independent touchscreen gameplay of either Solitaire or Bubble Explode (see Table 5.3). Participants' emotional expression was rated as neutral for 98.87% (range 69%-100%, SD 3.05) of all gameplay sessions, with positive and negative expressions each accounting for less than 1% of the mean proportion. In 96 gameplay sessions, no positive or negative emotional expressions were recorded at all (participants' expressions in these sessions were rated as 100% neutral). The presence of an outlier should be noted, as in one gameplay session (of adapted Solitaire) a neutral facial expression was recorded at 69%, almost 30% below the mean. In this case, a positive expression (i.e., grinning, smiling or laughing) was recorded for 30.97% of the session.

Table 5.3. Emotional responses recorded during gameplay sessions

Emotion	Mean proportion of all gameplay sessions (N=148 sessions)
Positive	0.59%
Negative	0.51%
Neutral	98.87%

There was very little difference to participants' responses between gameplay sessions of Solitaire and Bubble Explode, or the adapted versions and original versions of each app (see Table 5.4). The gameplay sessions with the greatest amount of variance in reported emotion involved the adapted version of

Solitaire, where the mean proportion of positive and negative emotions were each reported as at least 1%. The gameplay sessions with the least amount of variance involved the adapted version of Bubble Explode, in which the mean proportion of positive and negative emotions combined totalled less than 0.4%.

Table 5.4. Emotional responses recorded during gameplay sessions, compared between app and app version

	Mean proportion of all gameplay sessions			
Emotion	Original Solitaire (N=27 sessions)	Adapted Solitaire (N=40 sessions)	Original Bubble Explode (N=40 sessions)	Adapted Bubble Explode (N=41 sessions)
Positive	0.59%	1%	0.43%	0.33%
Negative	0.74%	1.07%	0.25%	0.06%
Neutral	98.72%	97.82%	99.29%	99.63%

A Kruskal-Wallis H test was conducted to determine if there were differences to the proportions of neutral emotion reported between the four gameplay conditions: original Solitaire, adapted Solitaire, original Bubble Explode and adapted Bubble Explode. Distributions of the proportion of neutral emotion were similar for all groups, as assessed by visual inspection of a boxplot. Median proportions of neutral emotion were not statistically significantly different between conditions, $X^2(3) = 6.45$, $p = .09$. Therefore, the reported proportion of neutral emotion during gameplay sessions was not significantly affected by which app or version of the app was being played.

5.3.2 *Rate of interaction*

The number of screen interactions made by participants in each gameplay session was divided by gameplay time to calculate their rate of interaction per minute. Eleven gameplay sessions were not eligible for this analysis due to the participants initiating fewer than five screen interactions, or not playing for at least one minute (six sessions of original Solitaire and five sessions of adapted Solitaire). The mean rate of interaction for all eligible gameplay sessions was 16.14 interactions per minute (range 1.03-63.33, SD 12.81), which equates to a gameplay move every 3.72 seconds.

Inspecting the mean rates of interaction for each app and app version reveals that for both Solitaire and Bubble Explode, gameplay sessions involving the adapted versions of the apps featured slightly slower rates of interaction (see

Table 5.5). The variance between the slowest rate of interaction (adapted Solitaire) and the fastest rate (original Solitaire) equates to gameplay moves every 3.05 seconds and every 4.27 seconds, respectively. The presence of outliers in each of these two conditions should be noted (see Figure 5.2), with rates of more than 30 seconds faster than the mean being recorded in four sessions of original Solitaire (one participant) and three sessions of adapted Solitaire (two participants).

Table 5.5. Rates of interaction during gameplay sessions, compared between app and app version

	Original Solitaire (N=21 sessions)	Adapted Solitaire (N=35 sessions)	Original Bubble Explode (N=42 sessions)	Adapted Bubble Explode (N=41 sessions)
Mean rate of interaction (interactions per minute)	19.66	14.06	16.37	14.38

A Kruskal-Wallis H test was conducted to determine if there were differences to the rates of interaction reported between the four gameplay conditions: original Solitaire, adapted Solitaire, original Bubble Explode and adapted Bubble Explode. Distributions of the interaction rates were not similar for all groups, as assessed by visual inspection of a boxplot. The mean rank of interaction rates was not statistically significantly different between conditions, $X^2(3) = 5.55$, $p = .14$. Therefore, the recorded rates of interaction during gameplay sessions was not significantly affected by which app or version of the app was being played.

5.3.3 *Eye gaze*

The direction of the participant's eye gaze during each gameplay session was estimated from the participant-facing video recordings, and the proportion of time that gaze was directed at the tablet computer screen was calculated. Across all gameplay sessions, the mean proportion of time participants' gaze was directed at the screen was 97.16% (range 65.78%-100%, SD 5.2).

There was very little difference to participants' gaze direction between gameplay sessions of Solitaire and Bubble Explode, or the adapted versions and original versions of each app (see Table 5.6). Gameplay sessions involving the adapted versions of each app featured a marginally higher mean proportion, and this was slightly higher in gameplay sessions of Bubble Explode compared with Solitaire. The presence of outliers in five gameplay sessions should be noted (three in adapted Solitaire, one in original Solitaire and one in adapted Bubble Explode;

see Figure 5.1), with proportions of at least 10% lower than the mean being recorded.

Table 5.6. Proportion of gameplay sessions during which participants' gaze was directed at the touchscreen tablet, compared between app and app version

	Original Solitaire (N=27 sessions)	Adapted Solitaire (N=40 sessions)	Original Bubble Explode (N=40 sessions)	Adapted Bubble Explode (N=41 sessions)
Mean proportion of screen-directed gaze	95.48	96.21	98.21	98.41

A Kruskal-Wallis H test was conducted to determine if there were differences to the proportions of screen-directed gaze reported between the four gameplay conditions: original Solitaire, adapted Solitaire, original Bubble Explode and adapted Bubble Explode. Distributions of the proportion of screen-directed gaze were not similar for all groups, as assessed by visual inspection of a boxplot. The mean rank of interaction rates was not statistically significantly different between conditions, $X^2(3) = 6.21$, $p = .1$. Therefore, the reported proportion of screen-directed gaze during gameplay sessions was not significantly affected by which app or version of the app was being played.

5.3.4 *Combined indicators of engagement*

As presented, expressions of positive and negative emotion during 148 independent gameplay sessions of Solitaire and Bubble Explode were rare. Their inclusion as indicators of engagement during independent gameplay is therefore not justified (this will be discussed in depth in the next section). Consequently, a combination of rates of interaction and screen-directed gaze for each gameplay session will be explored as evidence of engagement.

Figure 5.2 presents the combined outcomes from 134 gameplay sessions, where both participant-facing (for gaze direction) and iPad-facing (for interaction rates) video recordings were available, and the sessions were eligible for each outcome (i.e., gameplay was initiated, and the minimum criteria of moves and gameplay time was achieved to calculate rates of interaction).

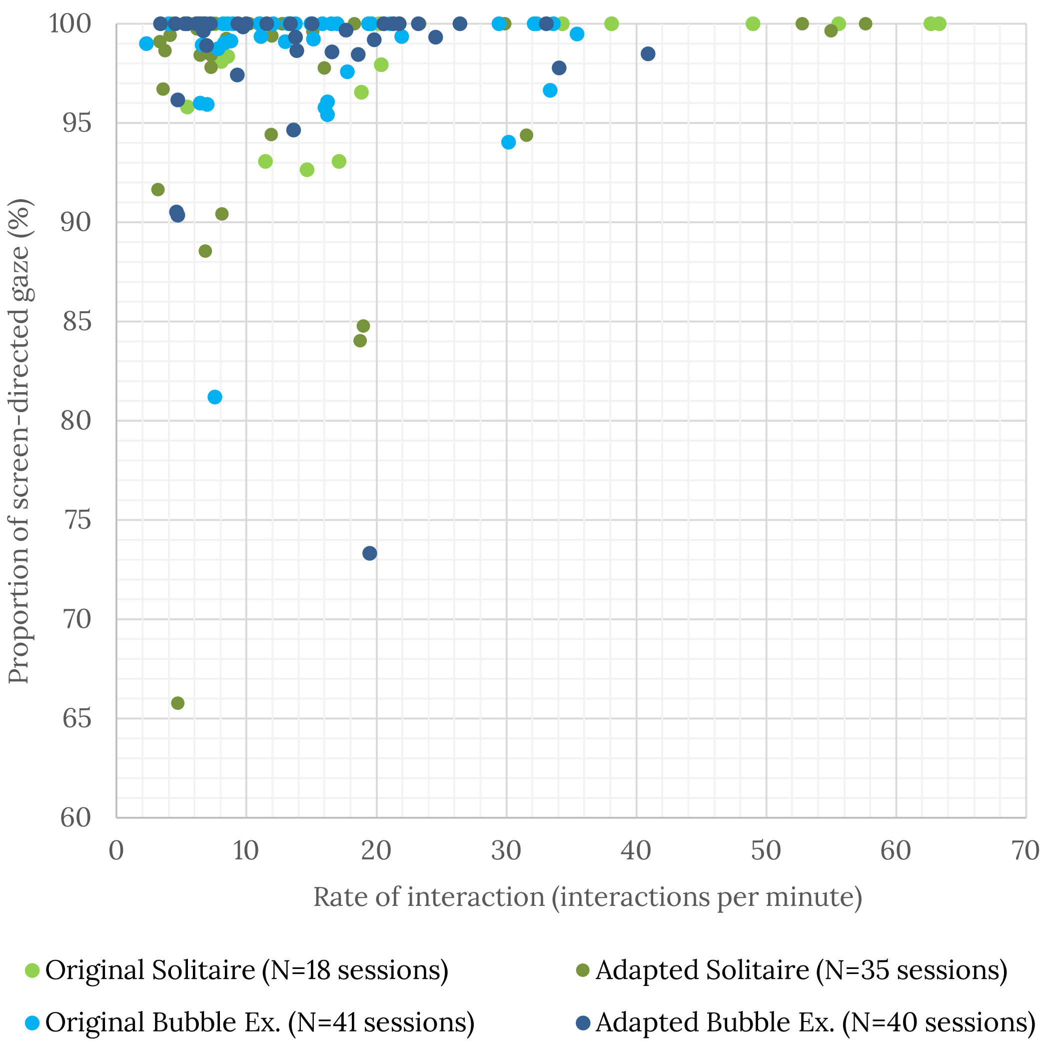

Figure 5.2. Scatter graph depicting the proportion of screen-detected eye gaze and rate of interaction with the tablet computer for each gameplay session

Assigning an arbitrary figure of four screen interactions per minute (equating to one interaction every 15 seconds; the definition of inactivity in MobilityWare's Solitaire app before the prompt is generated) as a minimum for defining regular gameplay; 128 (95.52%) gameplay sessions met this criterion. Of the six gameplay sessions that fell below this figure, four featured adapted Solitaire, and one featured each version of Bubble Explode.

Similarly, assigning an arbitrary figure of 90% for screen-directed gaze as a minimum for defining focused gameplay; 128 (95.52%) gameplay sessions met this criterion. Of the six gameplay sessions that fell below this figure, four featured adapted Solitaire, and one featured each version of Bubble Explode. None of the 134 gameplay sessions failed to meet both of these criteria. Consequently, 122 (91.04%) gameplay sessions in Studies 1 and 2 achieved both a minimum of four screen interactions per minute and 90% screen directed gaze.

Based on the above criteria, participants in these sessions demonstrated both regular and focused gameplay.

5.4 Discussion

A mean rate of 16 interactions per minute (or one move every four seconds), and a mean proportion of 97% screen-directed gaze, characterise the gameplay sessions of participants in Studies 1 and 2 and provide evidence that people living with dementia can engage independently with touchscreen apps. According to the proposed definitions of regular interaction with the tablet computer (at least one interaction per 15 seconds) and high proportions of screen-directed gaze (at least 90%), engagement was evident in 91% of gameplay sessions of Solitaire and Bubble Explode. However, expressions of positive and negative emotion were almost completely absent from gameplay sessions (each representing less than 1% of the mean proportion of observed emotion in all sessions) and therefore should not be considered as indicators of engagement. Instead, concentration, represented by a neutral facial expression, is evidently a more accurate indicator (observed for 99% of the mean proportion of observed emotion in all sessions), which may be counterintuitive and contrary to expectation.

5.4.1 *Combined indicators of engagement*

In isolation, the reported findings do not provide sufficient evidence for independent engagement with touchscreen apps, but rather it is in combination that they become strong indicators. For example, a neutral expression is commonly associated with both boredom and concentration (Tracy & Robins, 2004). Without the additional presence of regular interactions and screen-directed gaze, it would be difficult to differentiate between these two seemingly opposing (bored/concentrating) states. Similarly, in isolation, regular interaction with the tablet computer could be interpreted as habitual or reflexive, and lacking intent or awareness (Saling & Phillips, 2007); and screen-directed gaze could represent passive engagement, at best, or disengagement and apathy, at worst (Orsulic-Jeras et al., 2000). It is, therefore, the combination of a neutral expression, regular interaction and focused gaze that is proposed as being indicative of engagement in the specific context of independent touchscreen gameplay. This supports and complements the current evidence base in that regular interaction and focused gaze are characteristics of the 'attention' dimension in the OME (Cohen-Mansfield et al., 2009), but also highlights the fact that expressed emotion does not necessarily equate to engagement when using certain stimuli, such as touchscreen devices.

In proposing these combined indicators of engagement – neutral expression, tablet interaction and eye gaze direction – the implications for practice extend beyond the formal measurement of engagement in research and clinical contexts. As tablet devices become more common in care settings, caregivers will need indicators that a person with dementia is engaged with the device and the activity. With the knowledge of what engagement in touchscreen activities looks like, they may be more likely to recognise its effectiveness and to encourage future use, or recommend the technology to other people. This is particularly important in situations where the person living with dementia relies on the carer to initiate such recreational pastimes. The key message is that the absence of positive expressions of emotion during independent gameplay does not signify an absence of engagement or enjoyment.

5.4.2 Flow

Flow theory explains why the absence of visual expressions of positive emotion during activities does not mean that people are not experiencing them. There is a seemingly incongruous link between intense concentration and enjoyment that characterises flow (C. M. Jones, Scholes, Johnson, Katsikitis, & Carras, 2014). As a person enters flow: they experience intense and focused concentration on a task; their actions and awareness merge together; their concern for their sense of self disappears; they feel in control; their temporal experience is distorted; and the combination of these experiences creates a sense of deep enjoyment and reward (Csíkszentmihályi, 1990; Nakamura & Csíkszentmihályi, 2001). Of these components, focused concentration on the task, or engagement, is the only one that is measurable through observation (Norris, Weger, Bullinger, & Bowers, 2014). Therefore, it can be argued that the presence of observed engagement during gameplay and self-reported enjoyment after gameplay is a valid indicator that flow was achieved. Examining the results from the present analysis in combination with the enjoyment ratings from Studies 1 and 2, it is revealed that in 107 (79.85%) of the 134 eligible gameplay sessions, engagement (as defined in 5.3.4) was observed and enjoyment was reported. This would suggest that a flow state was achieved in 80% of gameplay sessions. The implications of this finding relate to the potential of touchscreen apps in providing rewarding experiences that can be achieved independently by people living with dementia. The fact that flow can be achieved relatively easily and without the need for extensive practice or training is a unique feature of digital games (McGonigal, 2011), and the wide range of games now available as touchscreen apps further increases the likelihood that people can achieve flow (Murphy et al., 2014). The clear demonstration that people living with dementia are equally able to achieve flow is a finding that is unique to the present body of work (the only previous published research to address this topic featured retrospective examination for features of flow, in videos recorded during an iterative development process of touchscreen games for people with dementia; Astell et al., 2014). It is hoped that this can facilitate further research into the optimal design of digital games and apps to be inclusive of people living with dementia, and encourage the promotion of touchscreen technology as a viable mode of independent entertainment for this population.

5.4.3 *Comparison of apps*

Based on the outcomes measured, there were no significant differences between the four gameplay conditions (original and adapted versions of Solitaire and Bubble Explode) for participant engagement. This would suggest that participants were equally likely to be engaged with one app or version than another, which is comparable to the enjoyment response reported in Studies 1 and 2 (see 4.3.3.3). However, whilst this demonstrates the potential for touchscreen apps to be engaging regardless of their accessibility and complexity, this may only be a short-term effect; it is perhaps inevitable based on technology acceptance models that in the long-term inaccessible features and overly complex gameplay would have more of an impact on engagement (Hwang, Hong, Hao, & Jong, 2011; O'Neill et al., 2014; Zhang et al., 2014). Based on existing literature of casual games, it could be predicted that over a longer period of time, and in more naturalistic contexts (i.e., spontaneous gameplay not for the purpose of research), factors such as game genre (Granic, Lobel, & Engels, 2014), level of challenge (Salen & Zimmerman, 2004) and user personality (Ravaja et al., 2004) may all have an effect on the extent of experienced engagement. Consequently, further investigation into the potential of touchscreen gameplay as an engaging pastime for people with dementia in their home environment over longer periods of time is warranted.

5.4.4 *Limitations*

The experimental conditions in which the data were collected in Studies 1 and 2 may have had an impact on the findings. It is possible that engagement, despite being reported in 91% of gameplay sessions, may have been negatively affected by the fact that participants were asked to play the games at specific times for the purposes of research. This is because the voluntary nature of gaming has been identified as an important aspect of engagement (McCallum, 2012). Obviously, the people involved in the studies were not forced to play, and were aware that their participation was voluntary. However, there is still a distinction between the spontaneous decision to play games during times of leisure, and the agreement to participate in a research project involving gameplay. Furthermore, the control of gameplay length through the inclusion of the checkpoints in Solitaire and Bubble Explode, excluded the possibility of including gameplay duration as a measure of engagement. This was a conscious prioritisation by the researchers to focus on progression as an outcome for Studies 1 and 2 (described in 3.3.1.2), which was felt to be justified based on the range of other evidence-based outcomes selected to measure engagement for the present analysis. However, duration has been used in previous studies as a contributing measure for engagement (Kolanowski, Litaker, Buettner, Moeller, & Costa Jr., 2011; Trahan et al., 2014), and may have offered an additional perspective. Both of these potential shortcomings could be overcome with the design of a more naturalistic study, where gameplay is observed outside of experimental conditions allowing participants to choose when they play and to play for as long as they choose. Such a study would dovetail effectively with the present analysis, to test some of the existing findings and also to reveal new information regarding engagement with independent touchscreen activities.

The identifying of two figures to represent cut-off points indicating sufficiently high rates of interaction (4 moves per minute, based on the timing of the inactivity prompt in Solitaire), and sufficiently high proportions of screen-directed gaze (90%) in order to measure engagement was undeniably arbitrary. The lack of comparable research prevented the selection of thresholds informed by previous evidence, although it is likely that different figures would be required for different genres of game, if not for different individual games. The intention of this study was to present the results as clearly as possible and then identify where the threshold was being placed, in order for readers to understand the definitions under which engagement was being identified. In reality, it is difficult to argue that the participant who focused on the screen for 89% of their gameplay session was not engaged, in comparison with the three participants who were focused for 90% (see Figure 5.2). However, to a certain extent this is the nature of threshold assignment, and in order to justify decision-making (in this case; who demonstrated engagement and who did not), it is a necessary practice (Cizek, 2001).

Finally, it should be acknowledged that, without the use of automated eye-tracking technology, the gaze direction reported in the present analysis can only be considered an estimate. As justification for this approach, the observation of video recordings of participants' faces to base decisions on gaze direction has been employed previously (Calvo & Avero, 2005). Furthermore, the observed stimulus (tablet computer screen measuring 9.7 inches) was large enough to confidently estimate the presence or absence of directed gaze, and there was deliberately no attempt to infer more specific fixations of on-screen elements (e.g., individual cards or bubble groups). However, the use of eye-tracking apparatus for this particular measure would have been beneficial, and this will be explored in the next study (see Chapter 6).

5.5 Conclusion

Regular interaction, focused gaze and a neutral facial expression, representing concentration, are proposed as indicators of engagement for people with dementia during independent touchscreen gameplay. The fact that such a high proportion (91%) of eligible gameplay sessions in Studies 1 and 2 featured all three of these proposed indicators demonstrates the potential that touchscreen apps can have as forms of engaging entertainment for people living with dementia. Furthermore, the combination of engagement and self-reported enjoyment provides a strong argument for the presence of flow in gameplay sessions, which was achieved in 80% of analysed sessions. These results have implications for the ongoing measurement of engagement with people with dementia, the designers of touchscreen apps, and people with dementia themselves and those in a caring role who may experience and identify engagement in practice in their daily lives.

Chapter 6. Using eye-tracking to investigate people living with dementia's visual response to prompts in touchscreen games (Study 3)

6.1 Introduction

In the context of living well with dementia, prompts can be defined as contextual cues that support people to accomplish an end goal (Rusted & Sheppard, 2002; Wherton & Monk, 2010). The overall purpose of prompting is to maintain or facilitate independence (Bewernitz, Mann, Dasler, & Belchior, 2009; Rusted & Sheppard, 2002; Wherton & Monk, 2010). Non-digital use of prompts in this context have often focused on ADL, such as making tea, washing and dressing (Bewernitz et al., 2009; Mihailidis, Boger, Canido, & Hoey, 2007; Rusted & Sheppard, 2002). A key component to any prompting system, whether technological or human, is *how* the prompt is delivered. Three categories have been proposed: auditory, visual and video prompting, with the latter often involving a combination of the other two (Lapointe et al., 2013). Evidence in support of one medium over another is varied. For example, verbal instruction, an example of auditory prompting, was found to be effective when supporting people with dementia to carry out some tasks of daily living but not others (Mao, Chang, Yao, Chen, & Huang, 2014). Elsewhere, the notion of multi-modal prompts (Hoey et al., 2011) or personalised prompts (Lapointe et al., 2013) has been recommended, with the consensus being that they are dependent on the task *and* the person undertaking the task.

In digital software, the use of integrated prompts for people with dementia is in its infancy (see 2.3.4.2). Where prompts have been implemented, the purpose has been to focus or regain the attention of the user during a digital activity or task. In contrast with other accessible design features that are static by nature (e.g., selecting a difficulty level), a prompt system is dynamic and should only generate within the digital environment if a user requires support (Bouchard, Imbeault, Bouzouane, & Menelas, 2012). Consequently, prompts may be considered an inclusive design feature, in that their presence may benefit those that need it without impacting those that do not. Importantly, this relies on effective implementation of the prompt system, as providing a prompt to a person with dementia when they do not need it, may be confusing or reduce feelings of independence (Blunsden et al., 2009).

Variations in the design of prompts in software intended for people with dementia have included text boxes, animations, audio and verbal instruction

(Alm et al., 2009a; Alm, Astell, et al., 2007; Blunsden et al., 2009). As with their non-digital counterparts, the reported effectiveness of the different prompt methods is varied, and subtle differences in the design or the context in which the prompt is deployed may be significant. For example, the use of verbal prompts has been explored in digital software for people with dementia. During the iterative design process of digital interactive games (Alm et al., 2009a), the researchers found that a synthetic vocal prompt was usually ignored, a finding that was attributed to its inhuman nature and the fact that it was not recognised as speech. However, in the design and evaluation of ePad (Engaging Platform for Art Development; Blunsden et al., 2009; Leuty, Boger, Young, Hoey, & Mihailidis, 2012), the use of human-recorded vocal prompts was also found to be ineffective when tested with users, with the researchers proposing that personalised vocal prompts including the user's name may be more successful. These studies also investigated other forms of prompts, finding success with less intrusive methods such as simple animations and text prompts (Alm et al., 2009a).
There is also variety in how digital prompts have been triggered, such as through inactivity (Alm, Astell, et al., 2007; Astell, Alm, et al., 2014), in response to errors (Manera et al., 2015), or using facial mapping to detect loss of interest (Leuty et al., 2013). In casual puzzle games designed for the mass market, it is the former two methods that are most common (Barlet & Spohn, 2012). In Studies 1 and 2 (Chapters 3 and 4), the use of animated prompts in response to inactivity and errors were investigated in two existing puzzle games with people living with dementia.

