

Introduction:

With expected worldwide growth in the number of people living with dementia from about 47 million today to over 130 million by 2050, greater attention is being paid to prevention, cure if possible, and improved care and support for people with dementia and their carers (Prince et al, 2015). As part of the response to these trends, the Department of Health (DH) in England commissioned a scoping study from the Policy Innovation Research Unit (PIRU) on the role of dementia in the care and support system. The focus of this paper is on identifying how technologies fit within the dementia care pathway. In order to do this, we conducted a scoping review of digital technology, robotics and other technology (as relevant) in the care and support of people with dementia and/or their unpaid family and other carers. We supplemented this review with experiential information gathered from people with dementia and carers, and conducted interviews with experts in the field.

The technologies identified were classified according to their function and then mapped onto a dementia care pathway structure which considered who were the main users and beneficiaries of the technology, the care setting in which they were used and the severity of dementia.

Methods:

Data collection

Data for the mapping of technologies was collected using a three-tiered approach including a literature review, user reports and expert interviews.

First, we looked for English-language studies that evaluated technological interventions for the use and care of people with dementia, unpaid and paid carers, as well as clinicians. The search spanned the period from January 2000 to July 2015, and covered three databases: Pubmed, PsycINFO and CINAHL. Search strings contained a combination of the following terms: dementia OR Alzheimer OR cognitive impairment AND care* AND health OR social AND tech* OR robot* OR tele* OR application OR app AND ICT AND cost AND effectiveness OR benefit. We included 47 studies evaluating technologies based on randomized controlled trials, systematic reviews, and /or economic evaluations and other robust designs. Feasibility studies and studies describing but not evaluating a technology were excluded from the review. As part of the review, nine relevant literature reviews were also identified, and studies included in these reviews that met our inclusion criteria were included in the mapping.

Second, experiential evidence on the use of technology by people with dementia and their carers was collected. As this was a short, rapidly commissioned study we did not have time to obtain ethical consent to interview people with dementia and carers. Instead, for people with dementia, we conducted web and social media searches for reports of use of technology by people with dementia. We found three public blogs written by authors living with dementia. We obtained permission from the authors via email or social media to include their texts in the study. For carers, we were able to gather views from a group of carers for people with dementia linked to a related project (Comas-Herrera et al, *in press*). Seven

members of the group provided, via email, reports of their use of technologies and their personal evaluation of technologies they themselves use to facilitate and enhance their role as carers.

Finally, we conducted interviews with a convenience sample of experts from different sectors: academia, social service commissioners, charities and care providers. A full list can be found in the Table 1.

Table1 - Interview respondents

Category of Experts	Number of interviews
Academic researchers	7
Providers of remote care services	UK: 3; Spain: 1
Local authority commissioners of adult care services	6
Independent telecare service commissioner	1
Health practitioners	2
Independent home care provider	1
Representative of leading dementia charity	1
Representative of an independent government agency for technology innovation	1
Representative of an independent think-tank for information and communication technology (ICT) solutions	1
Total number of interviews	24

Framework for analysis

The technologies found in the literature, the experiential evidence and the interviews were organized into a typology by function, based on work by Carretero (2015) and the framework used by AT Dementia (2015). This approach led to a set of six functions: “memory and support of self-care and activities of daily living”, “treatments and intervention delivery”, “safety, security, monitoring and reassurance”, “training”, “care delivery, management and support”, and “social interaction and networking”. We also included an “other” category, to include interventions that do not fall under the definitions of the six functions.

Definition of functions

Interventions and devices supporting **memory and support of self-care and activities of daily living** cover assistive technologies and a wide range of Information and Communication Technologies (ICT). Assistive technologies in this context refer to technical devices with digital or ICT component (Riikonen et al., 2010, Bharucha et al., 2009). The interventions included target people with dementia and their carers and aim to enhance the care recipients’ independence. Global Positioning Systems (GPS), communication systems, reminder and cue systems can be found in this group.