6.1.1 *Adapted prompts in existing apps*

Solitaire and Bubble Explode were originally selected for inclusion in Study 1 (see 3.2.3.1) due to their potential as accessible apps for people living with dementia. One of the key features in the selected version of Solitaire that elevated it above other versions of the game during the evaluation process, was the inactivity prompt (labelled as an 'auto-hint' within the app). If a player does not attempt a move for 15 seconds, they are directed towards a valid move in the form of a highlighted card (an animated white glowing light surrounds the edge of the card; see Figure 6.1). However, data from Study 1 revealed that this feature was seldom utilised (participants only responded to 20% of all generated prompts; see 3.3.2.2). Consequently, when discussing with the game's developer, MobilityWare, how their version of Solitaire could be adapted to make it more accessible for people with dementia, one of the agreed solutions was to redesign the inactivity prompt so that its presentation was more emphatic (described in 4.1.2.1; see Figure 6.1). In Study 2, the effectiveness of this adaptation was evaluated, and significantly more prompts were utilised in comparison with

Study 1 (61% of all generated prompts; see 4.3.1.3). However, neither study addressed why the differing designs of the inactivity prompt elicited such a varied degree of effectiveness; was it that the prompted cards became more visible after the redesign and participants were more able to notice them? Or was it that the prompt was more informative and participants were more able to interpret its purpose? Answering these questions is important for informing the design of future digital prompts. For example, when adapting Bubble Explode, a prompt feature was implemented that was similarly under-utilised in Study 2 as with the prompts in original Solitaire in Study 1, thus any further adaptation would benefit from the knowledge of what made the redesigned prompt feature in Solitaire effective. It is these questions that the present study sought to answer, and to do so required a slightly modified methodological approach from the one used in Studies 1 and 2.

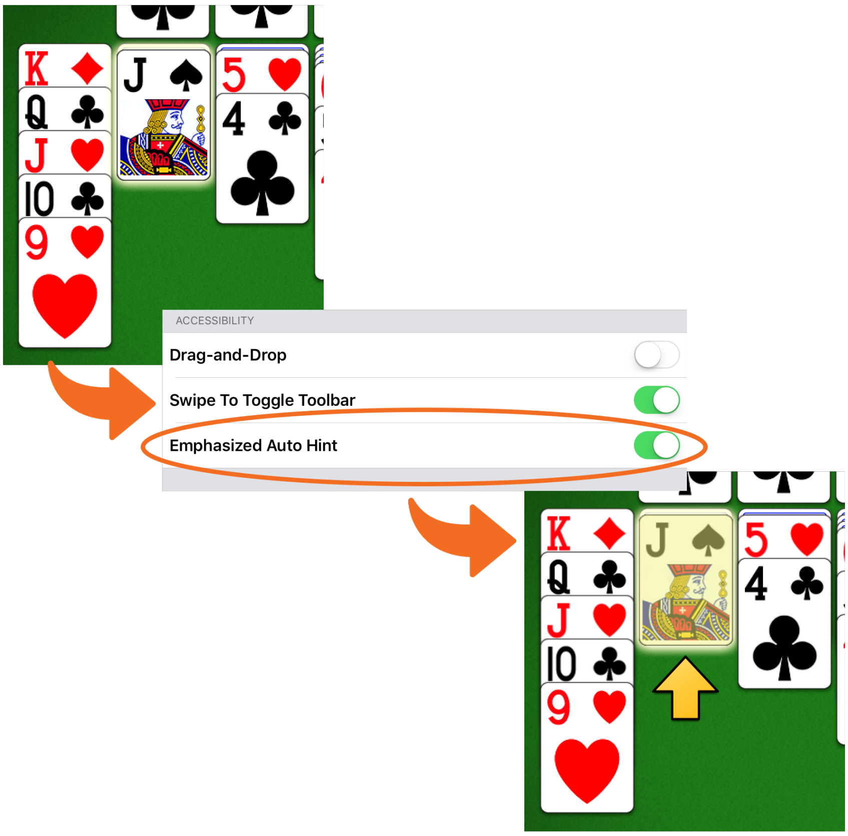

Figure 6.1. Process diagram of the original and adapted prompt feature in MobilityWare's Solitaire app

The reason why the existing data collected in Studies 1 and 2 could not be used to answer these questions is that the video recordings in isolation do not provide sufficient information to be able to differentiate between whether the inactivity prompt was (a) seen but ignored, or (b) not seen. The only observation possible in Studies 1 and 2 was what the participant did immediately after the presentation of the inactivity prompt (i.e., did they use the prompted card or not?).

For the present study, two options were considered: (i) by combining the existing methodology with either a think-aloud technique, where the participants would be asked to describe their thought process throughout their gameplay session; (ii) or by combining the existing methodology with eye-tracking, where the direction of each participant's gaze is measured during gameplay. Whilst the former could theoretically have been effective, the risk of confounding the results by increasing the cognitive demand of participants with cognitive impairment by asking them to report on their actions in the moment, was judged to be too high, and there is recent evidence that this technique is both ineffective and inappropriate with people living with dementia (Gibson et al., 2016). By contrast, measuring gaze direction using wearable eye-tracking technology was considered both an achievable and valid method for tackling the research question.

6.1.2 Eye-tracking

Eye-tracking is a technique that measures people's eye movement, providing the location of where they are looking at any point in time and the sequence in which their gaze moves from one location to the next (Hansen & Ji, 2010; Poole & Ball, 2005). In recent years, improvements to the accuracy and design of the technology has led to eye-tracking being used more commonly for usability testing in human-computer interaction research (Jacob & Karn, 2003; Poole & Ball, 2005). This has included research into the usability of video games (Alkan & Cagiltay, 2007; El-Nasr & Yan, 2006; Johansen, Nørgaard, & Rau, 2008). In these contexts, eye-tracking provides a valid method of improving the design of software (Poole & Ball, 2005), identifying usability problems and evaluating design modifications (Johansen et al., 2008). The use of eye gaze-tracking in human-computer interaction studies often relies on the 'eye-mind' hypothesis (Just & Carpenter, 1976); that the location of a person's eye gaze in a visual display is a reliable indicator of where their attention is being directed (Poole & Ball, 2005). Whilst specific cognitive processes cannot be inferred just from eye gaze (Holsanova, 2011), focus of attention is all that was required for the purposes of the current research into the visual response of users to a prompt feature.

In dementia research, eye-tracking has mainly been used as a means of supporting early detection of the disease (Crutcher et al., 2009; Zola, Manzanares, Clopton, Lah, & Levey, 2013), or as a measure of neurological impairment (Crawford et al., 2005; Hutton, Nagel, & Loewenson, 1984; Verheij et

al., 2012). The only published research including people with dementia using eye-tracking technology for evaluation purposes involve digital reminiscence (Burns, McCullagh, Nugent, & Zheng, 2014) and environmental wayfinding (Davis & Ohman, 2016). Very little information is included in the reports of these studies regarding the feasibility of using the technology with people living with dementia, therefore much is still to be learned.
Commercially available eye tracking systems take two forms: head-mounted equipment or desktop-mounted equipment (Jacob & Karn, 2003; Lanata, Greco, Valenza, & Scilingo, 2015). Whereas desktop-mounted eye-tracking systems are more commonly used in laboratory-based research, where the environment can be closely controlled, head-mounted systems are ideal for fieldwork, opening up the possibility of measuring eye gaze during natural tasks in real-life scenarios (Lanata et al., 2015). The use of head-mounted eye-tracking in this context has increased since the technology has been incorporated into wearable devices, offering a less invasive, more comfortable experience for the user (Johansen et al., 2008). It is this form, therefore, that was considered the most appropriate for integration within the existing method employed in Studies 1 and 2 (see 3.2).

6.1.3 *Research questions*

A comparison of the inactivity prompts in the original and adapted versions of Solitaire was the focus of the present study, utilising state of the art wearable eye-tracking technology to accurately measures users' attention when prompts are generated. The newly implemented prompt feature in Bubble Explode was also included to provide an additional, indirect comparison of prompt design in touchscreen games. The use of eye-tracking technology in this study also provided an opportunity to substantiate the tentative conclusion drawn in the previous chapter regarding gaze direction as an indicator of engagement (see 5.4). The following research questions were addressed: (1) How do user's visually respond to different designs of prompt features; (a) what proportion of generated prompts are noticed in each game; and (b) how much time does it take for these to be noticed? (2) How do user's respond once they have noticed different designs of prompt features; (a) what proportion of noticed prompts are utilised; and (b) how much time does it take for these to be utilised? (3) For what proportion of each gameplay session are users' gaze focused on the app?

6.2 Method

The present study employed a modified version of the method used in Studies 1 and 2. This section is therefore a summarised account of the method described in 3.2, with more detail provided for the unique elements of this study.

6.2.1 Design

The same research design used in Studies 1 and 2 (see 3.2.1) formed the basis of the design of the present study, but with fewer participants and with the addition of eye-tracking measurement. The reduction in scale of the present research was due to the narrow focus of the research question and the fact that the feasibility of utilising eye-tracking technology in evaluation research with people living with dementia had not been established (see 6.1.2). Six participants were recruited and alternately assigned to play either the original version of Solitaire, the adapted version of Solitaire, or the adapted version of Bubble Explode (two participants playing each game). Each participant was asked to play the same game at three different time-points over the course of a five-day period.

6.2.2 Participants

Six people living with dementia were recruited from residential and specialist dementia services in Sheffield, UK. Four of the participants were female and two were male. Their mean age was 81 years (range 68-94; SD 8.07). The presence of cognitive impairment was confirmed using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), with a score of <26 required to distinguish between dementia and healthy controls. The participants' mean score on the MoCA was 13.38 out of 30 (range 10-16; SD 2.92).
The study received a favourable ethical opinion from the School of Health And Related Research (ScHARR) Ethics Committee at The University of Sheffield (see Appendix B). A member of the research team obtained consent from each participant, following the same consent procedure as in Study 1 (described in 3.2.2).

6.2.3 Materials

6.2.3.1 Apps

Solitaire (original version; described in 3.2.3.1). The original Solitaire app featuring the unaltered design of the prompt feature was presented to participants with the identifiers 3-01 and 3-02.
Solitaire (adapted version; described in 4.2.3.1) The adapted Solitaire app featuring the redesigned prompt feature was presented to participants 3-03 and 3-04.
Bubble Explode (adapted version, described in 4.2.3.1). The adapted Bubble Explode app featuring the newly implemented prompt feature was presented to participants 3-05 and 3-06.

6.2.3.2 Equipment

Two Apple iPads (fourth generation) running iOS 10 were used in the present study; one for the original version of Solitaire and the other for the adapted versions of both Solitaire and Bubble Explode (the same iPad could not have the two build versions of the same Solitaire app installed, hence the use of two separate devices). The same OS settings were used as in Studies 1 and 2, and both tablets were presented in the purpose-designed case used in these studies (described in 3.2.3.2).

One pair of Tobii Pro Glasses 2 (see Figure 6.2) was used throughout the present study. The gaze sampling frequency of the glasses is 100 Hz, which is more than adequate for usability studies (Poole & Ball, 2005). These glasses are lightweight (45g) and can be adjusted for individual users to ensure correct placement and optimal calibration, and can be worn over the top of existing visual aids (i.e., prescription glasses or contact lenses).

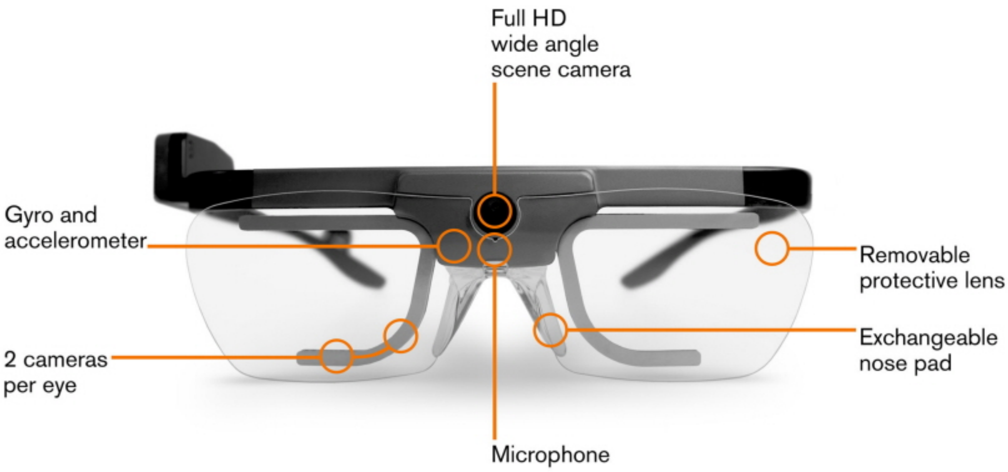

Figure 6.2. Labelled image of a pair of Tobii Pro Glasses 2 (image used courtesy of Tobii© 2017; CC BY-NC-ND 4.0; https://www.tobiipro.com/product-listing/tobii-pro-glasses-2)

The Tobii Pro Glasses provide, as an output, video recordings overlaid with a marker indicating the location of the user's gaze, filmed from a camera located centrally on the bridge of the glasses (see Figure 6.3).

Figure 6.3. A still image from the video output of the Tobii Pro Glasses 2 during a Solitaire gameplay session, featuring the eye-tracking marker (indicated by the arrow in the upper-right corner of the image)

6.2.4 Environment

A suitable environment to conduct the activity sessions was identified within each care service prior to the first data collection session (described in 3.2.4). The layout of equipment was slightly different from the two previous studies as no additional recording equipment was required. The Tobii Pro Glasses connect to their own recording unit which was placed to the side of the tablet on the table (see Figure 6.4).

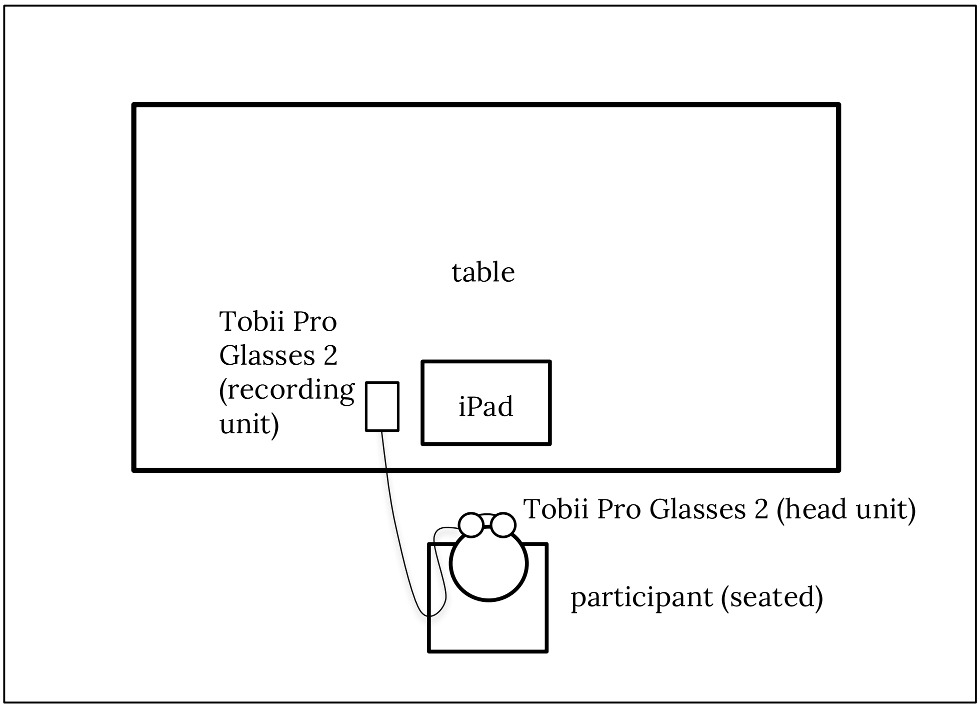

Figure 6.4. Diagram of the ideal environment setup for Study 3

6.2.5 *Outcome measures*

6.2.5.1 Primary outcomes

Time to first fixation on prompt. Each time a prompt was generated, the participants gaze direction was recorded as either fixed on the prompt or not ('yes' or 'no'). If gaze was directed toward the prompt, the number of seconds elapsed between the prompt's first appearance on-screen and the moment the participant's gaze was directed at the prompt was recorded.
Prompts utilised following visual response. Each time a participant's gaze was directed toward a prompt, their response was recorded as to whether they utilised the prompt or not ('yes' or 'no'). Utilisation was defined as their next intentional interaction after a prompt is generated being the selection of the prompted element. Unintentional interactions were discounted. If the participant did utilise the prompt, the number of seconds elapsed between the participant's gaze locating the prompt and their interaction with the screen was recorded.

6.2.5.2 Secondary outcome

Focus on gameplay. The proportion of each gameplay session during which the participant's gaze was directed toward the screen was measured and recorded, from the time their gameplay session was initiated by the researcher to the time that the session ended.

6.2.6 *Procedure*

For each participant at each data collection session the following procedure was used. At the beginning of each session, the researcher spoke with the participant and reiterated the purpose of the research project, using their signed consent form as a reference. If the participant provided verbal consent to continue and the researcher was satisfied that they had the capacity to do so, the session proceeded.

The participant was asked to wear the Tobii Pro Glasses 2 head unit, and upon receiving verbal consent to proceed, the researcher assisted the participant to put them on, using the headstrap to secure the glasses in place. The head unit connected to a recording unit via a mini-HDMI cable, which was placed on the table slightly to one side of the participant. Once it had been confirmed that the participant was comfortable wearing the glasses, the researcher conducted the calibration phase (required for each new gameplay session). This involved the researcher asking the participant to focus on a held target briefly whilst the system calibrated their gaze. The researcher was able to monitor the calibration using the Tobii controller software installed on a Dell Latitude 10 tablet computer running Windows 8 OS. When calibration was confirmed, the researcher initiated the recording on the controller software and the session could begin. If the calibration failed, there were several troubleshooting solutions the researcher could attempt sequentially, including adjusting the location of the held target, adjusting the position of the head unit, or simply resetting the system.

At this point, the iPad within the purpose-designed case was presented to the participant with the start of their assigned game ready on the screen. The researcher provided a rehearsed physical demonstration of the game, consisting of three ‘game moves’ (described in 3.2.6). The researcher then reset the game to the beginning and invited the participant to begin in his or her own time. Participants were given the opportunity to play the game through to completion unless they indicated that they wanted to finish earlier or if their gameplay session exceeded 10 minutes. The researcher retreated out of the participant’s line of sight and resisted any initial requests for advice or support from the participant during gameplay by politely encouraging them to try and continue themselves. However, if the participant requested support more than twice, or was deemed to be in any discomfort or distress, then the researcher responded to the participant and offered support.

Once the session had ended, the researcher stopped the recording and supported the participant to remove the Tobii Pro Glasses 2 head unit, and the participant was thanked and reminded of when their next session would be.

6.2.7 *Observation of video recordings*

Analysis of the video recordings was conducted as in both previous studies (described in 3.2.7) using The Observer® XT software.
A new coding scheme based on the outcome measures (see 6.2.5) was developed for the purpose of analysing the videos recorded with the eye-tracking marker from the Tobii Pro Glasses (see Table 6.1). Each video was uploaded from the Tobii Pro Glasses recording unit to The Observer® XT software. The researcher viewed each video at half-speed and entered codes chronologically within the monitored duration of gameplay, that is from the point that the researcher invited the participant to begin to the point the gameplay session ended (see 3.2.6).

Table 6.1. Coding scheme used to analyse the Tobii Pro Glasses video recordings with eye-tracking marker

Prompts (Mutually exclusive)	**Definition**
No prompt	*No prompt is displayed on the screen*
Prompt	*Prompt is displayed on the screen*

Screen interactions (Start-Stop)	**Definition**
Successful prompted move	*An intentional game move that is highlighted by the prompt system and successfully completed*
Unsuccessful prompted move	*An intentional game move that is highlighted by the prompt system but not successfully completed*
Unprompted move	*An intentional game move that was not highlighted by the prompt system*
Unintentional interaction	*An interaction with the screen that was not intended by the participant*

Gaze direction (Mutually exclusive, Exhaustive)	**Definition**
Screen	*The participant's eye-tracking marker is situated within the confines of the tablet computer screen*
Prompted element	*The participant's eye tracking marker is situated on the prompted element of the game (i.e., playing card or bubbles)*
Away from screen	*The participant's eye tracking marker is situated outside the confines of the tablet computer screen*
No data	*The eye-tracking marker is not visible on screen*

6.3 Results

All six recruited participants engaged with the study at all three time-points, resulting in a total of 18 gameplay sessions (see Table 6.2).

Table 6.2. Characteristics of participants and their contributions in Study 3

Participant	Gender	Age	MoCA score /30	Game played
3-01	F	87	16	Original Solitaire
3-02	F	83	10	
3-03	F	94	15	Adapted Solitaire
3-04	F	84	16	
3-05	M	68	11	Adapted Bubble Explode
3-06	M	80	12	

6.3.1 *Primary outcomes (prompt response using eye-tracking)*

A total of 71 prompts were generated across the 18 gameplay sessions. Eye-tracking revealed that participants noticed 59 (83%) prompts, of which 49 (69%) were subsequently utilised. A summary of all primary outcomes by game/game version is presented in Table 6.3, and these outcomes are described fully in the proceeding subsections.

Table 6.3. Summarised primary outcomes of all three apps

Outcome	Original Solitaire (N=6 sessions)	Adapted Solitaire (N=6 sessions)	Adapted Bubble Explode (N=6 sessions)
No. prompts generated	12	32	27
Prompt noticed	75%	87.5%	44.44%
Mean time to notice (SD) (secs)	2.18 (1.46)	1.38 (1.56)	7.54 (9.41)
Prompt utilised (if noticed)	77.78%	75%	91.7%
Mean time to utilise (SD) (secs)	8.33 (6.5)	2.19 (1.6)	1.87 (1.55)

6.3.1.1 Visual response to prompts

Participants playing the adapted version of Solitaire noticed a greater proportion of generated prompts (87.5%) than those playing the original version of Solitaire (75%). Descriptive statistics indicated that participants who played Adapted Solitaire were also quicker to notice prompts (mean = 1.38 seconds) than participants playing the original version (mean = 2.18 seconds). Histograms depicting the results (times taken to notice prompts) from each game version were inspected. As these data were skewed, and the number of prompts generated in gameplay sessions of original Solitaire was low, the most appropriate statistical test was Mann-Whitney. The Mann-Whitney test revealed, however, that the time taken to notice prompts was not significantly affected by which version of the app was played (U = 74.5, z = -1.83, p = .07, r = -.3).

Descriptive statistics were also calculated for participants assigned to play the adapted version of Bubble Explode, to allow for an indirect comparison of results between the differently designed prompt features within the two different games. The proportion of generated prompts noticed by participants playing Adapted Bubble Explode (44.44%) was much lower than those playing either of the solitaire versions, and visual response speed was slower in comparison (mean = 7.54 seconds).

6.3.1.2 Prompts utilised following visual response

The proportion of prompts that were utilised after having been noticed by participants playing the two versions of Solitaire was comparable, with a slightly higher proportion in the original version of Solitaire (77.78%) than in the adapted version (75%). Descriptive statistics, however, indicated that participants playing Adapted Solitaire were quicker to utilise prompts once they had been noticed (mean = 2.19 seconds) than participants playing original Solitaire (mean = 8.33 seconds). Histograms depicting the results (times taken to respond to prompts) from each game version were inspected. As these data were skewed and the number of prompts generated in gameplay sessions of original Solitaire was low, the most appropriate statistical test was Mann-Whitney. The Mann-Whitney test confirmed that the speed in which prompts were utilised after having been noticed was significantly quicker for participants presented with the redesigned prompt feature (U = 30, z = -2.31, p = .02, r = -.44).

The proportion of noticed prompts that were subsequently utilised by participants playing the adapted version of Bubble Explode (91.7%) was higher than in either of the versions of Solitaire and the speed in which they utilised the prompt was also quicker (mean = 1.87 seconds).

A comparison of prompt utilisation, calculated from the total number of prompts generated (regardless of whether the prompt was noticed or not), between the results from Studies 1 and 2 and the present study is presented in Table 6.4. The figures are similar between the two versions of Solitaire, indicating consistency of the results in the present study with those reported in Studies 1 and 2. The difference in prompt utilisation in Bubble Explode is more marked, increasing from 10.23% in Study 2 to 40.74% in the present study. However, this is easily explainable by the smaller sample size in the present study (two participants playing the game as opposed to 15), and the fact that the range of prompt utilisation in each gameplay session in the present study (0%-60%) fits within the range from Study 2 (0%-66.67%).

Table 6.4. Comparison of prompt utilisation between results from Studies 1 and 2 and results of the present study

Outcome	Original Solitaire	Adapted Solitaire	Adapted Bubble Explode
Study 1/2	20.45%	60.83%	10.23%
Study 3	25%	50%	40.74%

6.3.2 Secondary outcome (gaze direction during gameplay)

The direction of the participant's eye gaze during each gameplay session was measured using the eye-tracking marker from the Tobii Pro Glasses video recordings, and the proportion of time that gaze was directed at the tablet computer screen was calculated. Across all gameplay sessions, the mean proportion of time participants' gaze was directed at the screen was 97.47% (range 84.12%-100%, SD 4.3). A comparison with the estimated gaze direction data from Studies 1 and 2 (where eye-tracking was not measured) is presented in Table 6.5. These data confirm that estimated gaze direction in Studies 1 and 2 was accurate, and that wearing the Tobii Pro glasses in the present study did not interfere with the amount of time they looked at the screen.

Table 6.5. Mean proportion of gameplay sessions in Studies 1-3 that participants' eye gaze was directed at the tablet computer screen

Game played	Study 1 (N=81 sessions)	Study 2 (N=84 sessions)	Study 3 (N=18 sessions)
Solitaire	95.2%*	96.2%*	95.81%
Bubble Explode	98.5%*	98.29%*	100%

*Gaze direction estimated from video footage of participant's faces during sessions

6.4 Discussion

In a novel investigation exploring the visual response to prompt features in touchscreen games with people with dementia, several key findings were revealed that have the potential to improve future software design in this area. These findings are discussed in the following sections.

6.4.1 Solitaire

The discovery in Study 2 that the redesigned prompt feature in the app Solitaire was utilised more frequently than its previous incarnation led to the question of why this difference had occurred. Were users more likely to notice the redesigned prompt because of the increased emphasis to its animation, or were they responding more effectively to the prompt after they had noticed it? The present study sought to provide an answer to this question by exploiting the use of eye-tracking technology to provide more insight into the visual response of users once a prompt was generated onscreen. Figure 6.1 depicts the differences between the original prompt feature and the redesigned feature for people living with dementia.

The results revealed that the redesigned prompt was noticed more often than the original design, and there was a non-significant trend indicating that the speed at which participants gaze was directed toward the prompted card was quicker for the new design. With regards to how the participants reacted *after* they had noticed the prompt in each condition, there was very little difference between the proportion of prompts utilised (in fact this was slightly higher for the original design), but there was a significant difference reported in the speed at which participants utilised the prompt, with the redesigned prompt eliciting a quicker response.

Two possible interpretations of these findings are proposed. The fact that the redesigned prompts were utilised significantly quicker, once they had been noticed, could be interpreted as users being more able to interpret their purpose, given the increased emphasis to their presentation. An association between the meaningfulness of digital icons and the duration of eye gaze fixation has already been established (Poole & Ball, 2005), which supports this notion. There was also a trend in the results suggesting that the redesigned prompt was noticed more frequently and faster than the original design. There is existing research demonstrating that quicker times to first-fixation on a digital object is indicative that the object has better attention-getting properties (Poole & Ball, 2005). Therefore, rather than one or the other proposed explanation, it is possible that a combination of improved visibility *and* meaningfulness both contributed to the increased effectiveness of the prompt feature in the adapted version of Solitaire. Clearly this topic warrants further investigation, and given the feasibility of using eye-tracking technology in this context of dementia research, conducting a larger-scale study may provide more clarity to the tentative results found in the present study.

6.4.2 Bubble Explode

The results from participants who played the adapted version of Bubble Explode, whilst lacking a direct comparator, do provide an interesting insight into the discussion of prompt design in apps for people living with dementia. The prompt in this game was noticed considerably less often than the prompts in either version of Solitaire. This echoes the findings of Study 2 where it was suggested that the low utilisation of the newly-introduced prompt feature in Bubble Explode and the original feature in Solitaire could be explained by its very subtle presentation (see 4.4.3). However, the results in the present study indicate that the design of the prompt in Bubble Explode – a static glowing animation surrounding the bubbles (see Figure 6.5) – was much less successful at capturing users' attention than the original one in Solitaire. This is apparent from the comparatively low proportion of prompts that were noticed (44.44%) and slower speed in which they were noticed (mean 7.54 secs; see Table 6.3). However, when users did direct their gaze at the prompted bubbles, utilisation was higher (91.7%), and the speed to utilise the prompts quicker (mean 1.87 secs), than in either version of Solitaire (see Table 6.3). This suggests that despite the apparent similarity with the original design of the prompt in Solitaire – a pulsating glowing animation surrounding the edge of the card (see Figure 6.1) –, the way in which users respond to the prompt in Bubble Explode may be quite different. This is potentially explained by one of the conclusions of Studies 1 and 2 (see 4.5), that Bubble Explode was a less complex game to play for the majority of participants, in comparison with Solitaire. Therefore, when prompts were noticed in Bubble Explode, participants understood their meaning more readily, most likely because they had understood more of the rules of the game. If the prompt in Bubble Explode could be redesigned to increase its visibility, this may create a highly effective feature to assist people with dementia.

Figure 6.5. Screenshot of Bubble Explode depicting the newly implemented prompt feature that is triggered when a user is inactive for 10 seconds or attempts an invalid move

6.4.3 Verification of gaze direction

In the preceding chapter, it was proposed that an indicator of engagement for people with dementia using touchscreen apps is focused gaze on the tablet (see 5.4). This proposal relied on a rudimentary interpretation of participants' gaze direction from observation of the participant-facing video recordings collected in Studies 1 and 2, given the absence of more sophisticated eye-tracking technology. The present study provided an opportunity to test this method of estimating gaze direction by accurately measuring the gaze of participants, recruited using the same protocol and playing the same touchscreen games, using the Tobii Pro Glasses. The finding that the mean proportion of time participants' gaze was directed at the tablet computer in all gameplay sessions in Study 3 was 97.47%, is directly comparable with the 97.23% figure from Studies 1 and 2 combined (reported in 5.3). Furthermore, the breakdown of this figure according to which game was being played is also comparable (as presented in Table 6.5), with focused visual attention slightly higher for participants playing Bubble Explode. Considering this verification, it is suggested that the use of video recorded footage of users' faces during tablet computer interaction is an acceptable method of gauging general eye gaze direction, where eye-tracking technology is not available. Consequently, the conclusions drawn in the preceding chapter (see 5.5) are strengthened, and the suggested limitation to the data analysis can be revised.

6.4.4 Prompt design implications

While investigating various possible designs of prompts within their interactive digital games, Alm et al. (2009) advocated for the use of the least intrusive design; in order to avoid the possible detrimental effect of divided attention that may occur with the presentation of an overly disruptive feature. Whilst the present research is not based on originally designed software for people with dementia, the use of existing apps has advantageously provided an opportunity to begin by evaluating minimally intrusive prompt design and scale up the level of emphasis. With Solitaire, the desired level may have now been achieved, although it would be of interest to continue increasing the emphasis of the prompt animation incrementally and testing to see if its effectiveness eventually decreased, supporting a bell-curve theory of prompt emphasis and effectiveness. However, with Bubble Explode, the contrasting results presented here between the visibility of the prompt and how users react when they do become aware of its presence, strongly suggest that a more visually perceptible design would be beneficial. Consequently, one outcome of this study is to re-establish contact with Spooky House Studios (developers of Bubble Explode) and share the results of the present study in the hope that further adaptations may be implemented in the future.

The findings that both prompt features in the adapted versions of Solitaire and Bubble Explode were utilised relatively quickly once they had been identified by participants has important implications for the future design of prompts in relation to flow (see 1.3.2). One of the components of flow theory is that the task in question has clear goals (Csíkszentmihályi, 1990); that users understand what they need to do and how they need to do it (Murphy et al., 2014). Participants presented with the original design of the prompt feature in Solitaire recorded an average of eight seconds between noticing the prompted card and responding to it. It could be argued that spending eight seconds deciding how to respond to a prompt is symptomatic of a feature that is not effectively communicating a clear goal to the sample population. Previous research into software design has demonstrated that longer fixations on interactive elements indicate a lack of meaningfulness, to the extent that a redesign is required (Poole & Ball, 2005). This fits with the evidence from the present study, as redesigning the prompt with increased emphasis (whilst still retaining the same basic design) significantly decreased the decision time. It also demonstrates the potential that minor design adaptations can have to the gameplay experience of people living with dementia.

The increased emphasis to the adapted prompt in Solitaire comprises two separate design modifications: (i) the original pulsating, glowing animation surrounding the edge of the card was extended to cover the entire card, and to effectively facilitate this the colour of the light was changed from white to yellow (as a white light effect would not have been as visible over a white card face); and (ii) an animated yellow arrow, pointing to the prompted card, 'bounces' beneath the card (see Figure 6.1). As both of these changes were implemented in the same update, the effect of each one individually is not known. It may be that both were required in unison to achieve the responses evident in the results of Studies 2 and 3. However, it may also be possible that given the implications of the present study – that both visibility and meaningfulness of the prompt may have been increased – it is conceivable that the two design adaptations had separate effects. There is existing evidence that in animation, the use of colour-changes may not provide enough clarity to be effective cues (De Koning, Tabbers, Rikers, & Paas, 2009). Furthermore, there is also evidence that the inclusion of an arrow goes beyond merely guiding attention toward an element; but communicates a sequential cue to the user (Tversky, Morrison, & Betrancourt, 2002). In other words, the presence of an arrow may be informing the user that the highlighted element should be their *next* consideration. In relation to the prompt in Solitaire, this evidence would indicate that the inclusion of the arrow within the redesign might have been the key factor to its effectiveness. Further research would be required to validate this claim. However, it is argued that there is sufficient evidence from the present body of research to advocate the inclusion of arrows as a starting point in future iterative design processes of prompt features.

6.4.5 *Limitations*

The sample size for this study was, as has been highlighted, very small. This was in part due to the available time and resources. Also, to the best of the author's knowledge, no prior research had been published detailing use of the Tobii Pro Glasses 2 with people living with dementia, and therefore the feasibility of such research had not been established. It was also impossible to control for the number of prompts presented to each participant during each gameplay session, as this was entirely dependent on their style of gameplay. With an increased sample size, this variance would have less of an impact on the results.

6.5 Conclusion

It is proposed that the reason behind the effectiveness of the redesigned prompt feature in Solitaire is a combination of increased visibility and an increased recognition of their purpose by players. The newly implemented prompt feature in Bubble Explode demonstrably lacks visibility, but was highly utilised when users became aware of it. Whilst these findings can only be considered tentative given the small-scale nature of the present study, they do provide insight into the mechanisms of prompts in digital touchscreen games for people with dementia, that may be useful in future design. Further and larger-scale research would be beneficial to develop and strengthen the results, and with the feasibility of using wearable eye-tracking technology in this context demonstrated, similarly designed studies should be considered.

Chapter 7. Developing a framework to identify accessible touchscreen apps for people living with dementia

7.1 Introduction

In Chapters 3 through 6, three studies were reported involving 66 people living with dementia participating in gameplay sessions to evaluate two touchscreen apps: Solitaire (by MobilityWare) and Bubble Explode (by Spooky House Studios), for their performance on a range of dimensions: familiarity, engagement, enjoyment and accessibility. The selection process for the two games in these studies necessitated a systematic approach, given the vast quantity of available apps for even the most specific game type.

Since the introduction of the 'App Store' for Apple iOS devices in 2008, 180 billion apps have been downloaded (Statista, 2017a) and there are currently more than two million apps available for download in this store and also Google's 'Play Store' (Statista, 2017b). For any user, finding apps that meet their individual requirements is challenging, but where those requirements are more complex, as with dementia, the challenge becomes even greater.

The purpose of the current chapter is to (i) describe this selection process and how it has evolved since its conception, and (ii) present how app recommendations identified using the framework as suitable for people with dementia, have been shared with the public.

7.2 App Selection Framework

When designing Study 1, it was decided that existing touchscreen apps would be used to answer the research questions regarding the concept of familiarity as a criterion for selecting apps (see Chapter 3). With the specific game types identified (Solitaire/Patience as the familiar game and a 'bubble' based matching tile game as an example of a novel game), searches of the Apple App Store returned more than 500 results for each game type (see 3.2.3.1). It was therefore necessary to select a proportion of the available apps and conceive a set of parameters to test each app against, in order to find the most suitable version for people living with dementia. Initially these parameters were devised based on the information gathered from the review of the evidence base regarding touchscreen design for people living with dementia (see 2.3.4.4). This comprised 15 items spanning six categories (see Table 7.1). Ten apps representing each of the game types (Solitaire/Patience and a 'bubble' based matching tile game) were downloaded from the App Store and tested against the listed parameters. The two apps from each review that represented the most accessible version of their type for people with dementia, based on the evidence provided, were selected for use in Study 1.

Table 7.1. The original parameters used to identify the two apps for Study 1

Items	**Category**	**Definition and justification**
1. Tap 2. Drag-and-drop 3. Multi-touch	Interaction	Apps with more interaction methods were favoured *No guidance from the literature was found for people with dementia, however it was hypothesised that more available methods of interaction would allow users more freedom to intuitively control the apps*
4. Audio 5. Animation 6. Text	Feedback	Apps providing multiple forms of feedback were favoured *The importance of feedback in response to user input was highlighted in several articles* (Astell, Alm, *et al.*, 2014; Pignatti *et al.*, 2005; Riley *et al.*, 2009)
7. Object size 8. Text size	Visual design	Apps featuring interactive objects and text of a larger size were favoured *This was advocated as users may have visual impairment* (González *et al.*, 2013; Nezerwa *et al.*, 2014; Pang & Kwong, 2015) *or find precise motor control difficult* (González *et al.*, 2013)
9. Prompts 10. Hints 11. Customisation	Game design	Apps featuring automated prompts, hints and customisation options were favoured *Several articles recommend the use of prompts and hints to direct or regain the attention of the user* (Alm, Astell, *et al.*, 2007; Astell, Alm, *et al.*, 2014; Leuty *et al.*, 2013; Manera *et al.*, 2015), *and customisation to tailor the experience is highlighted as beneficial* (Astell, Malone, *et al.*, 2014; Hoey *et al.*, 2010; Leuty *et al.*, 2013; Pang & Kwong, 2015; Satler *et al.*, 2015)
12. Portrait 13. Landscape	Orientation	Apps that operated in either orientation were favoured *No guidance from the literature was found for people with dementia, however it was hypothesised that apps that functioned in both portrait and landscape mode would allow users more choice*
14. In-app 15. Menu	Obstacles	Apps without adverts or pop-up messages were favoured *No guidance from the literature was found for people with dementia, however it was hypothesised that intrusive obstacles could distract and confuse users*

Over the course of the research project, the original 15 parameters have been developed and refined into the present version containing 42 items across eight categories, to incorporate findings from Studies 1, 2 and 3, further evidence from relevant published studies and the experience of the researcher putting the framework into practice. With the growth of the review criteria, the need for a scoring system became apparent to simplify the identification of the most suitable apps after multiple reviews have been conducted. Each item is now assigned a score depending on the response provided; therefore, once multiple apps have been reviewed using the framework, their total scores (out of a maximum of 48) can be compared, with the higher scoring app indicating the most accessible app for people living with dementia. A detailed description of the framework is presented including the 42 items and their evidence-base.
The framework comprises two stages; the first stage involves the identification of the type of app that is required, and the second stage involves the testing of an app or group of apps for suitability.

7.2.1 *Identifying apps for review (stage one)*

The first stage requires a specific idea of the sought-after app, such as 'chess' or 'draughts', rather than 'board game'. The next step involves entering search terms into an app store, which will often be quite a straightforward task, as with the previous example where the search term could simply be 'chess'. Having entered the terms into the app store's search field, the next step is to decide how many apps are to be tested, or in other words, how thorough a search is necessary. In Study 1, it was decided that 10 apps would be an appropriate and manageable figure (see 3.2.3.1), although this should be judged depending on the available resources and the volume of available apps. Before downloading, exclusion criteria may be required to ensure that the apps are relevant to the original brief. For example, whether to exclude apps above a certain level of cost; whether to exclude games with rule variations; or whether to exclude apps with superfluous design elements or themes. Identifying this information does not require each app to be downloaded, as it is possible to access titles, pictures, descriptions, reviews and costs all from within the app stores. In Study 1, the decision was made to use the rankings of the Apple App Store to inform the selection process; therefore, the top 10 search results that met the criteria were downloaded. These rankings are defined by algorithms unique to each app store, but commonly known as App Store Optimisation (ASO). For Apple, the primary factor is number of downloads, but there are also secondary factors such as keywords and visuals (Cailean, 2015). Therefore, by opting to download the top 10 (or however many is required), an element of the selection process is deferred to the searched app store and its own ASO. This should be recognised as a potential bias but is an unavoidable consequence unless all of the search results are downloaded for testing (in excess of 500 results, in the example of 'chess').

7.2.2 Reviewing apps using evidence-based parameters (stage two)

The second stage of the framework involves testing the app or apps that are under consideration against a set of evidence-based parameters. This stage can be utilised in isolation of the first stage, depending on the context. For example, if someone wanted to test a single app for suitability with people living with dementia, or if a developer wanted to test their own app for accessibility.

The test process involves a thorough exploration of the app/s identified in stage one. Each app should be tested for a sufficient length of time to ensure that all of the criteria can be confidently addressed before moving to the next app and repeating the process. This involves assigning a score on each criterion. After reviewing all of the apps under consideration, a comparison of the total scores can be viewed for an indication of which app/s are the most accessible for people living with dementia, according to the evidence-based framework. Finally, a decision can be made as to whether the top-scoring app, or any of the highest-scoring apps, are appropriate for recommendation. For example, the highest scoring app may still contain one or more negative features that warrant a discussion as to whether or not it should be recommended. Whilst this introduces a higher degree of subjectivity to the process, it was felt to be a necessary component of the process to prevent the automatic recommendation of apps that, despite being the best of their type, may not be suitable for people with dementia. If there are no apps deemed suitable, it may be necessary to rerun the review with the next 10 search results, or to abandon the search altogether.

The process of scoring apps is presented below. Each of the 42 criteria are presented including a definition, scoring criteria, examples in practice and supporting evidence. What follows is the final version of the App Selection Framework which has been developed into an instructional manual and as such is written in the present tense.

7.2.2.1 Interaction

Items relating to the methods of user interaction with apps are included in this category (summarised in Table 7.2).

Table 7.2. Summary of items in the 'Interaction' category of the App Selection Framework

Interaction	
1.	Is more than one type of gesture control required for essential functions?
2.	If yes for item 1, is there an option to select which type of gesture control is used?
3.	Are interactive elements easy to operate (e.g., responsive)?
4.	Is prior knowledge of gesture controls required, without direction or labels (e.g., scrolling, pinch to zoom)?

Item 1: Is more than one type of gesture control required for essential functions?
Scoring: Yes = 0; No = +1.
Definition: If the app features multiple gesture control methods to operate essential functions, score 0.
Example: In Solitaire (MobilityWare), using the default settings, users can either tap on cards to auto-complete moves or they can drag-and-drop cards. Therefore, Solitaire would score 0 for this item.
Evidence: In Study 1, it was reported that just over 40% of interactions coded as unsuccessful moves in Solitaire gameplay sessions (see 3.3.2.1) were caused by a misalignment between the intentions of the participant and the interpretation of the software regarding the control method.

Item 2: If yes for item 1, is there an option to select which type of gesture control is used?
Scoring: Yes = +1; No = 0 (N.B. If the answer to item 1 is no; this item is ignored).
Definition: If there is there an option available for the user to select which gesture control they employ, score +1 for this item.
Example: In the adapted version of Solitaire (MobilityWare), the user can choose to toggle on or off the 'tap' to move and 'drag-and-drop' to move gesture controls. Therefore, Solitaire would score +1 for this item.
Evidence: In Study 2, the adapted version of Solitaire was evaluated by people living with dementia and the total number of interactions coded as unsuccessful moves reduced by 40% (see 4.3.1) because of the implementation of the option described in the example above.

Item 3: Are interactive elements easy to operate (e.g., responsive)?
Scoring: Yes = +2; Moderately = +1; No = 0.

Definition: Whilst using the app, if interactive elements behave as expected (i.e., they are responsive to gesture, smooth, without lag, etc.) score +2. If there are some minor issues, score +1. If interactions are not at all easy to operate, score 0.
Example: In Push Puck (James Bosiljevac), the gesture control used to slide the pucks down the board is not very responsive to the user's motion (i.e., the speed and direction of the user's gesture does not always equate to the speed and direction that the puck travels on screen). Therefore, Push Puck would score 0 for this item.
Evidence: This item was included based on the experience of the researcher testing multiple touchscreen apps where responsiveness was low, and the fact that the responsiveness of the touchscreen interface had been highlighted as one of the major strengths of tablet computers for people living with dementia (Astell et al., 2009; Hackner & Lankes, 2016).

Item 4: Is prior knowledge of gesture controls required, without direction or labels (e.g., scrolling, pinch to zoom)?
Scoring: Yes = 0; No = +1.
Definition: If one or more gesture controls are required in order to effectively navigate the app, that a person unfamiliar with common gestures (e.g., scrolling, pinch to zoom, etc.) might not have knowledge of, and there is no guidance to explain their use, score 0.
Example: In Recolor (Sumoing Ltd.), the spread to zoom gesture control (see Figure 7.1) is required in order to fill any small areas of the picture. However, there are no instructions during the colouring task to inform the user that this is possible or how to do it (although this is available through a separate information screen). Therefore, Recolor would score 0 for this item.
Evidence: When designing for people with dementia, it is recommended that the number of steps to navigate or achieve goals (Kerkhof et al., 2017; Kikhia et al., 2015; Nezerwa et al., 2014; Pang & Kwong, 2015; Riley et al., 2009), and the use of gesture controls (Hackner & Lankes, 2016), should be kept to a minimum.

Figure 7.1. Process diagram depicting the spread to zoom gesture control

7.2.2.2 Feedback

Items relating to the presence of various modes of feedback to user interaction within apps are included in this category (summarised in Table 7.3).
Evidence for items 5-11: When designing touchscreen software for use by people with dementia, the use of feedback in response to user input is recommended (Astell, Alm, et al., 2014; Pignatti et al., 2005; Riley et al., 2009; Tziraki et al., 2017). Feedback should be contextual to the input and should be immediate, to acknowledge the user interaction (Astell, Alm, et al., 2014). Multiple forms of feedback are beneficial to account for a range of possible impairment (Bouchard et al., 2012). Immediate and concrete feedback help to facilitate flow during gameplay (Granic et al., 2014; C. M. Jones et al., 2014; Murphy et al., 2014).

Table 7.3. Summary of items in the 'Feedback' category of the App Selection Framework

Feedback	
5.	Is there audio feedback following correct user input?
6.	Is there *different* audio feedback following incorrect user input?
7.	Is there text feedback following correct user input?
8.	Is there *different* text feedback following incorrect user input?
9.	Is there animated feedback following correct user input?
10.	Is there *different* animated feedback following incorrect user input?
11.	Is there audio, text and/or animated feedback upon completion of a task/activity?

Item 5: Is there audio feedback following correct user input?
Scoring: Yes = +1; No = 0.
Definition: If when the user successfully interacts with elements of the app, an audio response is triggered, score +1.
Example: In Bubble Explode (Spooky House Studios), when a group of bubbles is tapped and they disappear, a popping sound is triggered. Therefore, Bubble Explode would score +1 for this item.

Item 6: Is there different audio feedback following incorrect user input?
Scoring: Yes = +1; No = 0.
Definition: If when the user unsuccessfully interacts with elements of the app, an audio response that is different to the successful response is triggered, score +1.

However, if the feedback provided is in some way critical of the user (e.g., sarcastic or mocking), score 0.
Example: In Solitaire (MobilityWare), when the user taps a card that cannot be placed, a sound is triggered that is different from the sound triggered when a card is successfully placed. Therefore, Solitaire would score +1 for this item.

Item 7: Is there text feedback following correct user input?
Scoring: Yes = +1; No = 0.
Definition: If when the user successfully interacts with elements of the app, a text response is triggered, score +1.
Example: In Pro Darts 2014 (iWare Designs), the score for each thrown dart is displayed on screen after the dart has connected with the board (see Figure 7.2). Therefore, Pro Darts 2014 would score +1 for this item.