The **treatments and interventions delivery** category covers interventions for people with dementia and carers using therapeutic and assistive technologies and ICT. Therapeutic technologies intend to support cognitive and physical fitness, entertainment, leisure and wellbeing. These can include therapeutic approaches using robots (e.g. the robotic seal, Paro), art therapy delivered using technology, distance psychotherapeutic support groups, and use of music for reminiscence or stress reduction. Games delivered to contribute to cognitive training

or reminiscence are also included in this category (Moyle et al., 2013, Wada et al., 2005, Tedim Cruz et al., 2014, Leuty et al., 2013, Marziali et al., 2006; Topo et al, 2004; Alzheimer’s Disease International, 2012; Lewis et al, 2015).

Safety, security, monitoring and reassurance tools can technologically support the safety and monitoring of people with dementia. They include options to set off alarms in the case of emergency (alarm and pager units, fall detectors, flood detectors, water temperature monitors, lighting) and thereby aim to support the wellbeing, independence and security of the person with dementia as well as to provide reassurance to carers (York Health Economics Consortium, 2013). Other examples of technologies with this function are activity monitors, wandering/safer walking technologies and telemonitoring. Smart homes, which support the technological running of a household through, for example, door sensors or remote-controlled home automation systems, also fall into this category. (Knapp et al., 2016, p.10, Carretero, 2015, p.20).

Training interventions target mostly unpaid carers, paid carers and other professionals. Training can have a range of purposes, from general education about dementia to training on specific medical and care needs. Technologically supported training interventions frequently use computer and the internet, which both enable recipients to participate in distance education programmes and can facilitate learning at their own speed in their own time.

The **care delivery, management and support function** covers telecare and telehealth interventions, and assistive technologies. We define telecare and telehealth as interventions facilitating “the delivery of health and care from a distance, and the monitoring of [the health and well-being of] care recipients using technologies” ranging from sensors to assistive robots

(Knapp et al., 2016, p.11, Carretero, 2015, Barlow and Knapp, 2014). Interventions classified under this category aim to facilitate direct contact and exchange of relevant information between professionals, people with dementia and their unpaid carers. Furthermore, both distance assessment and the provision of services and applications to enhance coordination and management of the different actors involved in the provision of care fall into this group. This category focuses on people with dementia and the use of technology to deliver care and to manage and arrange care.

Social interaction and networking includes the use of technology that frequently falls under the classification of ICT (Carretero, 2015, p.19). These services offer distance communication via mobile phone or Internet applications. They also play an important role for people with dementia and their carers as they can support the maintenance of social interaction despite limited ability to leave the house or potential distance to family and friends. Social interaction and networking can also be facilitated using online platforms where people concerned can exchange their experience and provide support to each other (Knapp et al., 2016, p.9).

The category **other** was added to accommodate technologies that did not fit in the functions outlined above. Examples include MP3 music playing devices, entertainment robots and game consoles (Lewis et al. 2015, AJDC Team, 2013, Khosla, R., 2015, Alzheimer's Australia 2014, Inoue 2014, Padala 2008, Tobiasson 2010)

Categorising the wide range of existing technologies into discreet functions is a complex task, and there are some technologies for which there is an overlap between categories. For example, the monitoring of people with dementia to ensure they are safe and well is an

important aspect in the use of many technologies, and monitoring technologies can be found under different functions reflecting their different purposes. These can range from distance monitoring (Global Positioning Systems (GPS)) enabling independent living for people with dementia, to safety technologies (e.g. gas shut-off valves) in peoples' homes and distance health monitoring (Pot et al., 2012, Tunstall Healthcare (UK) Ltd, 2012b).