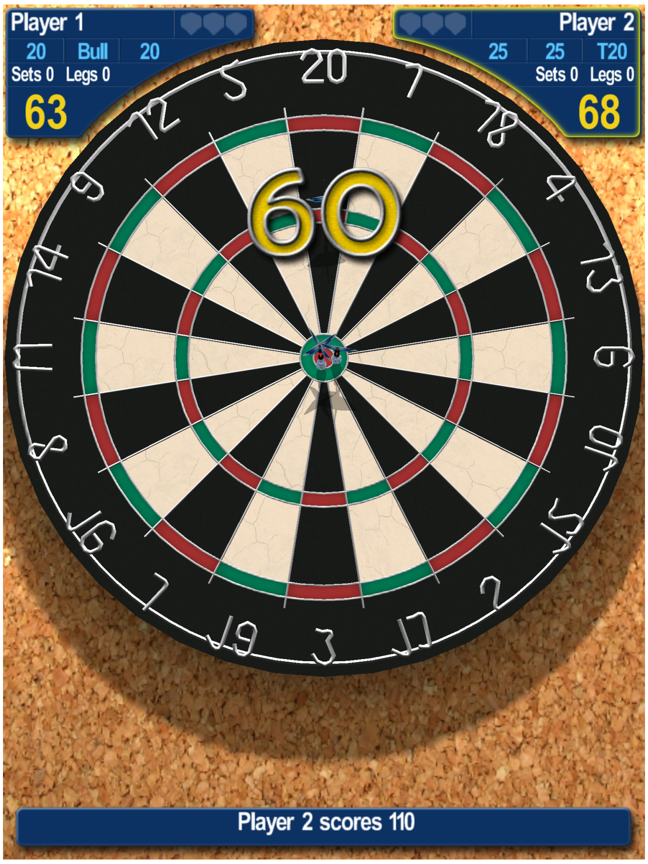

Figure 7.2. Screenshot depicting an example of text feedback in response to correct user input

Item 8: Is there different text feedback following incorrect user input?
Scoring: Yes = +1; No = 0.
Definition: If when the user unsuccessfully interacts with elements of the app, a text response that is different to the successful response is triggered, score +1. However, if the feedback provided is in some way critical of the user, (e.g., sarcastic or mocking), score 0.
Example: In Flick Kick Football (Prodigy Design), text is displayed on-screen if the target is missed, encouraging the user to try again (see Figure 7.3). Therefore, Flick Kick Football would score +1 for this item.

Figure 7.3. Screenshot depicting an example of text feedback in response to incorrect user input

Item 9: Is there animated feedback following correct user input?
Scoring: Yes = +1; No = 0.
Definition: If when the user successfully interacts with elements of the app, an animated response is triggered, score +1.
Example: In Mahjong (DoraLogic), when pairs of tiles are matched, an animation is triggered that visualises the tiles breaking and disappearing (see Figure 7.4). Therefore, Mahjong would score +1 for this item.

Figure 7.4. Screenshot depicting an example of animated feedback in response to incorrect user input

Item 10: Is there different animated feedback following incorrect user input?
Scoring: Yes = +1; No = 0.
Definition: If when the user unsuccessfully interacts with elements of the app, an animated response that is different to the successful response is triggered, score +1. However, if the feedback provided is in some way critical of the user, (e.g., sarcastic or mocking), score 0.
Example: In Solitaire (MobilityWare), if a card is tapped that cannot be placed, an animation is triggered displaying the card shaking slightly from side to side. Therefore, Solitaire would score +1 for this item.

Item 11: Is there audio, text and/or animated feedback upon completion of a task/activity?
Scoring: Yes = +1; No = 0.
Definition: In apps where there is an element of completion (e.g., the ending of a game or the finishing of a task), if there is some indication that the activity has ended through at least one feedback method (audio, text or animation), score +1.
Example: In Jigty (Outfit7), when a jigsaw puzzle is completed, an audio response is triggered and a green banner featuring the text 'PUZZLE SOLVED!' is displayed (see Figure 7.5). Therefore, Jigty would score +1 for this item.

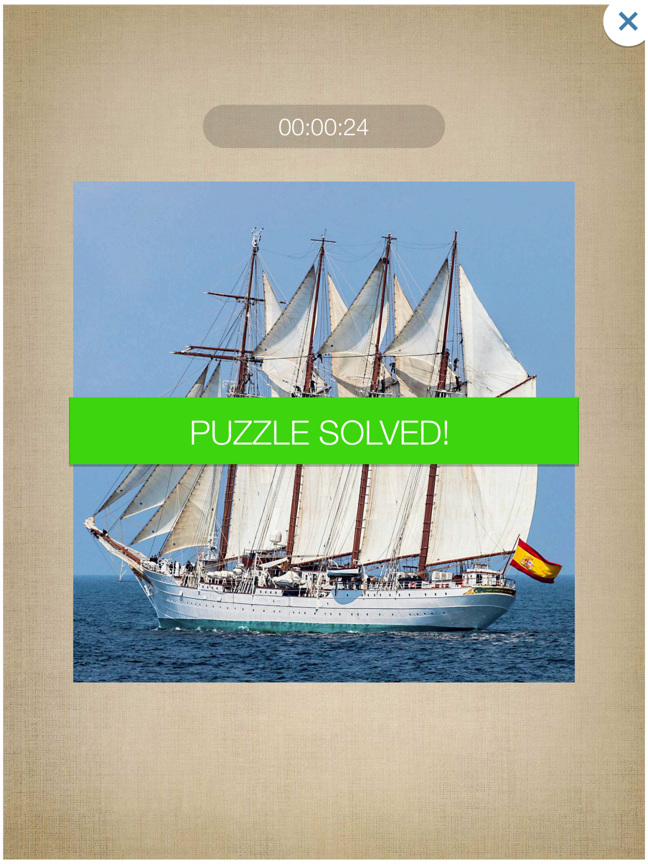

Figure 7.5. Screenshot depicting an example of text feedback in response to the completion of the activity

7.2.2.3 Aesthetic design

Items relating to the visual appearance of apps are included in this category (summarised in Table 7.4).

Table 7.4. Summary of items in the 'Aesthetic design' category of the App Selection Framework

Aesthetic design	
12.	What is the size of the smallest *necessary* text?
13.	Are the fonts used for *necessary* text easy to read?
14.	What is the size of the smallest *necessary* interactive elements?
15.	Are the colours of interactive elements well contrasted with other elements/the background?
16.	Is the background clear and undistracting?

Item 12: What is the size of the smallest necessary text?
Scoring: Large = +2; Medium = +1; Small = 0.
Definition: If the app features text, estimate the font size of the smallest *necessary* text and score as follows;

- Size 16 or above (large) would score +2;
- Size 11-15 is (medium) would score +1;
- Size 10 or below (small) would score 0.

Necessary text can be defined as anything that the user needs to read in order to engage with the main activity of the app. Text within a menu, for example, would not be considered necessary, *unless* that menu formed part of the main activity and the activity couldn't be completed without access to the menu.
Example: In Color By Numbers (Kedronic UAB), some of the numbers within the pictures indicating which colour should be selected are estimated to be size 10 font or smaller (see Figure 7.6). As this text is necessary in order for the user to complete the activity, Color By Numbers would score 0 for this item.
Evidence: Text should be appropriately sized for people who may have visual impairment (González et al., 2013; Hackner & Lankes, 2016; Kerkhof et al., 2017; Nezerwa et al., 2014; Pang & Kwong, 2015). Font sizes of 12-14 have been recommended for people living with dementia for paper materials (The Dementia Engagament and Empowerment Project, 2013), whilst size 18 on a traditional computer screen monitor was confirmed as readable for people with dementia (Tak, Zhang, & Hong, 2015).

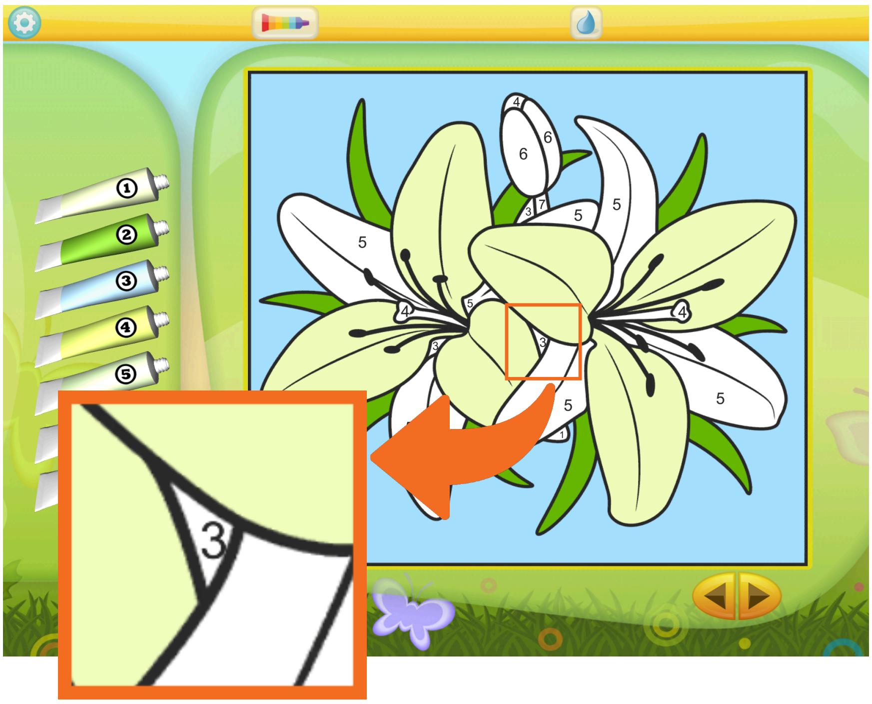

Figure 7.6. Screenshot, including close-up image, depicting an example of small text

Item 13: Are the fonts used for necessary text easy to read?
Scoring: Yes = +1; No = 0.
Definition: If the font of any *necessary* text within the app is clear and easy to read, score +1. See the description of Item 12 for a definition of 'necessary' text.
Example: In Hangman Hero (mobiventi0n), the font used for the puzzle is in a cursive style using swashes and might not be easy to read or interpret for someone with visual or cognitive impairment (see Figure 7.7). As this text is necessary in order for the user to complete the puzzle, Hangman Hero would score 0 for this item.
Evidence: People with dementia may find fonts easier to read if they are clear and without stylised flourishes (Kerkhof et al., 2017; The Dementia Engagament and Empowerment Project, 2013).

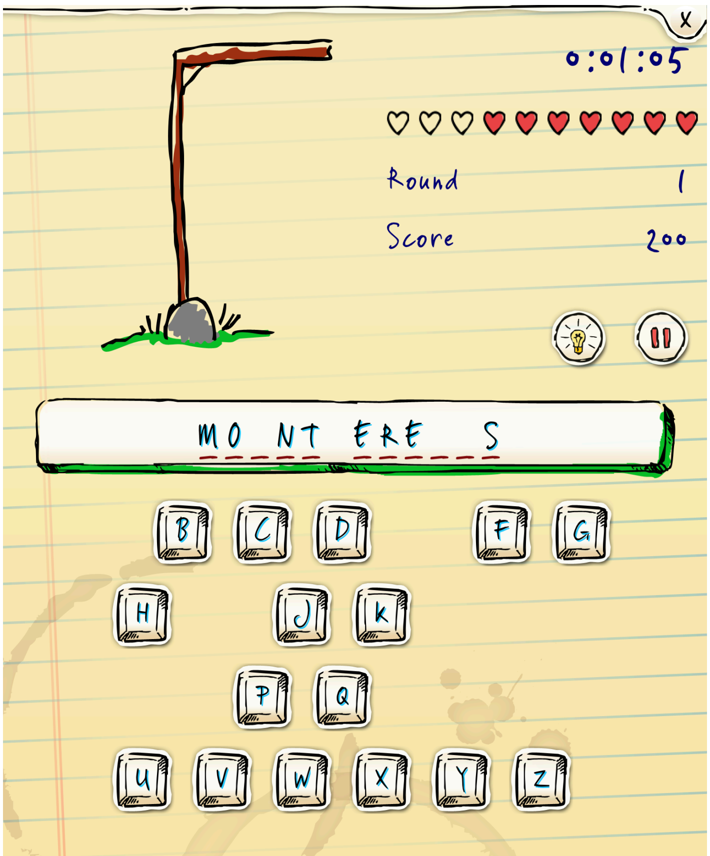

Figure 7.7. Screenshot depicting an example of text that may not be clear for people living with dementia

Item 14: What is the size of the smallest necessary interactive elements?
Scoring: Large = +2; Medium = +1; Small = 0.
Definition: Measure the size of the smallest *necessary* interactive element within the app and score as follows;

- >2cm by length AND width (Large) would score +2;
- 1-2cm by length AND/OR width (Medium) would score +1;
- <1cm by length AND width (Small) would score 0.

Necessary elements can be defined as anything that the user needs to interact with in order to engage with the main activity of the app. Menu buttons, for example, would not be considered necessary *unless* that menu formed part of the main activity and the activity couldn't be completed without access to the menu.
Example: Figures 7.8a, 7.8b and 7.8c all feature pucks (actual size) from the analysis of shuffleboard apps. 10 Pin Shuffle Bowling (Digital Smoke; Figure 7.8a) features a puck longer in both length and width than 2cm and would score +2. Push Puck (James Bosiljevac; Figure 7.8b) features a puck between 1-2cm in both length and width and would score +1. Shufflepuck (Giraffe Lab; Figure 7.8c) features a puck shorter than 1cm in both length and width and would score 0.
Evidence: Icons and graphics should be appropriately sized for people who may have visual impairment (González et al., 2013; Hackner & Lankes, 2016; Kerkhof et al., 2017; Nezerwa et al., 2014; Pang & Kwong, 2015) and the interactive elements should be of a large enough size to allow for less precise motor control (González et al., 2013). The average size of an adult finger pad is 1cm (Google, 2015).

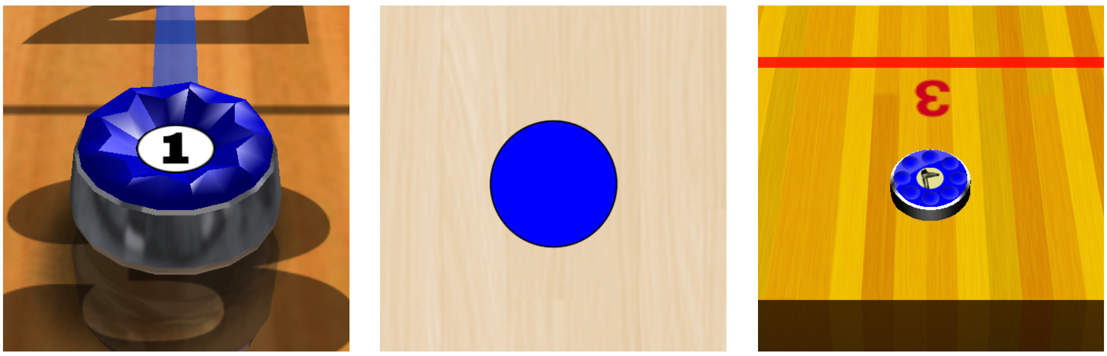

Figure 7.8a (left), 7.8b (centre) and 7.8c (right). Screenshots of three Shuffleboard apps depicting examples of large (7.8a), medium (7.8b) and small (7.8c) objects

Item 15: Are the colours of interactive elements well contrasted with other elements/the background?
Scoring: Yes = +1; No = 0.
Definition: If interactive elements within the app are of different colours and shades to other elements or the background (or can be changed in the settings), score +1. Example: In Dots (Playdots), the colours of the dots contrast well with the white (or black) background and with each other (see Figure 7.9). Therefore, Dots would score +1 for this item.
Evidence: High contrasting colours can enhance object recognition for people with cognitive and visual impairment (Davis & Ohman, 2016; Yamagata et al., 2013).

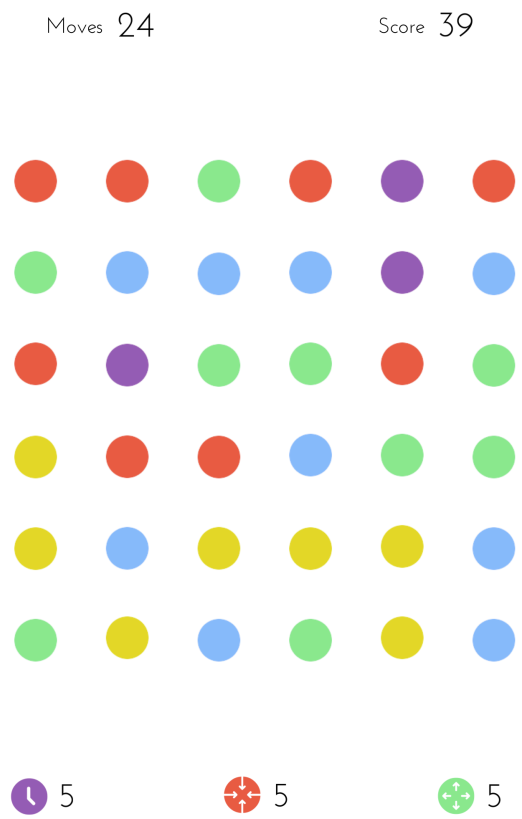

Figure 7.9. Screenshot depicting an example of the use of contrasting colour for objects

Item 16: Is the background clear and undistracting?
Scoring: Yes = +1; No = 0.
Definition: If the background of the app is a solid colour or subtle pattern (e.g., wood), and features no, or very few, moving elements, thereby minimising the risk of distraction or confusion with foreground elements, score +1.
Example: In Bubble Bang Bang (Abele Games), the background features images of other bubbles which could be confused with the interactive bubbles (see Figure 7.10). Therefore, Bubble Bang Bang would score 0 for this item.
Evidence: A calm interface and background is recommended for people living with dementia to avoid for them having to coping with multiple sources of information (Astell, 2006; Kerkhof et al., 2017).

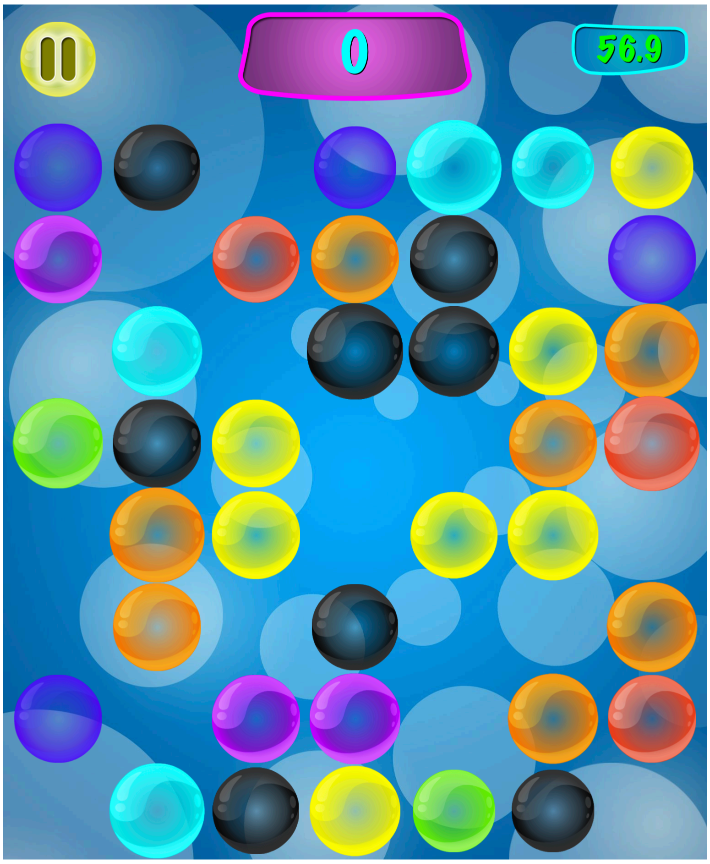

Figure 7.10. Screenshot depicting an example of an app where the background design may be distracting or confusing for people with dementia

7.2.2.4 App design

Items relating to the content of apps are included in this category (summarised in Table 7.5).

Table 7.5. Summary of items in the 'App design' category of the App Selection Framework

App design	
17.	Are there automatic prompts/hints if the user is inactive?
18.	Are there automatic hints if the user is incorrect?
19.	Are there hints available for the user to access manually, if required?
20.	Are all required elements visible on-screen at the same time?
21.	If no for item 20, are there clear labels/instructions informing the user how to access the off-screen elements?
22.	Does the app feature any themes of explicit or violent materials?
23.	If yes for item 22, is there an option to turn these off?

Item 17: Are there automatic prompts/hints if the user is inactive?
Scoring: Yes = +1; No = 0.
Definition: If the app automatically attempts to regain the user's attention or guides the user to a potential interaction when they have not touched the app for a certain length of time, score +1. However, if the prompt/hint provided is in some way critical of the user, (e.g., sarcastic or mocking), score 0.
Example: In Solitaire (MobilityWare), if the user is inactive for 15 seconds, one of their potential next moves is highlighted by a glowing light over the card face and an animated arrow pointing to the card (see Figure 7.11). Therefore, Solitaire would score +1 for this item.
Evidence: The use of prompts in touchscreen software for people with dementia can increase self-efficacy and independence, and support people to complete or re-engage with activities (Alm, Astell, et al., 2007; Tziraki et al., 2017).

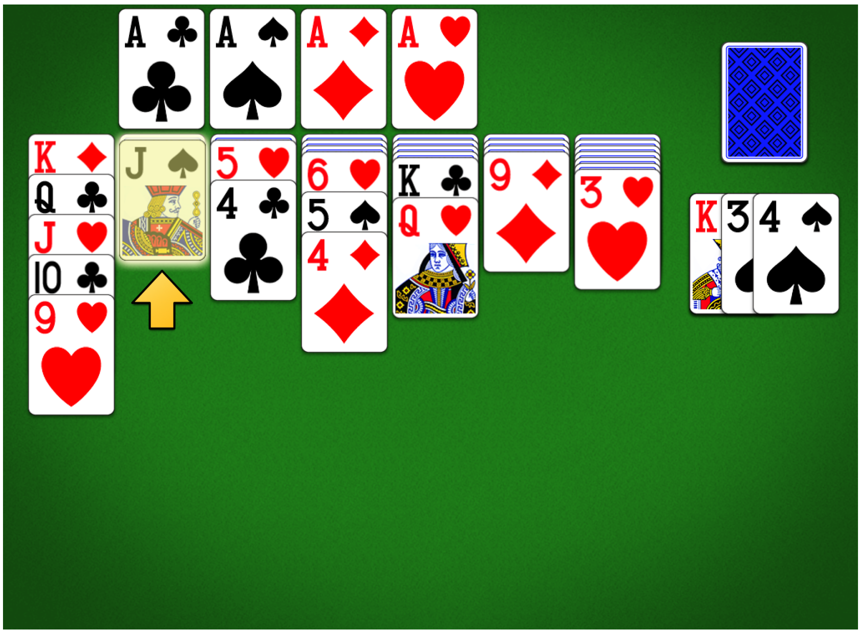

Figure 7.11. Screenshot depicting an example of an app that includes an automatic prompt feature

Item 18: Are there automatic hints if the user is incorrect?
Scoring: Yes = +1; No = 0.
Definition: If after one or more incorrect interactions, the app automatically informs the user of their mistake and/or suggests an alternative interaction, score +1. However, if the hint provided is in some way critical of the user, (e.g., sarcastic or mocking), score 0.
Example: In Flick Kick Football (Prodigy Design), if the user is unable to score a goal after several attempts, a message is displayed suggesting that they try a different approach (see Figure 7.12). Therefore, Flick Kick Football would score +1 for this item.
Evidence: The use of prompts in response to errors can minimise erroneous learning for people with dementia (Tziraki et al., 2017).

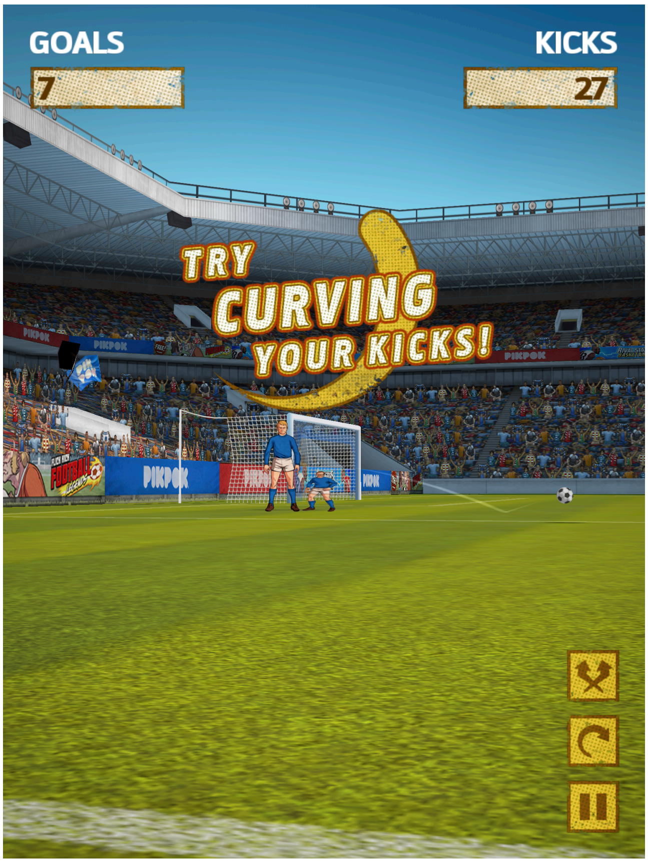

Figure 7.12. Screenshot depicting an example of an app that includes a hint feature in response to errors

Item 19: Are there hints available for the user to access manually, if required?
Scoring: Yes = +1; No = 0.
Definition: If there is an option present on-screen that allows the user to manually access a hint, score +1.
Example: In t-Chess (Tom Kerrigan), the lightbulb icon on the task bar can be tapped to provide a hint, which is displayed by highlighting the user's piece and its recommended location (see Figure 7.13). Therefore, t-Chess would score +1 for this item.
Evidence: The inclusion of manually-accessed hints for people living with dementia is recommended (Kerkhof et al., 2017). This provides a more autonomous option to automatic prompts, and follows the principle that prompts should be as minimally intrusive as possible (Alm et al., 2009b).

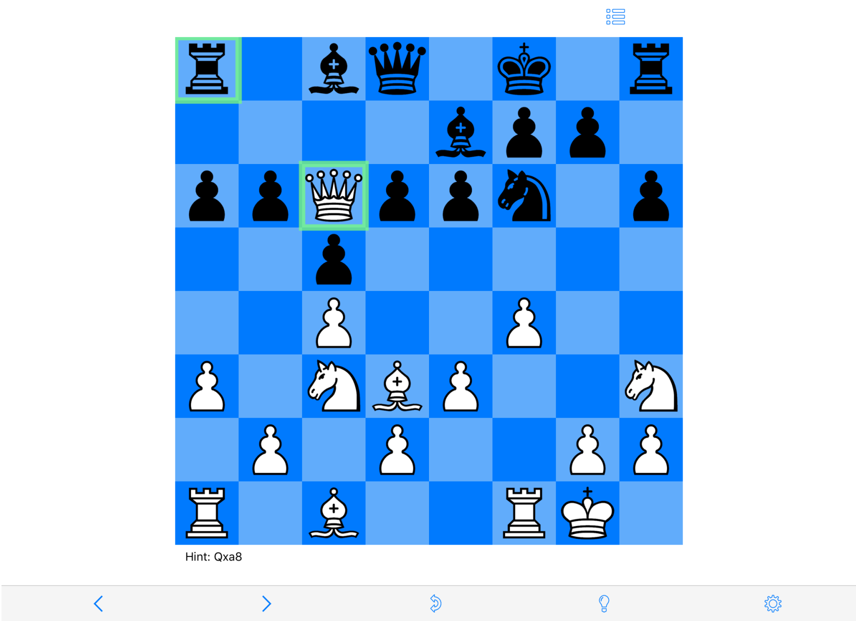

Figure 7.13. Screenshot depicting an example of an app that includes a hint feature that the user can access manually

Item 20: Are all required elements visible on-screen at the same time?
Scoring: Yes = +2; No = 0.
Definition: If any important elements of the app are not visible on-screen at the same time (i.e., the user is required to navigate the environment in order to find them), score 0.
Example: In Push Puck (James Bosiljevac), the end of the game board cannot be seen from the screen view that the user is presented with when required to slide the puck; making it difficult to know where to aim (see Figure 7.14). Therefore, Push Puck would score 0 for this item.
Evidence: In touchscreen activities for people with dementia, the purpose of a task should be clear from the outset, and the requirement of users to scroll through the environment should be minimised (Kerkhof et al., 2017).

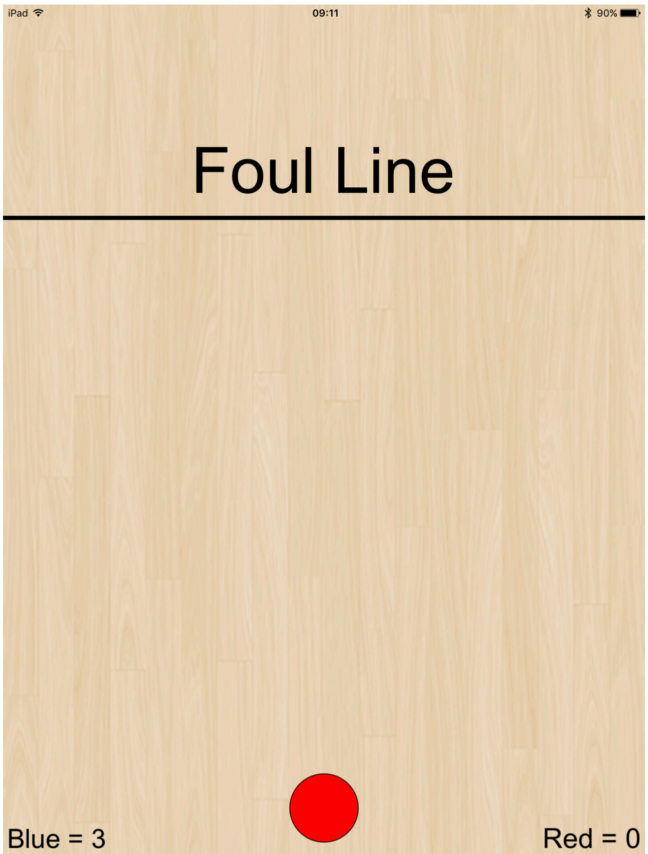

Figure 7.14. Screenshot depicting an example of an app where an important element of the task (in this case, the end of the game board) is not visible on-screen

Item 21: If no for item 20, are there clear labels/instructions informing the user how to access the off-screen elements?
Scoring: Yes = +1; No = 0 (N.B. If the answer to item 20 is yes; this item is ignored).
Definition: Although an ideally designed app would not require the user to manually navigate the environment (hence the scoring of +2 for item 20); if there are labels or instructions to guide the user to navigate to the off-screen elements, and they are easy to understand, score +1.
Example: In Dominoes (Gano Technologies), when there are placed tiles off-screen, the app displays an icon to indicate that the user can navigate in the direction of the arrow to find a playable location (see Figure 7.15). Therefore, Dominoes would score +1 for this item.
Evidence: Visual instructions for interactive elements in contextual locations can minimise cognitive overload for people with dementia (Hackner & Lankes, 2016).

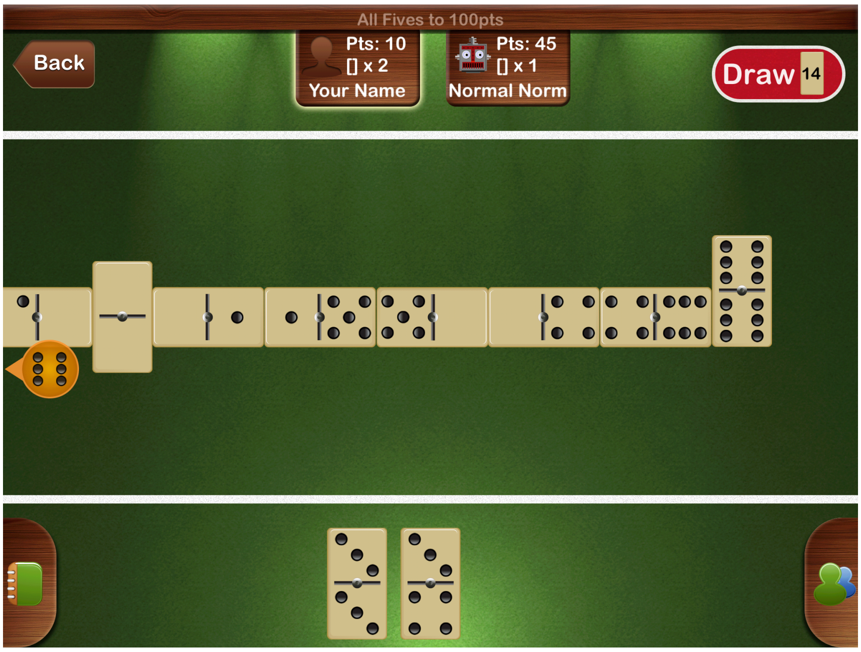

Figure 7.15. Screenshot depicting an example of an app where an important element of the task (in this case, placed domino tiles) is not visible on-screen, but there is a visual guide to the element

Item 22: Does the app feature any themes of explicit or violent materials?
Scoring: Yes = 0; No = +1.
Definition: If the app features any offensive language, violence or potentially distressing content, score 0.
Example: In Hangman (FBF Sistemas), the final image of the hangman character has the potential to cause distress (see Figure 7.16). Therefore, Hangman would score 0 for this item.

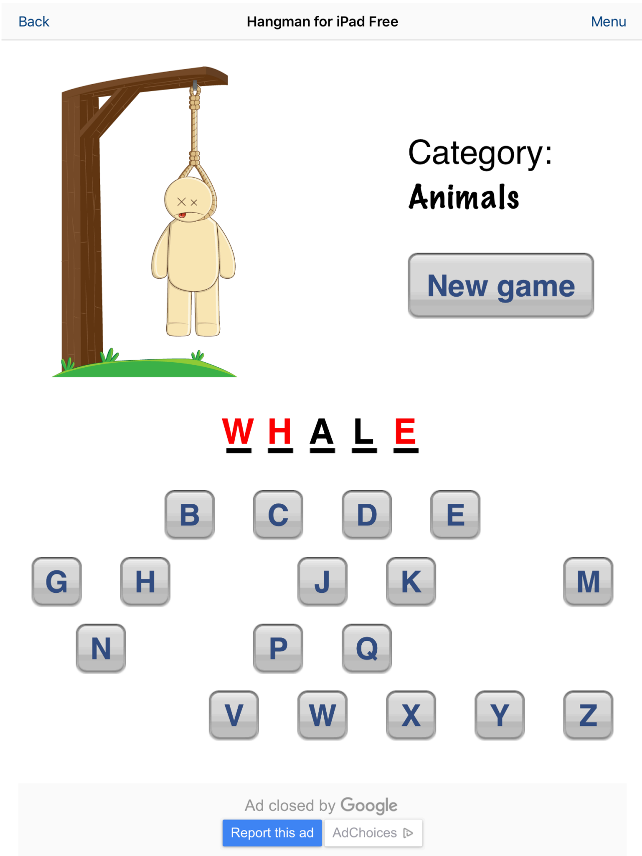

Figure 7.16. Screenshot depicting an example of an app featuring content that has the potential to cause distress to users

Item 23: If yes for item 22, is there an option to turn off explicit or violent content?
Scoring: Yes = +1; No = 0 (N.B. If the answer to item 22 is no; this item is ignored).
Definition: If there is an option within the app to turn off explicit or violent elements, score +1.
Example: In Hangman (Optime Software), there is an option to turn off the gallows and only feature the image of the hangman character (see Figure 7.17).
Therefore, Hangman would score +1 for this item.
Evidence for items 22 and 23: The inclusion of these items were not based on specific evidence for people living with dementia, but on the fact that recommendations of apps are based on the use of this framework, and the inclusion of explicit or violent content may not appeal to all users. Therefore, apps only score +1 if there is the option to choose whether or not this content is present.

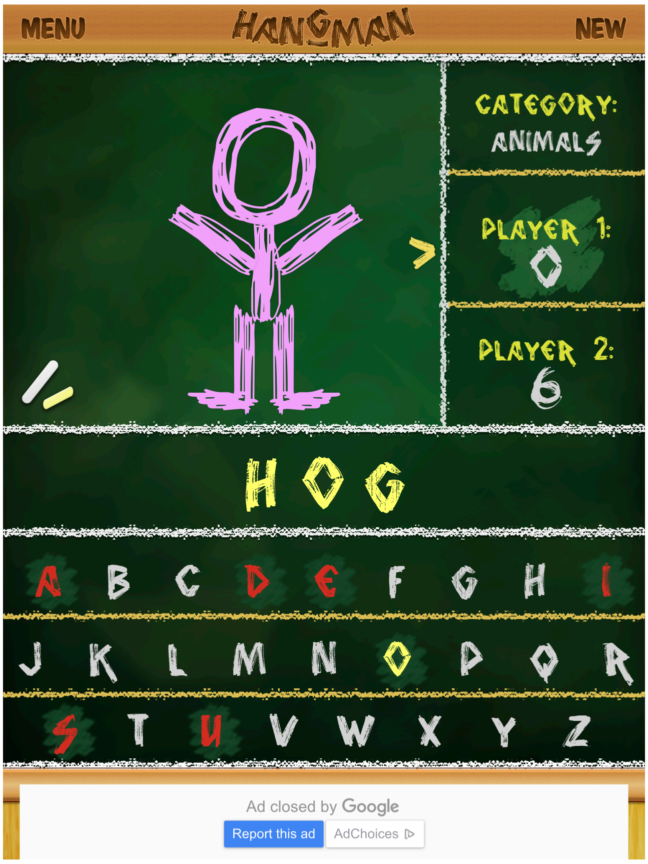

Figure 7.17. Screenshot depicting an example of an app that allows the control of potentially distressing content

7.2.2.5 Customisation

Items relating to the customisation of apps are included in this category (summarised in Table 7.6).
Evidence for items 24-26: The ability to customise and adapt apps to tailor the experience for people living with dementia is advantageous (Critten & Kucirkova, 2017; Hoey et al., 2010; Leuty et al., 2013). This includes the option to control the presence and volume of background music or audio effects (Kerkhof et al., 2017), or to ensure that text size and the use of colour is appropriate for different levels of visual impairment (Davis & Ohman, 2016; González et al., 2013; Hackner & Lankes, 2016; Kerkhof et al., 2017; Nezerwa et al., 2014; Pang & Kwong, 2015).

Table 7.6. Summary of items in the 'Customisation' category of the App Selection Framework

Customisation	
24.	Is there an option to control the volume or presence of audio effects *within* the app?
25.	Is there an option to increase the size of the text?
26.	Can you customise the colour scheme/backgrounds?
27.	Does the app feature a simplified option (e.g., change the difficulty level)?
28.	Can you change the speed of any automatic animations or processes?

Item 24: Is there an option to control the volume or presence of audio effects within the app?
Scoring: Yes = +1; No = 0.
Definition: If the app features the option to toggle the presence of music or sound effects, or control their volume within the app (as opposed to using the external volume controls of the device's software or hardware), score +1.
Example: In Fleet Battle (Smuttlewerk Interactive), users can choose whether to turn on or off both sounds and music (see Figure 7.18). Therefore, Fleet Battle would score +1 for this item.

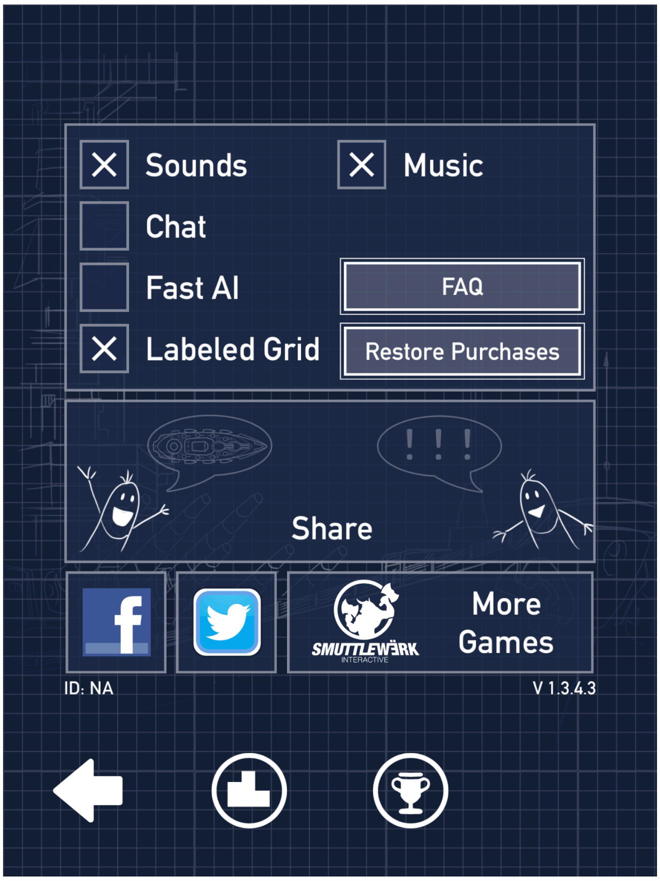

Figure 7.18. Screenshot depicting an example of an app that includes an option to adjust the presence of sound effects and music

Item 25: Is there an option to increase the size of the text?
Scoring: Yes = +1; No = 0.
Definition: If the app features an option to change the font size of any text, score +1.
Example: In Word - Search (Byterun), users can choose between five different font sizes for the letters featured within the puzzles (see Figure 7.19). Therefore, Word - Search would score +1 for this item.

Figure 7.19. Screenshot depicting an example of an app that includes an option to change the size of text

Item 26: Can you customise the colour scheme/backgrounds?
Scoring: Yes = +1; No = 0.
Definition: If there is an option within the app to change the colours and/or the background, thereby offering different colour combinations for the user to select, score +1.
Example: In Gin Rummy (DoraLogic), users can change both the colour/design of the background and the colour of the playing cards (see Figure 7.20). Therefore, Gin Rummy would score +1 for this item.

Figure 7.20. Screenshot depicting an example of an app that includes an option to change visual design elements (in this case the colour and style of the background and playing cards)

Item 27: Does the app feature a simplified option (e.g., change the difficulty level)?
Scoring: Yes = +1; No = 0.
Definition: If the app allows the user to increase or decrease the level of skill required to complete tasks/activities, score +1. This might be through the use of explicit difficulty levels (e.g., easy, medium and hard), or through the use of alternative modes or settings that change specific elements (e.g., shorten the task/activity).
Example: In Jigty (Outfit7), the user can adjust the difficulty of each puzzle by selecting the number of jigsaw pieces and whether or not to turn on piece rotation (see Figure 7.21). Therefore, Jigty would score +1 for this item.
Evidence: Providing different levels of difficulty or challenge allows people with dementia to find a suitable entry point to the task, and ensures that the app has the potential to provide continuous stimulation to the user as they progress (Pang & Kwong, 2015). This is also an important factor for achieving flow (C. M. Jones et al., 2014).

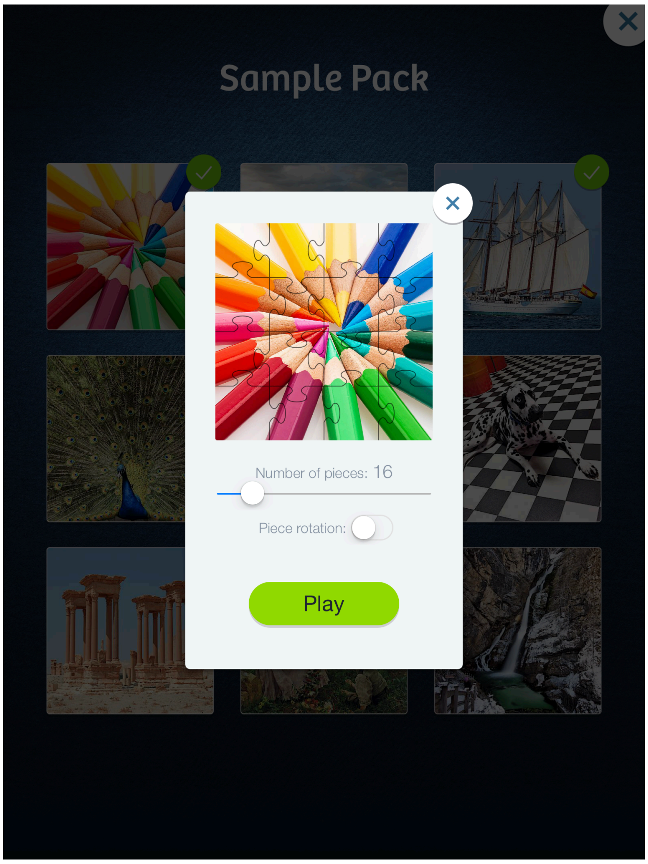

Figure 7.21. Screenshot depicting an example of an app that includes an option to adjust the difficulty level

Item 28: Can you change the speed of any automatic animations or processes?
Scoring: Yes = +1; No = 0.
Definition: If the app contains a feature allowing the user to adjust the speed of any computer-controlled processes or animations, score +1.
Example: In Bubble Explode (Spooky House Studios), the user can change the animation speed of the exploding bubbles within the game to one of five different options (see Figure 7.22). Therefore, Bubble Explode would score +1 for this item.
Evidence: The presence of options to control the speed of animated processes or to remove any time pressure can support people with cognitive impairment to understand what is happening on screen at a pace suitable for their needs (Barlet & Spohn, 2012; Cutler et al., 2016). People with impaired dexterity, precision and strength would also benefit from these settings (Barlet & Spohn, 2012).

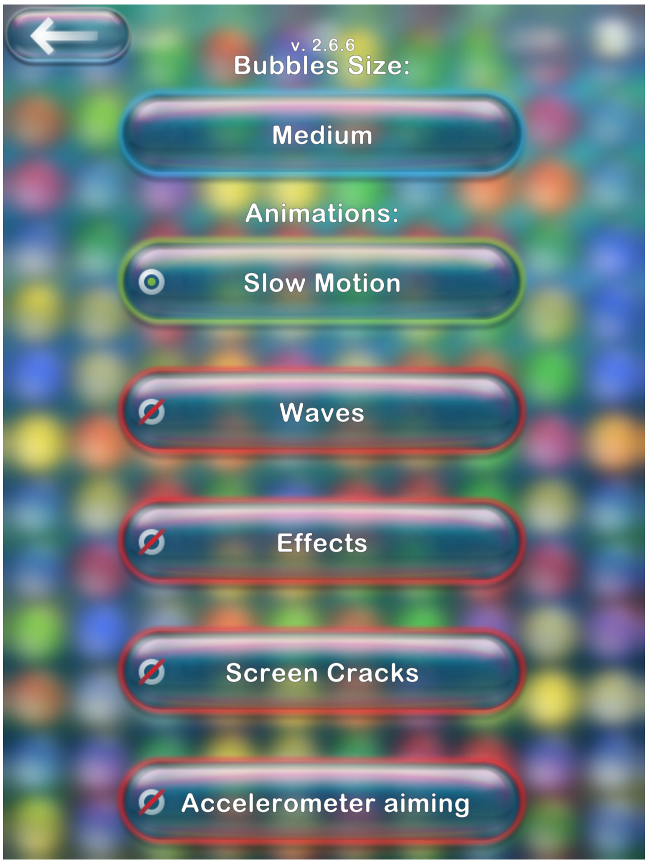

Figure 7.22. Screenshot depicting an example of an app that includes an option to adjust the speed of animations

7.2.2.6 Obstacles

Items relating to potential obstacles within apps are included in this category (summarised in Table 7.7).
Evidence for items 29-34: Pop-up windows and links to external websites (e.g., adverts) can be disruptive for people living with dementia when using technology (Kerkhof et al., 2017). In order to achieve flow during activities, distractions should be minimised by reducing the presence of these unrelated elements (Sweetser & Wyeth, 2005). However, the inclusion of adverts is usually a compromise to offer apps without cost (Vratonjic, Manshaei, Grossklags, & Hubaux, 2013), which can be a motivation when selecting apps for people with dementia (Pang & Kwong, 2015). From the researcher's experience testing more than 300 apps, the placement and timing of adverts can vary. Given the knowledge learned from Studies 1 and 2; that interactive elements placed in the lower portion of the screen can be disruptive (see 4.1.2.1), the placement of adverts or any other unnecessary objects in this location should be avoided.

Table 7.7. Summary of items in the 'Obstacles' category of the App Selection Framework

Obstacles	
29.	Does the app feature adverts?
30.	Was the app free to download?
31.	Are there any In-App Purchases available?
32.	Are there interactive elements in easily accessible locations onscreen that could disrupt the user's experience if unintentionally touched?
33.	Are there recurring pop-ups (e.g., Game Centre, Facebook, Twitter, etc.)?
34.	Did the app crash during testing?

Item 29: Does the app feature adverts?
Scoring: No = +3; Yes (but not intrusive) = +1; Yes (intrusive) = 0.
Definition: If there are no adverts within the app, score +3. If there are adverts, score as follows;

- Adverts that do not interfere with, or have minimal potential to disrupt the user's experience using the app, score +1;
- Adverts that do interfere with, or have increased potential to disrupt the user's experience using the app, score 0.