Mapping the technologies in the dementia care pathway

The abilities and needs of people with dementia and those who provide care for them will change along the path defined by the progress of the symptoms and the ability to cope with them. These changing needs also mean that some technologies will be more appropriate or effective at different stages of severity of dementia. To reflect this, we also categorised the technologies according to their usefulness for people with mild cognitive impairment (MCI) and early stages of dementia on the one hand, and people with moderate or severe dementia on the other. Within each of these stages we also distinguished between living at home in the community or in institutional care settings. We also identified three user groups that may benefit from the technologies: people with dementia, unpaid carers and paid carers or other health care professionals.

Results

Table 2 provides an overview of the number of technologies (N=146) identified by stage of dementia and care setting (at home in the community or institutional care setting) as well as by function as described above. Table 3, on the other hand, focuses on the target user of technologies, differentiating between people with dementia, their carers and health

professionals, using the same dimensions of stage of dementia and function. The total number of technologies in Table 3 (N=141) is lower because some can be used in both home and institutional care settings, and these duplications have been eliminated in this table.

Technology Interventions by stage of dementia and location of care

Most technologies included in our review (N=70), have been targeted at people with moderate or severe dementia living at home in the community (Table 2). The next most common set of technologies focus on people with MCI and early stages of dementia living at home in the community (N=43). We identified 33 technologies aimed at supporting people in institutional care settings. We did not find technologies targeting people with MCI and early stages of dementia living in institutional care settings.

When investigating the table by function, it is interesting to note that most technologies (N=37) target safety and security of people with dementia. Most of these safety and security technologies were for people with moderate and severe dementia living at home in the community (N=21).

Safety functions also played important role for people with MCI and early stages of dementia living at home in the community (N=13). Among people with MCI and early stages of dementia living at home in the community most technologies were seeking to support and enhance people's memory function (n=20).

Relatively few technologies for people with MCI and at the early stage of dementia could be found in the categories "Training", "Care delivery" and "Social".

Table 2 Overview of number of technologies found by stage of dementia and function

Functions	Mild Cognitive Impairment to early stages of dementia				Moderate to severe stages of dementia				Total	
	Home		Care home		Home		Care home			
	N	%	N	%	N	%	N	%	N	%
Memory	20	47	0	-	6	9	3	9	29	20
Treatment	4	9	0	-	9	13	3	9	16	11
Safety	13	30	0	-	21	30	3	9	37	25
Training	1	2	0	-	4	6	3	9	8	5
Care delivery	3	7	0	-	15	21	7	21	25	17
Social	1	2	0	-	7	10	3	9	11	8
Other	1	2	0	-	8	11	11	33	20	14
Total	43	100	0	100	70	100	33	100	146	100

When focusing on people with moderate to severe dementia in institutional care, such as day care or care home settings, the largest number of technologies identified are technologies with therapeutic effects such as pet robots, or simulated presence therapy. Other examples of therapeutic ‘entertainment and reminiscence’ interventions are photo albums, music, games, films or karaoke-style apps (Wada et al., 2005, Sony-AIBO, 2015, Zetteler, 2008, Living made easy, 2015, Alzheimer's Disease International, 2012, Topo et al., 2004, Tobiasson, 2010, Padala, 2008, Capstick, 2011). These technologies fall into the categories “treatments” and “other”. It

is important to note that while these technologies have been developed for use in institutional care settings there is very little evidence of practical application.

Technology can also be used to link with people's relatives, and in some cases to help the relatives to be more involved and to better understand the care of their family members.

Some care homes and day centres explore the use of mobile technology to facilitate person-centred care, to take notes 'on the spot', to carry out risk assessments, and to coordinate with other professionals involved in the care of an individual outside the care setting (Pitts et al., 2015, Riskman, 2012, MyBrainBook, 2015, Memory & Company, 2015). These interventions fall into the category "social".

We could also identify a number of technologies supporting the delivery of care. These include items such as Radio Frequency Identification buttons, which allow care home staff to identify residents' clothes (Tunstall Healthcare (UK) Ltd, 2012b). Another example is a micro-blogging mobile phone app, which enables the carer to make notes to the log while being on duty, but also to catch up on most recent developments before a shift start (Pitts et al, 2015).

Memory and safety tools remain relevant in care home settings. Examples of tools that are becoming widely used are sensor mats and movement sensors. These devices can set off alarms if people with dementia get up and start moving. When used correctly these tools can reduce the need for checking on people at night and potentially disturbing their sleep (Cheng and Zhuang, 2011).

Technology interventions by stage of dementia and target users

In Table 3 we distinguish between two target user groups “people with dementia” and “carer and other health professionals”. We further present interventions by severity of dementia. This leads to four sub-categories: interventions targeted at people with MCI and mild dementia, interventions aimed at carers and other health professionals looking after people with MCI and mild dementia, interventions to support people with moderate and severe dementia and interventions for carers and health professionals looking after people with moderate to severe dementia.

Most of the interventions targeting people with MCI and early stages of dementia (N=15) and their carers (N=5) aim to support people’s memory and their ability to live independently. Examples of technologies falling into this category are GPS and communication devices and other technologies that can help mitigate memory problems (such as medication reminders, locators, voice cues to help perform daily activities, and ‘dementia-friendly’ versions of household gadgets), as well as tools promoting self-management of health (Alzheimer's Society, 2014, Loc8tor healthcare, 2014, Attainment Company, 2016, Pot et al., 2012). People with dementia discussing their experience with technologies refer positively to the freedom and peace of mind that GPS systems provide to them and their carers, as expressed in this extract from a blog (Clasper, 2015a). Others express their gratitude towards softwares such as Speech Interpretation and Recognition Interface (SIRI), as expressed in this extract from a blog (LeBlanc, 2015).

“---Back to me sitting in the care in a complete blank state of mind. I don’t know how long I was there. I again went to my phone to try and look for the Google Maps app. I used the main button on the phone and I guess I

held it for too long. I heard a sound and the words “What Can I Help You With” appeared on the screen. It was my friend Siri.

[...] Although I couldn’t remember the name of the restaurant, I could remember Bang Bang Shrimp. So I asked Siri where to find Bang-Bang Shrimp. Bonefish Grill came up with directions.” (LeBlanc, 2015)

As previously highlighted, technologies to improve safety and security at home also play an important role for people at the early stages of dementia or with MCI and their unpaid carers. The second highest number of technologies for people with dementia (N=10) and their family carers (N=3) has been identified in this category (Table 3). At this stage of the dementia pathway many people are able to live on their own in the community. Systems that monitor activity using sensors can also help relatives by reducing their anxieties and so often benefit the family carer providing unpaid care (Pot et al., 2012).

While technology can also facilitate the delivery of care, we only found three examples, one for people with dementia and two for family carers. One study described the use of videoconferencing to run memory clinics for people with dementia living in remote areas (Weiner et al., 2011). The two technologies for family carers involved using video conferencing to run psychotherapeutic groups (Marziali and Garcia, 2011, Marziali et al., 2006).

Some people with MCI or dementia use social media and the internet to obtain information about their conditions, share experiences, get support or facilitate an advocacy role. A blogger with dementia reports that the use of social media can give people with dementia the possibility to engage with others, and exchange about experiences and problems (Clasper, 2015b).

“I think that if you can hang on to the computer, the world is your oyster, because you can keep in touch with others in the same boat. You can discuss your problem with others, and you soon realise that you are not alone. [...] I know for a fact that although some look at social media with disdain, it’s certainly kept me going over the last few months when things have been stressful. So to me it has a very good role in supporting people these days. (Clasper, 2015b)

While this illustrates a very positive view on the use of social media it is important to note that this was the only evidence we were able to identify.