Adverts can be defined as banners or full-page images or videos that encourage the user to interact with them in order to view an external website or app store

page. Recommendations for other apps by the same developer that are accessed by the user from a menu do not count as advertisements in this context.
Non-intrusive adverts are defined as either banners at the top of the screen or full-page adverts that appear infrequently and don't interrupt an activity/task.
Intrusive adverts are defined as either banners at the bottom of the screen (which can be easily touched unintentionally) or full page adverts that interrupt an activity/task or are difficult to dismiss.
Example 1: In Solitaire (MobilityWare), a full-page advert that can easily be dismissed appears each time the user starts a new game. There is also a small banner advert at the top of the settings menu. These are both defined as non-intrusive, therefore Solitaire would score +1 for this item.
Example 2: In Hangman (Critical Hit Software), a banner advert is featured at the top of the page during gameplay (see Figure 7.23). This would be defined as non-intrusive, however there is also a full-page advert that appears regularly in between individual puzzles and is therefore defined as intrusive. Consequently, Hangman would score 0 for this item.

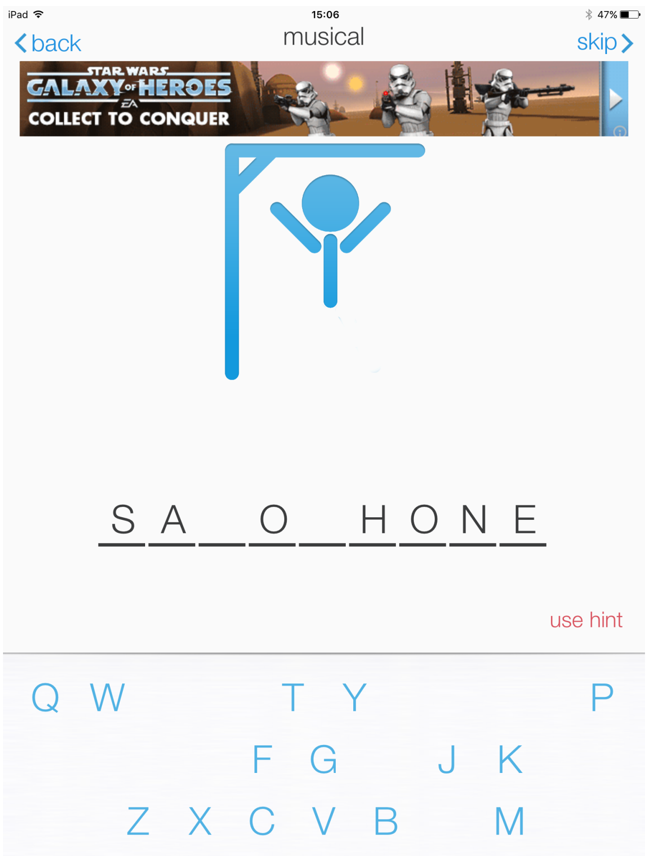

Figure 7.23. Screenshot depicting an example of an app that includes a non-intrusive advert banner

Item 30: Was the app free to download?
Scoring: Yes = +1; No = 0.
Definition: If the app did not cost any money to download, score +1.
Example: In Four In A Row (Indygo Media), there are In-App Purchases and intrusive banner adverts at the bottom of the screen (meaning it would score 0 for item 29). However, the app was free to download from the app store, therefore Four In A Row would score +1 for this item.

Item 31: Are there any 'In-App Purchases' available?
Scoring: Yes = 0; No = +1.
Definition: If the app contains any In-App Purchases, score 0. In-App Purchases are additions or upgrades to the app which have an associated cost, for which the user pays within the app itself.
Example: In Flick Kick Football (Prodigy Design), there is a customisation menu where the user can purchase additional designs of balls, shirts and crowds, for a fee (see Figure 7.24). Therefore, Flick Kick Football would score 0 for this item.

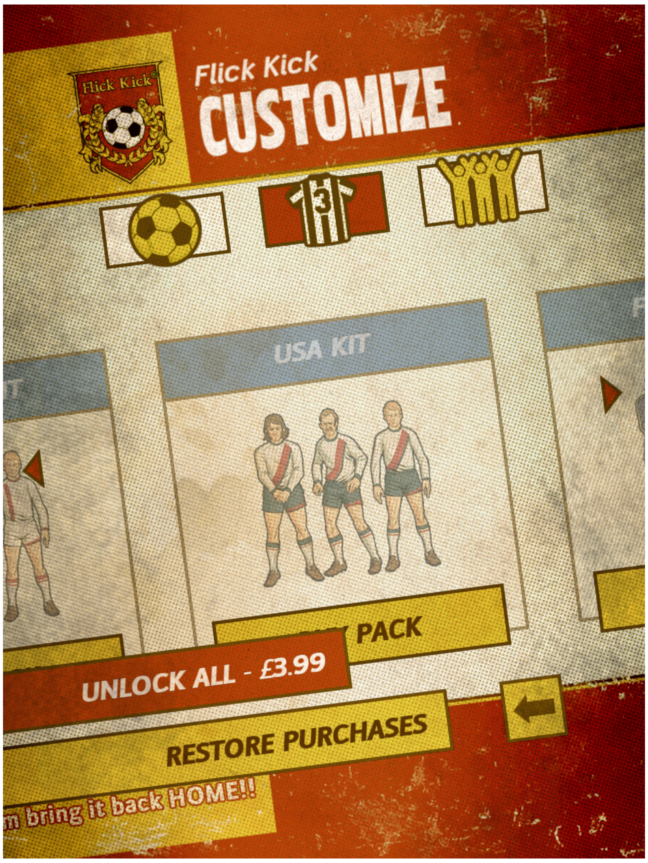

Figure 7.24. Screenshot depicting an example of an app that includes In-App Purchases

Item 32: Are there interactive elements in easily accessible locations onscreen that could disrupt the user's experience if unintentionally touched?
Scoring: Yes = 0; No = +1.
Definition: If the app features icons or buttons in the lower section of the screen, for example within a task bar, that (i) cannot be hidden; (ii) are not directly required for the main task/activity of the app; and (iii) trigger a function that could disrupt the user's experience if they unintentionally interacted with them, score 0.
N.B. Advert banners at the bottom of the screen should not be considered for this item as they have already been scored for item 29.
Example: In Backgammon Deluxe (Fat Bird Games), there is an undo button and a menu button present on a task bar throughout the game (see Figure 7.25). Due to their location at the bottom of the screen, these buttons could easily be triggered unintentionally during gameplay which could cause confusion. Therefore, Backgammon Deluxe would score 0 for this item.

Figure 7.25. Screenshot depicting an example of an app that features interactive buttons in the lower portion of the screen that could be unintentionally interacted with during gameplay

Item 33: Are there recurring pop-ups, (e.g., Game Centre, Facebook, Twitter, etc.)?
Scoring: Yes = 0; No = +1.
Definition: If the app features recurring pop-up messages related to external functions (e.g., social media, requests to review the app, etc.), score 0.
N.B. Adverts should not be considered for this item as they have already been scored for Item 29.
Example: In Tic Tac Toe (Yao Wang), there is a recurring pop-up message between games requesting that the user reviews the app (see Figure 7.26). This message requires interaction from the user in order to dismiss it, and links to an external location. Therefore, Tic Tac Toe would score 0 for this item.

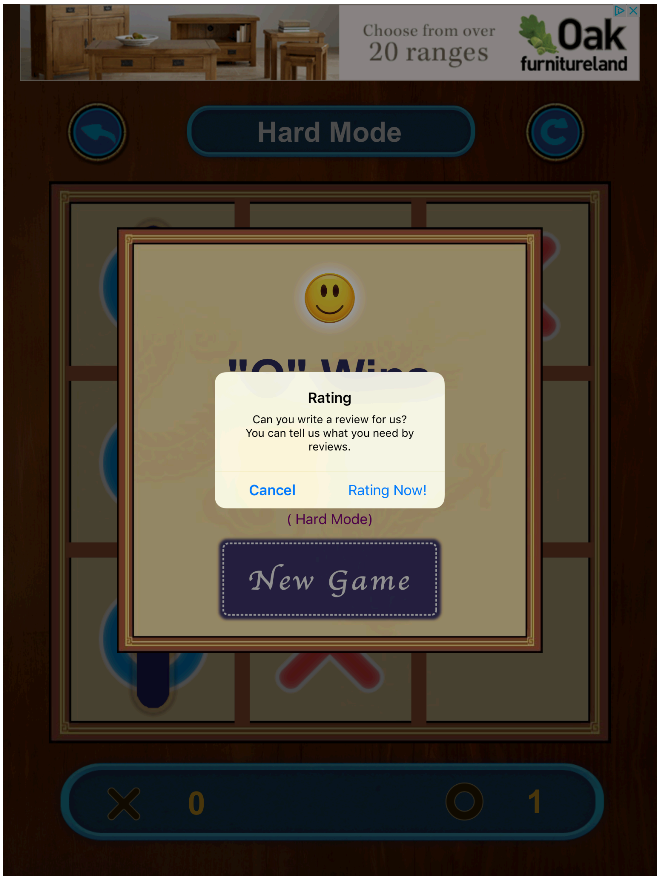

Figure 7.26. Screenshot depicting an example of an app that features a recurring pop-up message

Item 34: Did the app crash during testing?
Scoring: No = +2; Yes (once) = +1; Yes (repeatedly) = 0
Definition: If the app does not crash during testing, score +2. If the app crashes, but only on one occasion, score +1. If the app repeatedly crashes, score 0. Crashing is defined as closing unexpectedly or becoming stuck on a particular screen.
Example: Dominoes (Bit Time International) repeatedly closes when the initial loading screen appears after the user launches the app. Therefore, Dominoes would score 0 for this item.

7.2.2.7 Age-appropriateness

Items relating to the age of the intended audience for apps are included in this category (summarised in Table 7.8).
Evidence for items 35-38: Choosing children's activities and games for people living with dementia is common (Hackner & Lankes, 2016), but should be avoided as these are not age-appropriate for adults and can perpetuate stereotypes and stigmatisation (Cutler et al., 2016; Kerkhof et al., 2017). As demonstrated in Studies 1 and 2, and supported by evidence from the literature (Astell, Malone, et al., 2014; Cutler et al., 2016; Kerkhof et al., 2017; Leng et al., 2014; Lim et al., 2013), people with dementia are capable of engaging with and enjoying existing apps intended for use by the general adult population.

Table 7.8. Summary of items in the 'Age-appropriateness' category of the App Selection Framework

Age-appropriateness	
35.	Is the overall theme childish/juvenile?
36.	Are any animations childish/juvenile?
37.	Are any sound effects/vocal effects childish/juvenile?
38.	Is the app recommended for users under the age of 16?

Item 35: Is the overall theme childish/juvenile?
Scoring: Yes = 0; No = +1.
Definition: If the overall theme of the app (i.e., design, sound effects, visuals, etc.) could be perceived as being aimed at children and therefore potentially patronising and stigmatising toward people living with dementia, score 0.
Example: 1010 World (GramGames) features animated characters, background visuals, sound effects and music that could all be perceived as being aimed at children (see Figure 7.27). Therefore, 1010 World would score 0 for this item.

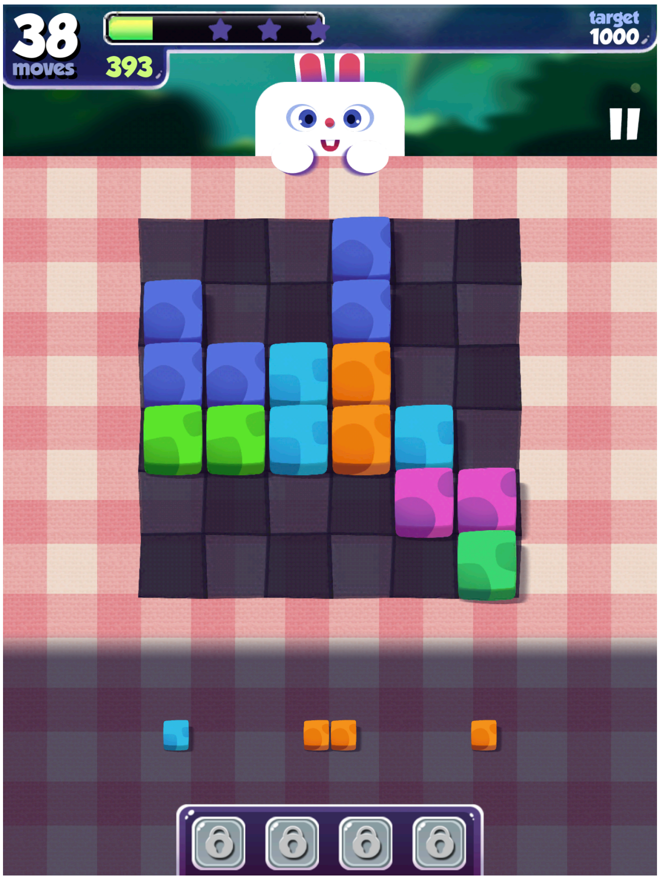

Figure 7.27. Screenshot depicting an example of an app that features design characteristics that could be perceived as being aimed at children

Item 36: Are any animations childish/juvenile?
Scoring: Yes = 0; No = +1.
Definition: If the overall theme of the app is age-appropriate, but there are animations that could be perceived as being aimed at children and therefore potentially patronising and stigmatising toward people living with dementia, score 0.
Example: In Perfect Kick (Gamegou), the animation of certain characters during goal celebrations could be perceived as childish or juvenile (see Figure 7.28). Therefore, despite other elements of the app being age-appropriate, Perfect Kick would score 0 for this item.

Figure 7.28. Screenshot depicting an example of an app that features an animation that could be perceived as being aimed at children

Item 37: Are any sound effects/vocal effects childish/juvenile?
Scoring: Yes = 0; No = +1.
Definition: If the overall theme of the app is age-appropriate but there are sound or vocal effects that could be perceived as being aimed at children and therefore potentially patronising and stigmatising toward people living with dementia, score 0.
Example: In Popping Stars 3 (Simply Game), the background music and vocal effects could be perceived as childish or juvenile. Therefore, despite other elements of the app being age-appropriate, Popping Stars 3 would score 0 for this item.

Item 38: Is the app recommended for users under the age of 16?
Scoring: Yes = 0; No = +1.
Definition: If the app is recommended for users under the age of 16, either within the app itself or in the app store, score 0.
Example: Color By Numbers (Kedronic UAB) is listed in the app store as being recommended for ages 6-8. Therefore, despite the design of the app itself being age-appropriate, Color By Numbers would score 0 for this item.

7.2.2.8 Game-specific

Items relating specifically to gaming apps are included in this category (summarised in Table 7.9). This section is only completed if the app under review is a game.

Table 7.9. Summary of items in the 'Game-specific' category of the App Selection Framework

Game-specific	
39.	Is there a multiplayer option using the same device (i.e., 'pass & play')?
40.	Does the game require prior knowledge of the rules (i.e., could not be played intuitively)?
41.	Does the app impose rules in addition to, or different from, the traditional/classic version of the game?
42.	Can you customise game specific options?

Item 39: Is there a multiplayer option using the same device (i.e., pass & play)?
Scoring: Yes = +1; No = 0.
Definition: If the app features an option to play with at least one other human using the same device, (i.e., 'pass & play', as opposed to an online or network game), score +1.
Example: Four In A Row (OutOfTheBit) features both a single player and multiplayer option using 'pass & play' on the same device (see Figure 7.29). Therefore, Four In A Row would score +1 for this item.
Evidence: Touchscreen gaming can be a social activity that people with dementia can share with friends and family of different generations (Astell, Alm, et al., 2014), and can improve social engagement (Kong, 2017).

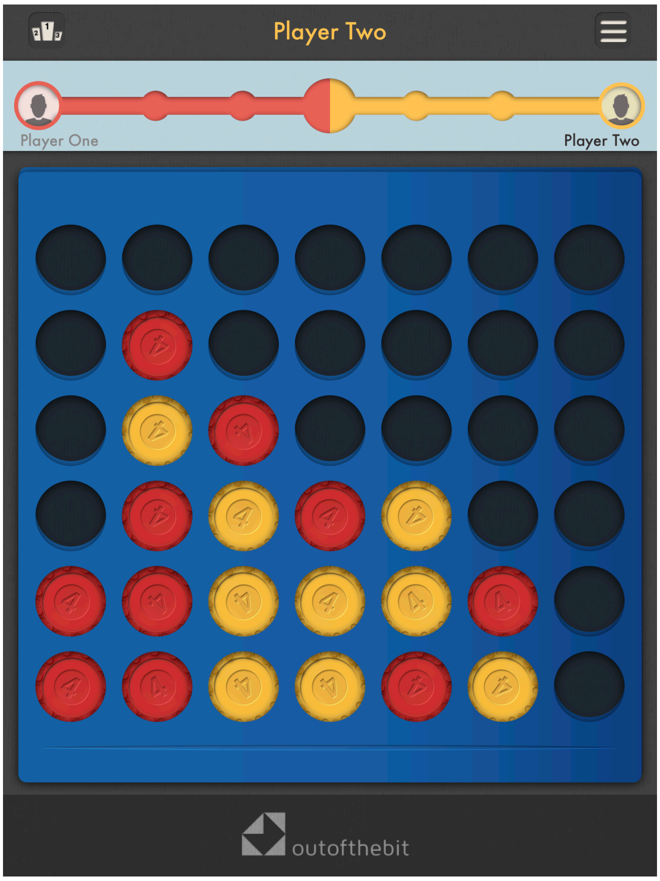

Figure 7.29. Screenshot depicting an example of an app that features a multiplayer game option

Item 40: Does the game require prior knowledge of the rules (i.e., could not be played intuitively)?
Scoring: Yes = 0; No = +1.
Definition: If the game involves complex rules that the user would be unlikely to learn intuitively by playing the app, score 0. However, if the game involves simple rules and there is high potential in the user being able to pick-up and play the game without prior experience, score +1.
Example 1: Bubble Explode (Spooky House Studios) involves the tapping of coloured groups of bubbles until the screen is cleared. The only rule is that the groups must consist of two or more bubbles. Therefore, there is increased potential that the game could be played intuitively without prior experience, and Bubble Explode would score +1 for this item.
Example 2: t-Chess (Tom Kerrigan) is a highly complex game with many rules. It would be highly unlikely that this game could be played without prior experience, therefore t-Chess would score 0 for this item.
Evidence: The differences observed between Solitaire and Bubble Explode in Studies 1 and 2 in terms of participant progression (see 4.3.3.2) were attributed to the difference in complexity between the two games. Whilst this had no observed effect on engagement or enjoyment for participants during the studies (see 5.4.3), this may only be a short-term effect, and it is likely based on technology acceptance models (Hwang, Hong, Hao, & Jong, 2011; O'Neill et al., 2014; Zhang et al., 2014) that in the long-term, game complexity would have more of an impact for people with dementia.

Item 41: Does the app impose rules in addition to, or different from, the traditional/classic version of the game?
Scoring: Yes = 0; No = +1.
Definition: If the game involves additional rules to those considered traditional to that game type (and they cannot be turned off), score 0. This item would not be applicable for an original gaming app that has no traditional rules (e.g., Bubble Explode).
Example: In the free version of 10 Pin Shuffle Bowling (Digital Smoke), the only game mode available features additional rules to those of shuffleboard/bowling, involving the acquisition of playing cards for scoring strikes or spares, with the aim of achieving a higher poker hand than your opponent (see Figure 7.30). Therefore, the free version of 10 Pin Shuffle Bowling would score 0 for this item.
Evidence: Based on the experience of the researcher reviewing many different types of app when evaluating digital representations of existing games, it is evident that there is a tendency for developers to embellish traditional games with new rules and features. Whilst this can provide an element of novelty (which, as Studies 1 and 2 demonstrated, is not necessarily a problem; see 3.4.1),

there may be an expectation from the user that the game will be as they have previously known it (Kerkhof et al., 2017), particularly if they have sought out the game or requested it specifically.

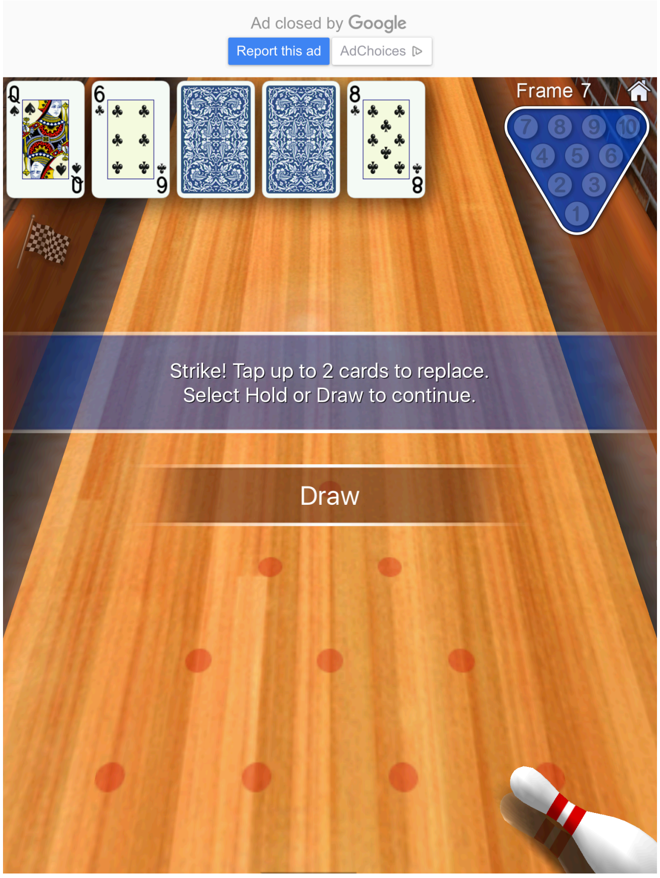

Figure 7.30. Screenshot depicting an example of an app that is a digital version of an existing game but with additional rules that cannot be turned off

Item 42: Can you customise game specific options?
Scoring: No = 0; Yes (1-2 options) = +1; Yes (3-4 options) = +2; Yes (<5 options) = +3
Definition: If the app allows the user to customise aspects of the rules or style of the game that have not already been addressed in a previous item; count the number of options and score according to the criteria above.
Example: In Dominos Pro (DoraLogic), customisation options include (i) rules for the first move, (ii) number of tiles in the starting hand, (iii) whether to count the 'spinner', (iv) difficulty level, (v) how many points are required for a win, (vi) presence of tile box on the screen, (vii) colour of background, (viii) colour of dominoes, and (ix) presence of sound (see Figure 7.31). As difficulty level, colour scheme and sound have already been addressed in previous items, Dominos Pro features five unique options and would therefore score +3 for this item.
Evidence: For people living with dementia, the ability to customise apps to tailor the experience for individual abilities and preferences is beneficial (Critten & Kucirkova, 2017; Cutler et al., 2016; Leng et al., 2014).

Figure 7.31. Screenshot depicting an example of an app that features game-specific options to customise the experience for the user

7.2.3 *Impact of the framework*

The App Selection Framework has been shared with researchers at the universities of Bangor in Wales and Saxion Applied Sciences in The Netherlands (through the INTERDEM Academy), and Ontario Shores Centre for Mental Health Sciences (through the AGE-WELL Network) in Toronto for use in a variety of studies (as yet unpublished) involving touchscreen apps and people living with dementia. The method of identifying apps for review presented in stage one of the framework has also been adapted by researchers at the University of Sheffield for use in a study investigating self-management apps for people with Attention Deficit Hyperactivity Disorder (ADHD; Powell, Joddrell, & Parker, 2017). Alongside the research presented in Chapters 2 to 6, the framework has been used to review and identify a range of touchscreen games and activities in an attempt to provide a catalogue of the most accessible apps available on the market for people living with dementia.

7.3 Sharing app recommendations with the public

The App Selection Framework has been used to identify 24 apps that represent the most accessible versions of their type for people living with dementia, based on the described evidence-based parameters. Whilst these apps have been used in demonstrations and events with people living with dementia in the researcher's local area, it was decided that the creation of a website to feature app recommendations would allow this work to reach a much wider audience. To facilitate this development, a project name was chosen to represent the work of the researcher to a public audience; AcTo Dementia.

AcTo is a portmanteau (a word combining the sounds and meanings of existing words) of the words 'accessible' and 'touchscreen'. These words were selected, in combination with dementia, due to them representing the key outputs of the present body of work; accessible touchscreen technology for people living with dementia. Prior to the development of the website, the researcher revisited the South Yorkshire Dementia Research Advisory Group to gather feedback and suggestions on the proposed concept (see 3.1.3).

7.3.1 *Patient and Public Involvement*

The researcher attended the group on Thursday 17th December 2015 to discuss the concept of the website, how people might search for the website, the proposed title and some logo designs. The idea for the development of a website to provide recommendations of accessible apps was met with approval, with several members sharing that they were tablet computer users and would be interested in such a resource. The title of the website and project was presented to the group just as 'AcTo', as initially the researcher had thought it beneficial to avoid use of the word 'dementia' in anticipation that people may resist a resource labelled with a term that has become associated with negative preconceptions and stereotypes (Cutler et al., 2016; S. K. Smith & Mountain, 2012). However, the resounding opinion of the group was that the term

'Dementia" should be included, as without it the intended audience would not know that the resource contained information designed for them.
Logo concepts were presented for comment (see Figures 7.32a-7.32d) and, after a short discussion regarding colour schemes, a vote was taken and Figure 7.32c was identified as the most popular choice.