Table 3 Number of technologies found by target users, dementia severity and function

Functions	Mild Cognitive Impairment to early stages of dementia				Moderate to severe stages of dementia				Total	
	Person with dementia*		Carers and Professionals*		Person with dementia*		Carers and Professionals*			
	N	%	N	%	N	%	N	%	N	%
Memory	15	48	5	42	8	15	1	2	29	21
Treatment	3	10	1	8	4	8	8	18	16	12
Safety	10	32	3	25	16	30	7	16	36	26
Training	0	-	1	8	0	-	5	11	6	4
Care delivery	1	3	2	17	2	4	19	42	24	17
Social	1	3	0	-	6	11	4	9	11	8
Other	1	3	0	-	17	32	1	2.	19	13
Total	31	100	12	100	53	100	45	100	141	100

* includes both home care and care home settings

In the moderate to severe stages, technology can play a role in supporting the ability to remain independent and to maintain their skills. Assistive and safety technology continues to play an important role for people with advanced dementia and their carers. Table 3 shows that, for people with moderate to severe stages of dementia the largest set of technologies are those that enhance safety (N=16). These include a range of technologies such as fall detectors, motion sensitive lights, and sensors measuring room temperature and raising alarm when it gets too warm or too cold as well as cooker or smoke alarms (Riikonen et al, 2010, Tunstall Healthcare (UK), 2012b).

At this stage of dementia, active use of safety technology tends to shift to the carer, while the person with dementia often becomes a less active user. One person with dementia expressed in a blog post how the usefulness of alarms diminished over time:

"This morning is driving me crazy. Since I have lost my auditory sense of direction, I can hear the sound but cannot tell what direction sound is coming from. And my memory is impaired so cannot remember what sounds the different appliances emit. I suspect the piercing chirps this morning were from smoke alarm somewhere. When I hear the other sounds I don't know whether to check the toaster, stove, the convection oven, the landline phone, my cell phone, or look around for what I have forgotten elsewhere. [...] For many years alarms were wonderful tools to meet need...but this year?... I think I have progressed past their usefulness. Grr-r-r!!"(Truthful Loving Kindness, 2015)

Family carers in our sample reported the use of baby monitors to ensure people with dementia are calm and secure without disturbing them in their sleep (Knapp et al., 2016, p.61). Devices such as panic buttons or pendant alarms enable people with dementia to raise alarms

in dangerous situation and alert the carer (Oysta Technology, 2012, Tunstall Healthcare (UK) Ltd, 2012a). A carer reported the use of monitoring technology in a blog.

“Before I knew it I had installed the following: talking motion sensors and personalised recorded messages that call Dad to the toilet, radio or front door; a cheap time plug with a mains-powered talking motion sensor; and a personalised recorded message tells Dad to go back to bed if he tries to walk around during the night. [...]

When Dad told me he was getting lost I realised that I could buy cameras that cover the downstairs living area. I bought four and can now keep an eye on him all day from my computer or my phone”. (Spink, 2015)

Technologies can also be used for ‘therapeutic’ interventions, often delivered by devices such as tablets or digital music players (Lewis et al., 2015, Nijhof et al., 2013a). These technologies can help people with dementia to reminisce and to experience pleasure from their favourite music, films, or looking at pictures (Lewis et al., 2015, Nijhof et al., 2013a, Upton et al., 2011).

Family carers providing care for a person with moderate or severe dementia often face huge demands, and they have difficulties with accessing support services outside their home. Technology can play a crucial role in delivering interventions to improve their health and wellbeing and increasingly address carers’ needs. In the literature we found interventions using ICT for psychotherapeutic support groups (Marziali et al., 2006). Other distance services provided are telehealth education programmes and social networking tools (Wray et al., 2010, Finerday, 2015).

There is also an important role for technology as a means to coordinate care, either between different family carers, or between family carers and professional health and care

services. Nijhof (2013a) used this approach in a study that connected people with dementia, their family carers and paid carers through a tablet-based application.