Figure 7.32a (top left), 7.32b (top right), 7.32c (bottom left) and 7.32d (bottom right). Prototype logos for the AcTo Dementia website, shared with members of the South Yorkshire Dementia Research Advisory Group for feedback

The consensus from group members was that the logo should have more colour, and that there was too much text, which would be difficult to read. The final design of the logo represented these suggestions; introducing a colour scheme of turquoise and orange and replacing the existing text with the word 'Dementia' (see Figure 7.33).

Figure 7.33. The final version of the AcTo Dementia logo

The final contribution from the group was a list of words that they might use to search for a resource such as had been described (see Table 7.10). These words were subsequently incorporated into the metadata (hidden descriptive terms) of the website to aid in its discovery through search engines by an audience of people represented by the attendees of the PPI group.

Table 7.10. Words suggested by members of the South Yorkshire Dementia Research Advisory Group to be incorporated into the metadata of the AcTo Dementia website

Search terms	
1.	Dementia
2.	iPad
3.	Apps
4.	Games
5.	Activity
6.	Support
7.	Help

7.3.2 AcTo *Dementia website development*

The researcher had no prior knowledge of website development, therefore Squarespace; a Web Content Management System (WCMS), was used to minimise the complexity of the process for a 'non-expert' (Coffey, 2015). In designing the website, the researcher sought inspiration from other online resources with the same target audience (e.g., Alzheimer's Society, Age UK, AT Dementia, Unforgettable) and also followed Web Content Accessibility Guidelines (WCAG) published by the W3C Web Accessibility Initiative (WAI; Caldwell, Cooper, Reid, & Vanderheiden, 2008). Key aspects of the accessibility features of the website include: the use of 'alt text' to describe images for visually impaired users (Welle Donker-Kuijer, de Jong, & Lentz, 2010); the use of structured headings to support users who require screen readers to navigate the content; the selection of colours that are accessible for users with colour blindness (deuteranopia, protanopia and tritanopia); and the selection of high contrasting colours for text and background to improve readability for users with visual impairment. The latter feature was tested against the WCAG contrast ratio standards, and the use of a dark navy blue (HEX value #0B3144) for all body text against a pale grey (HEX value #ECECEC) background equates to a contrast ratio of 11.57:1, which achieved the highest pass level (AAA).

The primary purpose of the website was to share the recommendations of apps identified using the App Selection Framework. Each app recommendation is presented on a separate webpage, with a screenshot of the app, download links for the Apple App Store, differences between basic and premium versions (where applicable), and a summary of the findings from the review process in the form of pros and cons (see Figure 7.34). Apps are categorised by genre (e.g., board games, puzzle games, sports, etc.) and also by feature (e.g., free to download, two-player games, 'pick-up and play', etc.). The website can be accessed here: https://www.actodementia.com

Figure 7.34. Example of an app recommendation webpage from the AcTo Dementia website

Other aspects of the website which are functioning but are still under development include a series of guides to support people using touchscreen tablet computers, a public forum for users to communicate with each other or with the researcher, information regarding the evidence-base underpinning the project and a contact page to allow users to privately contact the researcher.

7.3.3 *Impact of the website*

The inclusion of metadata during the design of the website (see 7.3.1) was intended to signpost people who might be looking for a resource such as AcTo Dementia using an online search engine (e.g., Google); a process known as Search Engine Optimisation (SEO; Google, 2010). To monitor the effectiveness of these optimisations in directing users to the website, two outcomes were monitored: website traffic (unique visitors) and Google's own ranking of the website under specified search terms.

Website traffic data was accessed through the WCMS provided by Squarespace. In the website's first 12 months since its launch in April 2016, there were a total of 2,578 unique visitors, making 3,723 visits and viewing 10,200 webpages. Figure 7.35 presents the total number of visits by month during the website's first active year. In February 2017, the website received its highest number of visits (427) since it was launched. Whilst monthly visitation has fluctuated during the first year, the figures indicate that there is a sustainable interest in the topic.

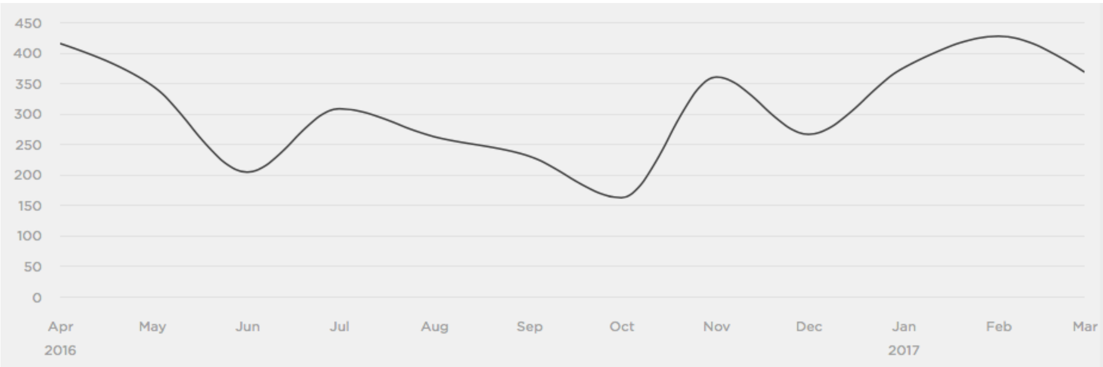

Figure 7.35. Visits by month to the AcTo Dementia website between April 2016 and March 2017 (image used courtesy of Squarespace; CC BY-NC-ND 4.0; *https://acto.squarespace.com/config/analytics)*

To monitor Google's search rank of the AcTo Dementia website, various combinations of the website's key terms (see Table 7.10) were entered into the Google search engine (www.google.com) using a web browser that does not trace user activity (to prevent the return of biased results). This process was undertaken on a monthly basis for the first 6 months after the website was launched (April 2016 to October 2017). The most successful search term combination was 'dementia' and 'apps' (see Figure 7.36), for which Google currently ranks the AcTo Dementia website at 6th. This rank is visible on the first page of Google search results; a key benchmark for increasing the number of visits to a website (McCormick, 2016).

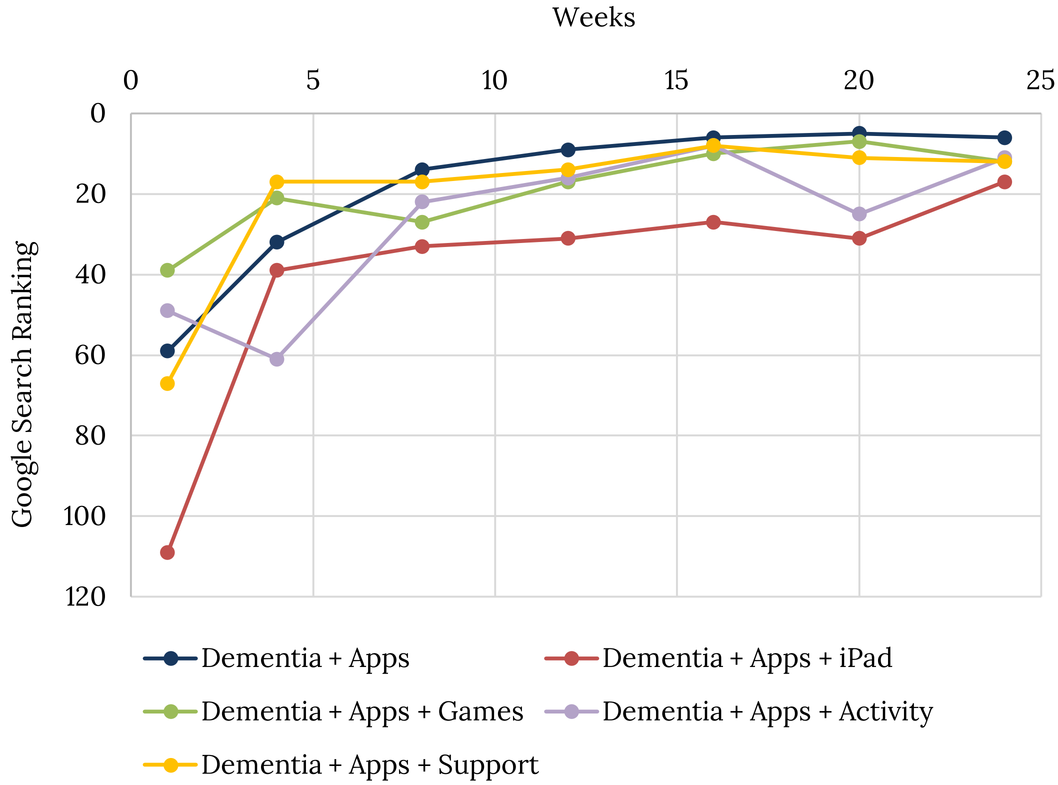

Figure 7.36. Google search rankings of the AcTo Dementia website defined by various search term combinations

7.4 Conclusion

The development of a framework to identify accessible touchscreen apps for people living with dementia can be viewed as a method of connecting a public audience with the work of the current research project. By extracting relevant information from the literature review (Chapter 2) and empirical studies (Chapters 3 to 6), a tool has been created that can be used to support people with dementia to access one of the most popular home technology devices on the market (Statista, 2015). The AcTo Dementia website serves as the medium by which this information can be communicated to as wide an audience as possible. Within the scope of the current research project, the goal was to develop the website, ascertain its relevance to the public and, through the release of regular content (app recommendations and news articles), establish it as a resource that can be located using appropriate search terms. The data reported on website traffic and search rankings would indicate that this has been achieved. Further work is now focusing on evaluating the content of the website with representatives from the target population; people living with dementia, relatives of people with dementia, and professional and informal caregivers. With regards to the framework itself, the potential for sharing and collaborating with other researchers has been demonstrated, which will permit examination of the reliability and validity of the review parameters. This should facilitate further impact of the present project in the wider research community by providing a robust method of identifying accessible touchscreen apps for people living with dementia.

Chapter 8. Discussion

8.1 Introduction

The work in this thesis was motivated by a report highlighting the need to identify stimulating recreational activities for people with dementia, as a research priority (Alzheimer's Society, 2012). It was evident that technology had the potential to contribute as part of a holistic approach to addressing this need, given its increasing application in the field (Topo, 2009). The popularity of touchscreen technology that emerged with the development of multi-touch devices such as smartphones and tablet computers from 2007 (Baanto, 2015), and the observation that these offered a more accessible computing experience for people with dementia (Wandke et al., 2012), led to a review of the existing literature on the use of touchscreen technology in the field of dementia (see Chapter 2). The key findings from this review were that people living with dementia can use touchscreen technology independently, but to date its application had predominantly been limited to assessing cognition and providing an assistive function. There were only a few examples of touchscreens being used for recreational activity, despite this being one of the most popular uses in wider society. Four research questions were posed based on the results of the review which were addressed through the work reported in Chapters 3-7. The findings relating to each of these questions will now be explicitly discussed over the proceeding sections.

8.2 Thesis research questions

8.2.1 What types of touchscreen games or leisure activities are most suitable for people living with dementia?

Study 1 (see Chapter 3) addressed the role of familiarity as a possible motivator when identifying types of gaming and activity apps for use with people with dementia, by investigating participants' responses to both a recognisable game and a game that was novel to them. The results revealed very little difference in the levels of engagement (see 5.4.3) and enjoyment (see 3.4.1) by participants playing these two games. Whilst it is acknowledged that this does not account for people's individual preferences, as participants were not given a choice as to which app they played, this finding suggests that novel games should be considered for people with dementia. This finding is worthy of report, given that in the existing evidence-base, novelty is largely overlooked, with many articles in the touchscreen literature (Alm et al., 2007; Cutler, Hicks, & Innes, 2016; Kerkhof, Bergsma, Graff, & Dröes, 2017; Kong, 2017; Lim, Wallace, Luszcz, & Reynolds, 2013, see 2.3.4.4) advocating familiarity as a design feature or a basis for selection. The reasoning that the use of technology should be tailored according to people's interests (Cutler et al., 2016; Kerkhof et al., 2017), is not contradicted or undermined by the findings relating to novelty. Instead, the results offer an additional consideration when apps are being recommended, and highlights a potential paradox in that if a person is unaware of the existence of a modern puzzle game (such as Bubble Explode), how are they to know to request or show interest in it? One example of how the concepts of familiarity and novelty can co-exist is if an individual indicates that they have historically enjoyed completing puzzles, they may enjoy a novel puzzle game such as Bubble Explode, that they have never tried before.

The combination of the existing evidence on familiarity and the new findings relating to novelty is reflected in the selection of apps included on the AcTo Dementia website (see 7.3.2). Digital representations of familiar games and activities such as dominoes, jigsaws and crosswords are included alongside novel apps such as Bubble Explode, Dots and Free To Fit. The presentation of apps in various categories according to genre or specific features, encourages the discovery of novel activities by or for people with dementia. This is achieved by presenting the novel and familiar apps side by side, such that when viewing the 'Puzzle Games', for example, visitors would see both. Whether these recommendations have received uptake is unfortunately unknown, as the metrics available to the researcher do not include the number of download links followed by people accessing the website. Also, it was not possible within the scope of the thesis to evaluate the website. This is acknowledged as a limitation of the present work and highlighted as an area for future concentration. Potential methods of conducting such an evaluation have been considered, with the inclusion of an optional survey on the website for visitors to complete offering a relatively simple source of naturalistic and quantitative feedback, or the hosting of interviews or focus groups offering an opportunity to gain more qualitative feedback. A final point with regards to the types of games and activities that might be most suitable for people with dementia relates to complexity. Clearly the results of Studies 1 and 2 (Chapters 3 and 4) indicate a disparity between the complexity of the evaluated games, Solitaire and Bubble Explode, as evidenced by the number of gameplay sessions where participants were able to progress to the checkpoint (see 4.3.3.2). Whilst Solitaire is undoubtedly the more complex of the two games, the fact that progression was achieved by five participants over the course of the two studies means that it would be false to claim that it is too complex for all people with dementia. Furthermore, cognitive scores were not an indicator of successful progression, as there were participants who did not manage to progress who scored higher on the MoCA than those who achieved progression (see 4.4.4). Therefore, whilst the factors dictating progression were not revealed within the present project, there was very little evidence of any adverse effects from participants playing a game through which they ultimately could not progress. On the contrary, reported enjoyment for Solitaire was higher in Study 1 in comparison with Bubble Explode (see 3.3.1.3). This does somewhat contradict assertions from the reviewed literature that touchscreen activities for people with dementia should be ‘failure-free’ (Kong, 2015; Riley et al., 2009), although this is a well-established concept in the wider field of dementia (Sheridan, 1987). However, the results perhaps highlight that there is variation between activities, with avoidance of failure being more important in some than others. For games to be engaging they require a degree of challenge (Granic et al., 2014), and this is a necessary step toward achieving flow (Csíkszentmihályi, 1988). As such, the exploration of different types of apps for people with dementia should be encouraged, and decisions should not necessarily be made on the basis of assumed ability, as enjoyment and engagement (at least in the short-term) do not appear to be constrained by progression in a game (see Chapters 3 and 5).

8.2.2 Can people with dementia play touchscreen games independently?

With minimal training, participants in Studies 1, 2 and 3 (Chapters 3, 4 and 6) demonstrated that touchscreen games can be played independently by people living with dementia. The reviewed literature contains reports of both successful (Alm, Astell, et al., 2007; Cutler et al., 2016; Kerssens et al., 2015; Lim et al., 2013) and unsuccessful (Ekström et al., 2017; Kerssens et al., 2015; Meiland et al., 2012; Tyack et al., 2015) independent use of touchscreen technology devices (see 2.3.4). In several cases where independent use was not achieved, it was reported that the person with dementia tended to rely on the support of a caregiver (Ekström et al., 2017; Meiland et al., 2012; Tyack et al., 2015). In the present project, the study design intentionally placed the researcher out of the participants’ view in order to encourage independent use (see 3.2.6). Under these circumstances, independent gameplay was observed in 93% of gameplay sessions featuring adapted Solitaire and 100% of gameplay sessions featuring Bubble Explode. It is possible that the experimental conditions of Studies 1 and 2 were ideal for the facilitation of independent functioning, as without the presence of another person, the concepts of learned helplessness (Jarrott & Gigliotti, 2010) or socially created dependency (Rust, 2012), where support is requested or given in *anticipation* of failure, were controlled for.

Whilst it is important not to overstate the level of independence demonstrated in the present project – as gameplay sessions lasted a maximum of 10 minutes and the tablet computers were setup in advance by the researcher – it is also important not to take it for granted, as demonstrations of independent engagement by people with dementia using everyday technology can help to reduce some of the stigma associated with the condition (Cutler et al., 2016). On several occasions during the data collection process of Studies 1, 2 and 3, members of staff expressed surprise to the researcher that the participants were able to use the tablet computer independently and engage with the touchscreen games. Similar experiences have been reported in the literature base (Leuty et al., 2013; Loi et al., 2017), but also anecdotally. It is proposed, therefore, that future research could investigate this concept as the primary focus of a study; working with caregivers on attitudes towards the capabilities of people living with dementia and measuring the effects on the quality of care provision, using mainstream technology as the catalyst for challenging stereotypes.
Another area in which the results of the present research can be seen as contributing towards a more progressive conception of dementia is with regards to flow (Csíkszentmihályi, 1988). The indicators of engagement based on the results of Studies 1 and 2 (see 5.4.1), amount to an observed measure of flow for people living with dementia during independent gameplay. Flow theory underpins the notion that because short-term engagement was evident in the present project for people living with dementia playing touchscreen games; long-term engagement should also be possible. This is because flow explains how certain activities are experienced as rewarding, and why people continue to seek out such activities despite there being no extrinsic benefits (Murphy et al., 2014; Salen & Zimmerman, 2004). The concept of flow has not previously been demonstrated with people with dementia, therefore long-term engagement with flow-inducing entertainment, such as touchscreen games, can only be theorised at this stage. The intrinsic rewards that have been associated with flow in gameplay in the general population include increased positive emotions (Granic et al., 2014; Horne-Moyer, Moyer, Messer, & Messer, 2014), improved mood (Horne-Moyer et al., 2014), and the sense of accomplishment (Granic et al., 2014). Whether these or other positive factors are evident for people living with dementia should be the focus of future research investigating touchscreen gameplay longitudinally.

8.2.3 How can suitable apps for people living with dementia be identified?

The App Selection Framework (see Chapter 7) was developed as a systematic method of identifying the most accessible tablet computer apps for people with dementia, using the outcomes of the present project. By synthesising relevant information from the literature base of studies involving touchscreen technology and people with dementia, a set of parameters was devised which were used to identify the two apps used in their existing form for Study 1 (see Chapter 3). The potential in this early iteration of the framework was evident from the results of that study, as despite the observations of the video analysis that led to the adaptations in both Solitaire and Bubble Explode; independent gameplay was evident in 88% of sessions (see 3.3.1.1) and enjoyment was reported in 86% (see 3.3.1.3). Using the outcomes of Study 1, and those of the subsequent studies, in addition to further evidence from relevant literature, the review parameters evolved from their original total of 15 to the current iteration containing 42 items.

Four articles returned from the literature review focused on leisure activities for people with dementia using existing touchscreen apps on a tablet computer (Cutler et al., 2016; Kerkhof et al., 2017; Leng et al., 2014; Lim et al., 2013). None of these articles reported using a systematic or evidence-based approach to selecting apps, although Kerkhof et al. (2017) describe being in the preliminary stages of creating a tool combining user needs with system requirements in order to match appropriate apps with people with dementia. Consequently, Studies 1, 2 and 3 of the present project are currently unique in their approach to identifying evidence-based accessible apps for people with dementia (using the App Selection Framework). It is, therefore, imperative to continue the development of the framework by establishing its reliability and validity and making it available for other researchers (in addition to clinicians, developers and the public). The AcTo Dementia website may be an appropriate location to share the framework with the widest possible audience, in addition to a peer-reviewed journal publication detailing its development.

The website was created to provide the public with the outcomes of the present project that had the most potential to have an impact on the lives of people with dementia. Using the framework to systematically identify the most accessible versions of a wide-range of gaming and activity apps for people with dementia, a catalogue of apps has been compiled that people can browse in an online environment developed for their needs (see 7.3.2), to narrow down the selection pool from the dauntingly high two million available apps (Statista, 2017b). By sharing the evidence behind the decisions made in the same environment, it is hoped that users who might be interested in such information can take confidence from the transparency by which the recommendations have been made. This is an area that was found to be lacking when exploring existing resources of app recommendations for people living with dementia. As reported in 7.3.3, when entering the terms ‘dementia’ and ‘apps’ into the Google search engine, the AcTo Dementia website is returned in the top 10 search results (accurate as of September 2017; see Figure 8.1). Of the six results returned above the AcTo Dementia website in this figure, five feature lists of apps recommended for people with dementia; none of which contain any evidence or justification for why they have been selected. The website ‘Senior Directory’, as an example, contains a list of nine apps “that have been proven to be helpful for people who suffer from dementia and Alzheimer's” (Senior Directory, 2017, paragraph 3). However, no evidence is cited to indicate how the listed apps have helped people with dementia, and the list contains an app titled Talking Tom at number one which would fail each of the four items in the App Selection Framework’s ‘Age appropriateness’ category (see 7.2.2.7). The list also contains the app Lumosity, the developers of which in 2016 agreed to settle a Federal Trade Commission charge of deceptive advertising for claiming that use of their app would protect against cognitive decline (Federal Trade Commission, 2016; John, 2016); which is not mentioned on the Senior Directory website. It is, therefore, the belief of the researcher that the AcTo Dementia website is a worthwhile resource in an area where evidence-based advice is deficient; particularly given that the consequences of using software unsuitable for people with dementia’s needs can lead to technology abandonment (Hartin et al., 2014). Future research should concentrate on evaluating the AcTo Dementia website’s effectiveness with target users, as discussed in 7.4.

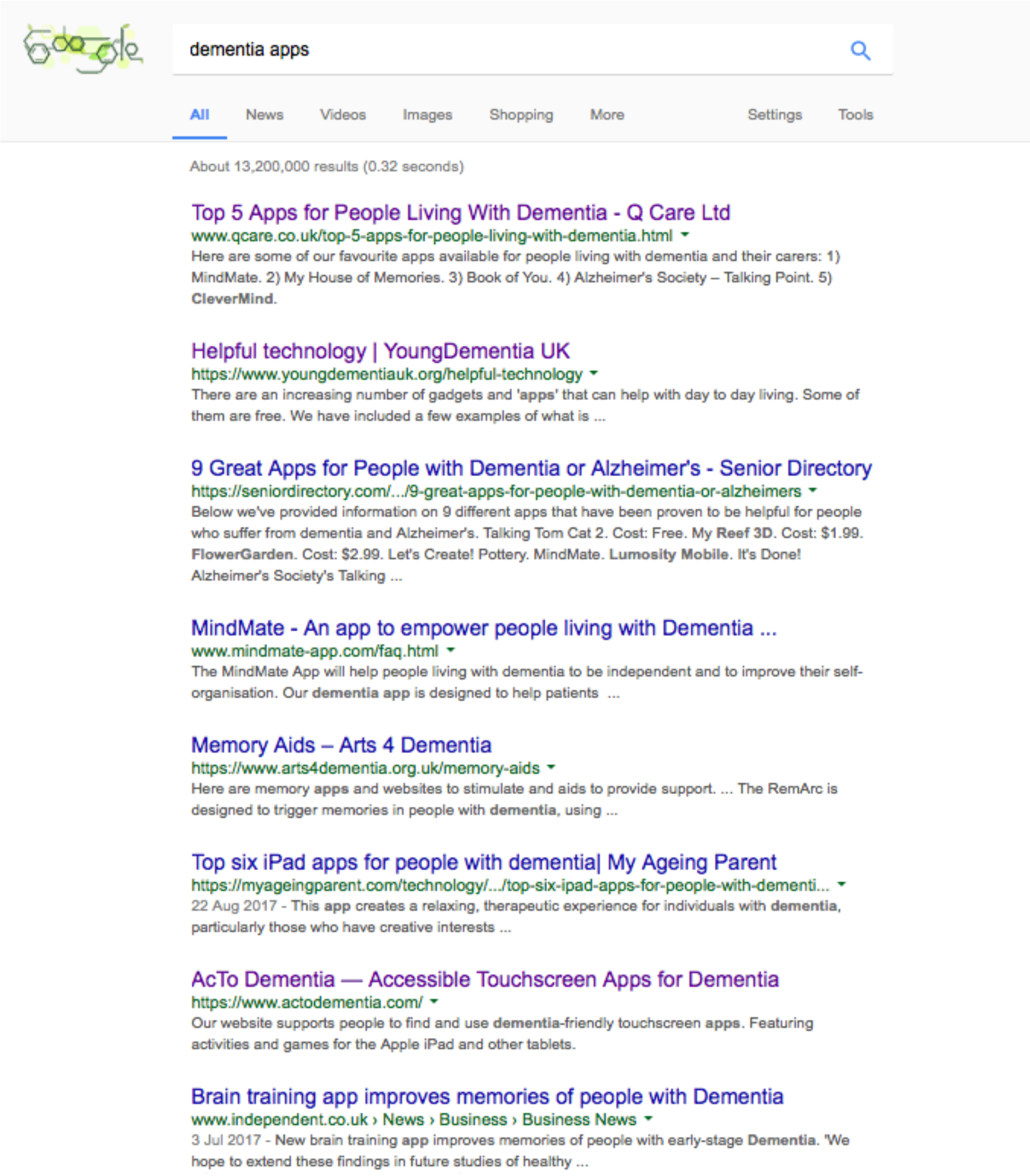

Figure 8.1. Screenshot of Google search results for the terms 'dementia' and 'apps' captured on the 23rd September 2017

8.2.4 How can touchscreen apps be customised to improve their accessibility for people living with dementia?

The ability to customise software was highlighted as a key benefit of modern touchscreen devices for people with dementia in the reviewed literature (Astell, Malone, et al., 2014; Hoey et al., 2010; Leuty et al., 2012; Pang & Kwong, 2015; Satler et al., 2015, see Chapter 2). Consequently, Solitaire and Bubble Explode were selected as the apps for evaluation in Studies 1 and 2 (Chapters 3 and 4) over other apps of the same type largely on the basis of the range of customisation options included in their design (see 3.2.3.1). Furthermore, the adaptations to Solitaire, implemented by the developers prior to Study 2, were all included as customisation options within the existing app, to allow users to select which of them they want to apply during gameplay, if any. Whilst the Bubble Explode developers did not include the adaptations as options, instead implementing them as design changes for all app users, they still adapted their existing app, as opposed to releasing a separate version specifically for dementia. By including adaptations and customisation options in this format, a blueprint has been laid out that it is hoped other developers can follow in the future. To the researcher's knowledge, these are the first examples of accessibility options specifically designed for people with dementia to be incorporated into mainstream apps (see Figure 8.2).

The benefits to this approach include the fact that people can tailor the gameplay experience to fit their own needs. Dementia affects each individual uniquely (Werner et al., 2016; see 1.1), and therefore no combination of settings will suit everybody. However, by including adaptations as a series of options that can be turned on or off, the accessibility of apps can impact a wider audience. A further benefit to the incorporation of accessibility settings in existing apps relates to the stigmatisation that can arise through the design of technology that is set apart from other products by its association with disability (Rosenberg, Kottorp, & Nygård, 2012). A separately-released 'Bubble Explode for Dementia', for example, would be unnecessarily segregated from the original game based on just a few accessibility features that allow the game to be played by a wider audience. By keeping apps unified, people with dementia are able to share the experience of using modern technology with other people around them without risking isolation. This has the potential to encourage intergenerational socialisation and raise awareness of dementia with younger audiences (Cutler et al., 2016). Finally, whilst the participants in the present project reported having no tablet computer experience prior to their involvement, it is inevitable that people receiving diagnoses of dementia now, and increasingly in the future, will be existing users. By 2020, it is forecast that 1.4 billion people globally will be tablet users (Statista, 2015). If the implementation of accessibility options for people with dementia were to be widely adopted by app developers, existing app users who receive a diagnosis of dementia would have an increased opportunity of continuing to use the same software while only having to adjust the settings to meet their changing needs as the condition develops. This concept corresponds with continuity theory (Morgan-Brown & Brangan, 2016), which emphasises the crucial role that continuity of activity can have on preserving a sense of identity and self-concept, and has also been linked to improved self-esteem (Boyd et al., 2017).

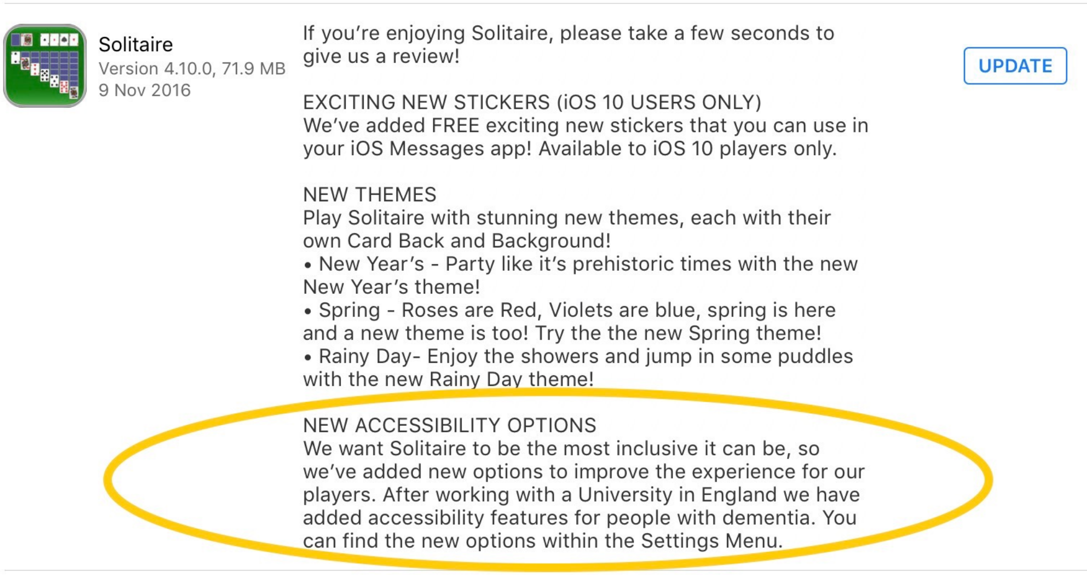

Figure 8.2. Screenshot from the Apple App Store of the release notes for version 4.10 of MobilityWare's Solitaire app, which included the accessibility options (highlighted) emanating from the present project

8.3 Conclusion

Touchscreen technology is ideally suited for use by people living with dementia as a means of independent activity and entertainment. The outcomes of the present research project have further strengthened the evidence base that people with dementia are capable of using the technology independently, whilst offering new knowledge related to the types of apps that might be suitable, how they can be identified, what independent engagement with touchscreen games looks like for people with dementia, and how collaboration with software developers can influence the future of touchscreen use for this population. The legacy of this project is represented by the App Selection Framework, which it is hoped will be used by researchers, developers, clinicians and members of the public in the future; the AcTo Dementia website, as a resource recommending accessible touchscreen apps for an international audience; indicators of engagement, which can be beneficial both for researchers and practitioners as a benchmark for future evaluation; and the blueprint of how accessibility can be incorporated into existing touchscreen software to facilitate the continuity of ubiquitous technology devices such as smartphones and tablets for people with dementia in the future.

Word count: 59,309

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Appendix A. Summarised results of literature review

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Alm et al. 2004[a]	Assistive technology	Practicalities	Personal computer with touchscreen monitor/interface	Supported use	6; 9	74.3 (57-95); 83 (65-95)	MMSE 15.6 (10-25); MMSE 16 (8-22)
Alm, Astell et al. 2007	Leisure activities	?	Personal computer with touchscreen monitor/interface	Independent use	5; 6	?	?
Alm, Dye et al. 2007[a]	Assistive technology	Intuitive control	Personal computer with touchscreen monitor/interface	Independent use	18	?	?
Alm et al. 2009a[a]	Assistive technology & leisure activities	?	?	?	N/A	N/A	N/A
Alm et al. 2009b[a]	Assistive technology & leisure activities	?	Personal computer with touchscreen monitor/interface	Independent use	N/A	N/A	N/A

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Armstrong et al. 2010[a]	Assistive technology	?	Touchscreen smartphone, Windows software	Independent use	N/A	N/A	N/A
Astell et al. 2009	Assistive technology	?	?	Independent use	N/A	N/A	N/A
Astell et al. 2010	Assistive technology	Practicalities	Personal computer with touchscreen monitor/interface	Supported use	11	83.5 (65-95)	MMSE 15.9 (9-23)
Astell, Alm et al. 2014[a]	Leisure activities	?	?	Independent use	100+	?	?
Astell, Malone et al. 2014[a]	Leisure activities	Customisation, multi-functional use	Touchscreen smartphone, Apple software	Independent use	1	63	?
Boyd et al. 2017[b]	Assistive technology	?	Personal computer with touchscreen monitor/interface	Independent use	9	? (73-86)	?

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Carr et al. 1986	Assessment/ screening	Intuitive control	Personal computer with touchscreen monitor/interface	?	14	82.2	Unspecified test 8.1
Critten et al. 2017[b]	Assistive technology	Customisation, multi-functional use	Touchscreen tablet computer, iOS software	Independent use	3	? (72-94	?
Cutler et al. 2016[b]	Leisure activities	?	Touchscreen tablet computer, iOS software	Independent use	29	? (65-80)	?
Davies et al. 2009[a]	Assistive technology	?	Personal computer with touchscreen monitor/interface, touchscreen smartphone	?	17	68.1 (56-86)	?
Ekström et al. 2017[b]	Assistive technology	Multi-functional use	Touchscreen tablet computer	Supported use	1	52 (N/A)	? (N/A)
Fukui et al. 2015	Assessment/ screening	?	Personal computer with touchscreen monitor/interface	?	124	75.6	MMSE <26

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
González et al. 2013	Cognitive rehabilitation	Intuitive control	?	Independent use	?	?	MMSE >23
Hackner & Lankes 2017[b]	Cognitive rehabilitation	Intuitive control	Touchscreen tablet computer, Android software	?	4	? (56-90)	?
Hoey et al. 2010	Assistive technology	Customisation	Personal computer with touchscreen monitor/interface	?	N/A	N/A	N/A
Hofmann et al. 2003	Cognitive rehabilitation	?	Personal computer with touchscreen monitor/interface	?	9	68.1	19.6
Hofmann, Hock, Kühler et al. 1996	Cognitive rehabilitation	?	?	?	10	69 (49-86)	MMSE 19.4 (12-23)
Hofmann, Hock & Müller-Spahn 1996	Cognitive rehabilitation	?	?	?	4	? (50-85)	MMSE ? (12-23)

Publication Author	**Purpose of technology**	**Reason for technology selection**	**Hardware/ software**	**Independent use**	**Cohort size (people living with dementia)**	**Mean age (range)**	**Mean cognitive score (range)**
Imbeault et al. 2017[b]	Assistive technology	Practicalities	Touchscreen tablet computer, Android software	Independent use	1	65 (N/A)	? (N/A)
Inoue et al. 2009[a]	Assessment/ screening	Intuitive control, practicalities	Personal computer with touchscreen monitor/interface	Independent use	72	80	MMSE 21.8
Inoue et al. 2011[a]	Assessment/ screening	Practicalities	Personal computer with touchscreen monitor/interface	Independent use	34	79.2	MMSE 21.8
Ishiwata et al. 2014	Assessment/ screening	Practicalities	?	Independent use	188	?	?
Kerkhof et al. 2017[a,b]	Assistive technology & leisure activities	Customisation	Touchscreen tablet computer; iOS and Android software	Supported use	8; 5	75.13 (60-82); 76 (59-95)	N/A
Kerssens et al. 2015	Assistive technology	?	?	Independent use	7	77 (60-88)	? (11-27)

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Kikhia et al. 2015	Assistive technology	Multi-functional use	?	Independent use	N/A	N/A	N/A
Kim 2017[b]	Cognitive rehabilitation	Practicalities	?	Supported use	12	79.3; 78.5	K-MMSE 22.56; 26.83
Kong 2015	Cognitive rehabilitation	Practicalities, multi-functional use	Touchscreen tablet computer, iOS software	?	10	? (64-84)	MoCA 15.7
Kong 2017[b]	Cognitive rehabilitation	Multi-functional use	Touchscreen tablet computer, iOS software	N/A	15	? (50-86)	MoCA 15.33
Leng et al. 2014	Leisure activities	Intuitive control, multi-functional use	Touchscreen tablet computer, iOS software	?	6	77 (68-86)	MMSE 21 (16-25)
Leuty et al. 2012	Assistive technology	Practicalities, customisation	?	Supported use	6	89.2	MMSE 16.5 (15-25)

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Lim et al. 2013	Leisure activities	Intuitive control, multi-functional use	Touchscreen tablet computer, iOS software	Independent use	21	73.5 (50-91)	Reisberg's Scale 2-5 ('Early-stage')
Loi et al. 2017[b]	Assistive technology	?	Touchscreen tablet computer, iOS software	?	7	78.5	?
Manera et al. 2015	Assessment/ screening	?	?	Independent use	12	80.3 (70-90)	MMSE 18.4 (15-24)
Meiland et al. 2012	Assistive technology	Multi-functional use	?	Independent use	16; 14; 12	? (56-78); ? (57-90); ? (57-84)	MMSE ? (17-25)
Nezerwa et al. 2014[a]	Assistive technology	Multi-functional use	?	?	N/A	N/A	N/A
Nijhof et al. 2013	Assistive technology	?	?	Independent use	16	78 (58-86)	MMSE 22 (13-29)

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Ott et al. 2008	Assessment/ screening	Practicalities	Personal computer with touchscreen monitor/interface	?	88	75.8	MMSE 24
Pang et al. 2015	Assistive technology	Customisation, multi-functional use	?	Independent use	N/A	N/A	N/A
Pignatti et al. 2005	Assessment/ screening	Practicalities	Personal computer with touchscreen monitor/interface	Independent use	16	74.8 (62-83)	MMSE 21.9 (15-27)
Pringle et al. 2013	Assistive technology	Practicalities	?	Supported use	8	?	?
Purves et al. 2014	Assistive technology	?	Personal computer with touchscreen monitor/interface	Supported use	3	? (81-90)	'Moderate' (anecdotal)
Riley 2007	Leisure activities	?	?	?	N/A	N/A	N/A

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Riley, et al. 2009	Leisure activities	?	?	Supported use	10; 10	?	'Mild-Severe' (anecdotal); 'Mild-Moderate' (anecdotal)
Ritchie et al. 1993[a]	Assessment/ screening	?	?	?	N/A	N/A	N/A
Sahakian & Owen 1992[a]	Assessment/ screening	Practicalities	?	Independent use	N/A	N/A	N/A
Sahakian et al. 1993[a]	Assessment/ screening	?	?	?	65	66.7 (52-84)	MMSE 17.3 (8-28)
Satler et al. 2015	Assessment/ screening	Intuitive control, practicalities, customisation	Personal computer with touchscreen monitor/interface	Independent use	22	78.3	?

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Tippett et al. 2006	Assessment/ screening	?	Personal computer with touchscreen monitor/interface	Independent use	14	79.7	MMSE ? (12-28)
Tomori et al. 2015	Assistive technology	Practicalities	Touchscreen tablet computer, iOS software	Supported use	116	78.5	MMSE 16.6
Tyack et al. 2017[b]	Leisure activities	?	Touchscreen tablet computer, Android software	Supported use	12	75 (64-90)	?
Tziraki et al.2017[a,b]	Cognitive rehabilitation	Intuitive control, practicalities	Touchscreen tablet computer	Independent use	24	? (65-90)	?
Vahia et al. 2017[b]	Assistive technology	Multi-functional use	Touchscreen tablet computer, iOS software	?	36	79.9	? (MoCA 'Mild - Severe')
Verheij et al. 2012	Assessment/ screening	?	?	?	16	75.4 (66-88)	MMSE 24.1 (19-28)

Publication Author	Purpose of technology	Reason for technology selection	Hardware/ software	Independent use	Cohort size (people living with dementia)	Mean age (range)	Mean cognitive score (range)
Weir et al. 2014	Assessment/ screening	Practicalities	Personal computer with touchscreen monitor/interface	Supported use	N/A	N/A	N/A
Yamagata et al. 2013[a]	Assistive technology	Intuitive control	Touchscreen tablet computer, iOS software	?	?	?	?
Zaccarelli et al. 2013[a]	Assistive technology	?	Personal computer with touchscreen monitor/interface	?	118	?	MMSE ? (20-24)
Zmily et al. 2014	Cognitive rehabilitation	Multi-functional use	Android software	Independent use	10	75	'Early-stage' (not defined)

[a]Indicates an article that was not identified through database searching

[b]Indicates an article that was identified in the second phase of database searching (September 2017)

Appendix B. Confirmation letters of ethical approval

The University Of Sheffield.

Kirsty Woodhead
Ethics Committee Administrator

Regent Court
30 Regent Street
Sheffield S1 4DA
Telephone: +44 (0) 114 2225453
Fax: +44 (0) 114 272 4095 (non confidential)
Email: k.woodhead@sheffield.ac.uk

Our ref: 0734/KW

16 April 2014

Phil Joddrell
ScHARR

Dear Phil

Touchscreen games for people with dementia (InTouch)

Thank you for submitting the above research project for approval by the ScHARR Research Ethics Committee. On behalf of the University Chair of Ethics who reviewed your project, I am pleased to inform you that on 16 April 2014 the project was approved on ethics grounds, on the basis that you will adhere to the documents that you submitted for ethics review.

The research must be conducted within the requirements of the hosting/employing organisation or the organisation where the research is being undertaken. You are also required to ensure that you meet any research ethics and governance requirements in the country in which you are researching. It is your responsibility to find out what these are.

If during the course of the project you need to deviate significantly from the documents you submitted for review, please inform me since written approval will be required. Please also inform me should you decide to terminate the project prematurely.

Yours sincerely

K Woodhead

Kirsty Woodhead
Ethics Committee Administrator

The University Of Sheffield.

Downloaded: 30/09/2017
Approved: 25/04/2016

Philip Joddrell
Registration number: 140132663
School of Health and Related Research
Programme: PH010A

Dear Philip

PROJECT TITLE: AcTo Dementia: Accessible Touchscreen Games for People Living with Dementia
APPLICATION: Reference Number 008273

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 25/04/2016 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 008273 (dated 04/04/2016).
- Participant information sheet 1016893 version 1 (04/04/2016).
- Participant consent form 1016895 version 1 (04/04/2016).
- Participant consent form 1016894 version 1 (04/04/2016).

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Jennifer Burr
Ethics Administrator
School of Health and Related Research

The University Of Sheffield.

School Of Health And Related Research.

ScHARR

Ellen Nicolson
Ethics Committee Administrator
Regent Court
30 Regent Street
Sheffield S1 4DA

23 February 2017

Telephone: +44 (0) 114 222 5446
Fax: +44 (0) 114 222 0749 (non confidential)
Email: e.l.nicolson@sheffield.ac.uk

Project title: AcTo Dementia: Accessible Touchscreen Games for People Living with Dementia

Reference Number: 008273

Dear Phil,

Thank you for submitting the above amended research project for approval by the ScHARR Research Ethics Committee. On behalf of the University, I am pleased to inform you that the project with changes was approved.

If during the course of the project you need to deviate significantly from the documents you submitted for review, please inform me since written approval will be required.

Yours sincerely

Ellen Nicolson
On behalf of the ScHARR Research Ethics Committee

Appendix C. Sample study materials

Sample consent form

Participant Consent Form

Title of Research Project: *Accessible Touchscreen Games for People Living with Dementia*

Name of Researcher: *Phil Joddrell* Participant Identification Number:

	Initial Box
1. I confirm that I have read and understand the information summary (version x.x, dated xx/xx/xxxx) explaining the above research project and I have had the opportunity to ask questions about the project.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to complete any particular task/s or answer any particular question/s, I am free to decline.	☐
3. I understand that my responses will be kept strictly confidential within the research team. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.	☐
4. I understand that video recordings will be made for use by the researcher and destroyed on completion of the project.	☐
5. I give permission for the research team to use extracts of these video recordings in public lectures, presentations and demonstrations. I can change my mind about this decision at any time and request that any video recordings of myself be destroyed.	☐

I agree to take part in the above research project.

________________________	________________	____________________
Name of Participant	Date	Signature
________________________	________________	____________________
Lead Researcher	Date	Signature

To be signed and dated in presence of the participant

Any further questions?
Please contact: Phil Joddrell
Telephone: 0114 2224399
Email: pmjoddrell1@sheffield.ac.uk
Address: School of Health & Related Research (ScHARR), University of Sheffield
Regent Court, 30 Regent Street, Sheffield, S1 4DA

The University Of Sheffield.

Information summary for participants

Research project title: Accessible Touchscreen Games for People Living with Dementia

You have been invited to take part in a research project and it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and if there is anything that is not clear or if you would like more information please contact the researcher using the details at the end of this document. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the research?

This research is looking at how people process visual information on a touchscreen tablet computer (iPad).

Why have I been chosen?

You were invited to participate in this research project through your service provider because you have received a diagnosis of dementia. In total, we are hoping to work with thirty people in Sheffield.

Do I have to take part?

It is completely up to you whether or not you take part in this research. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Even if you consent, you can withdraw at any time without giving a reason.

What will happen to me if I take part?

The researcher will visit you three times over the course of one week. These visits will be arranged with you at your convenience and should not interfere too much with your usual routine. Each visit will last no longer than half an hour and will take place in an area of your home environment where distractions and disturbances will be minimal. During each visit you will be asked to play a game on the iPad. You can stop playing the game at any point during the visit.

What are the possible disadvantages and benefits of taking part?

It is not anticipated that you will experience any disadvantages by taking part. We hope that you will enjoy playing the games and using the iPad and that by participating in the research this may benefit others in the future.

What if something goes wrong?

Your wellbeing is our top priority but if you wish to make a complaint about this research please contact the project supervisor: Professor Arlene Astell, ScHARR, Regent Court, 30 Regent Street, Sheffield, S1 4DA, or the Dean of ScHARR: Jon Nicholl (same address as above).

1 Version x.x xx/xx/xxxx

Will my taking part in this project be kept confidential?

The information collected from you during the course of the research will be kept confidential. You will not be identified in any reports or publications.

Will I be recorded, and how will the recorded media be used?

Video recordings will be made of you playing on the iPad on each of the three visits so that the recordings can be viewed and analysed at a later stage. Using video will allow the researcher to look carefully at how people learn to play iPad games and how much enjoyment people experience during gameplay. The recordings will not be used for any other reason without your written permission and will not be seen by anyone outside of the research team.

Who will have access to the data and where will it be held?

All data will be held securely, in confidence at the University of Sheffield under the supervision of the researcher. The data will be stored for a maximum of five years. No one outside the research team will have access to the data.

What will happen to the results of the research project?

The findings will be presented to national and international audiences with the aim of increasing knowledge on the use of technology in promoting enjoyable leisure activities for people with memory problems. Participants, carers, staff or volunteers will not be identifiable in any of the reported material.

Please contact me if you have any questions about this research:

Phil Joddrell
Tel: 0114 2224346
Email: pmjoddrell1@sheffield.ac.uk
Address: ScHARR, University of Sheffield, Regent Court, 30 Regent Street, Sheffield, S1 4DA

The University Of Sheffield.

Touchscreen games for people with dementia

Dear Sir or Madam,

My name is Phil Joddrell (pictured) and I am a researcher working at the University of Sheffield. Soon I will be conducting a short study looking at people's experiences playing on a touchscreen tablet computer. We would like to know whether the games we have selected are suitable for people with dementia and whether they are enjoyable to play.

The study would involve you playing a game on an iPad (pictured) for a short period of time and then answering some questions about how you experienced the game. This will happen three times on different days over the course of about a week.

If you are interested in taking part in this study, please let a member of staff know so that they can inform me. I will then come to see you at a convenient time to talk about the details of the study so that you know exactly what would be involved.

- It is completely <u>your decision</u> whether or not you take part in the study.
- You can leave the study at <u>any time</u> for <u>any reason</u>.
- The information collected from you during the course of the research will be kept <u>confidential</u>.

Thank you for taking the time to consider this research

Appendix D. Game Experience Questionnaire

Post-gameplay questionnaire
Modified from the Game Experience Questionnaire (GEQ; Ijsselsteijn, de Kort & Poels, 2008).

1. Did you find the game involving?
2. Did you think that the game was challenging?
3. Did you think that the game was responsive to your actions?
4. Were you able to control the game in the way that you wanted?
5. Did you understand the rules of the game?
6. Were you able to concentrate on the game?
7. Did you enjoy playing the game on your own?