As shown in Table 3, a number of technologies are also used for distance training and education on dementia (N=5) (van Mierlo et al., 2012, Wray et al., 2010, Nichols et al., 2011). Both people with dementia and carers can also benefit from technologies that facilitate social interaction and networking (Virtual College, 2015, Carers UK, 2014a, Salford, 2015, Wray et al., 2010).

While technologies requiring interaction tend to target carers or care professionals rather than people with moderate or severe dementia directly, ICTs can also be used to enable the provision of medical care with the help of distance memory clinics. This can be particularly beneficial for people living in remote areas with scarce access to health care providers (Comans et al., 2013).

Technologies cutting across the different dementia stages

The progressive nature of dementia means that it is also important to consider the duration of usefulness of technologies for people with dementia, their family carers and for people in the care workforce. In the early stages technologies mostly aim to support people to live independently. Some technologies, such as medication dispensers, smoke detectors or extreme heat sensors, can also be useful at moderate to severe stages of dementia (Alzheimer's Society, 2014, York Health Economics Consortium, 2013). Also reminiscence tools such as “*MyBrainBook*” have been found to be beneficial when the illness progresses. This online tool, for instance, allows the storing of photos and music and enables the connection with family and friends while it also offers storage of dietary and health information (MyBrainBook, 2015).

Although other technology interventions and devices may also prove useful for people with advanced dementia, no evidence of use could be found in this review.

Family carers may also find a number of technologies useful along the disease trajectory. These may be online tools providing information, such as the NHS health and symptom checker or distance education tools (e.g. assisted living app), as well as online communication tools enabling online videoconferencing services to exchange information with paid and/or other family carers (e.g. Jointly, Rally round), medical staff, friends and relatives or other unpaid carers (NHS choices health apps library, 2013, Virtual College, 2015, Rally Round, 2015, Carers UK, 2014b). GPS devices featuring a two-way communication system (e.g. Just in Case) may also be useful as they enable direct communication in case the person with dementia gets lost (Oysta Technology, 2012).

Paid carers supporting people with dementia and their family carers in the community and institutional care settings can also benefit from online training tools such as the Assisted Living app providing information on how ICT may be able to support care recipients (Virtual College, 2015). Furthermore, information management systems can enable the sharing of information (such as risk assessment) between care staff (Riskman, 2012).

Discussion

We found numerous technologies to enhance the memory and support self-care in people's daily lives, support their safety and security, their ability to interact over distance and facilitate treatment or intervention delivery, their care management and training. Particularly at the early stages of dementia, technologies such as memory aids target people with dementia,

sometimes jointly with their carers, to support independent living for as long as possible while ensuring the ability to communicate or to be located in case something goes wrong.

Anecdotally, for example, people with dementia have reported in their blogs that they use GPS monitoring devices to put their relatives' minds at ease (Clasper, 2015b). We found that the availability of designated technology tools for memory and safety functions in larger numbers than for other functions at this stage of the dementia pathway is mirrored in reports by people with dementia and carers who re-purpose everyday technologies for these functions.

The further dementia develops, the more interventions are targeted at family carers and health care professionals. Safety remains an important function: considerably more tools than at earlier stages are available in the 'care delivery' area for both people with dementia at this stage and for carers and professionals. Examples of these tools include internet based support groups for family carers (Chiu et al, 2009; O'Connell et al, 2014), software packages and online platform providing information and the ability to interact with other carers, trained personnel or even clinicians (Lundberg, 2014; Torkamani et al, 2014). Interventions developed for paid carers and other professionals include interactive online games to help the assessment of care recipient's needs or video conferencing systems enabling health professionals from different sectors to exchange information (Staffordshire Cares, 2015; RED Embedded Systems 2014). The results show that all of these care delivery tools are targeted at people living at home in the community rather than in institutional care settings. One possible explanation for this is the attention paid to the issue of caregiver burden. Developers may be responding to this perceived area of need, although there is scant evidence of actual use or data on actual impact on caregiver burden.

While there are more technology tools available in treatment and training functions for moderate to severe stages of dementia than in earlier stages, treatment and training interventions are mostly targeted at unpaid carers. Treatments offer carers the opportunity to participate in telecoaching or online video conferencing psychotherapeutic support groups (Van Mierlo et al, 2012; Marziali, E., Damanianakis, T. & Donahue, P., 2006; Marziali & Garcia, 2011), while training offers online tools to build networks with other carers and to learn about available resources (Wray et al, 2010; Virtual College, 2015; Carers UK, 2014a). Online tools on available ICT support and university based education using online tools are available for health care professionals (Virtual College, 2015; University of Salford, 2015). These examples are targeted at carers supporting people with dementia in their own homes. The greater emphasis on supporting people in their own homes compared to institutional care is reflected in Table 2 with greater numbers of treatment and training interventions targeting care provided in the community (N=9 versus 3 for treatment, 5 versus 4 for training). The lower number of technology tools targeted at institutional care settings may well reflect potential costs of technology when scaled to the care home level with potentially limited prospects for cost efficiencies.

Other technologies for people with dementia at the stage of moderate to severe symptoms have been developed for passive use (e.g. sensors). Here again we found anecdotal evidence of carers using everyday technologies such as phone alarms as reminders, installing smoke and gas sensors, use of baby monitors

While some reminiscence tools encourage active engagement by people with dementia at

moderate to severe stages by displaying pictures or playing music and thus facilitating interaction, we could only identify a limited number of such reminiscence tools in our review. People's changing abilities to handle complex technologies as symptoms develop, as well as ethical concerns regarding consent to data sharing, may be barriers to the development of useful tools and devices. The level of active engagement with technologies by people with dementia may be a sliding path depending on people's abilities; however, due to our categorisation between MCI to mild dementia on the one hand and moderate to severe dementia on the other, we can only pick up these differences to a limited extent.

The short period of usefulness of technologies due to the changing cognitive status of people with dementia also poses challenges for carers' willingness to engage with learning about new technologies. In order for technologies to be effective for people with dementia and their families they need to be accessible at the right time, able to adapt to changing needs, easy to use and of low cost. It is therefore not surprising that carers, who often have limited time and/or financial resources, may not search for the latest technologies but instead use off-the-shelf products such as simple music players or baby-monitors in supporting their relatives with dementia without having to disrupt them in their activity.

These factors may help explain why there is limited evidence of the actual utilization of these available technology tools in support of people with dementia and their carers (Ayres, 2013). The expert interviews conducted for this project suggest that a primary factor in perceived low levels of utilization is the lack of awareness of the options on the part of all of the potential users – people with dementia, their paid and family carers, care home staff, and the

professionals whose function it is to assess the needs of people with dementia and provide timely information and referrals regarding the best available resources (Knapp et al, 2015).

Increasing the knowledge and awareness levels of potential users might increase practical application. For people with dementia and family carers this is a role for local authorities, Dementia UK, the Alheimers Society, Carers UK, Help Age and similar organizations. Many have already developed useful websites and publications with helpful information, but a review of what is available suggests that more needs to be done to enhance awareness of the various technology-related tools and services available and how their cost might be covered.

Another role for practitioners is to engage more actively in the evaluation of existing and emerging technologies. Many of the studies reviewed in this project were small-scale, pilot explorations, often completed in laboratory settings rather than in the real world of service delivery on people's lives (Ayres, 2013). This limits their impact among potential users because they tend to be ignored by others attempting to establish a strong empirical evidence base for technology tools.

For paid carers the message is quite different. The fact that relatively few tools and services for paid carers have been identified in this review suggests that this area may need further development. As new tools are developed, paid carers will have to be shown that adopting these tools will make some aspects of their jobs easier and will ultimately not cost them their jobs because they will have enhanced IT skills (Consultancy.uk, 2016; Deloitte, 2015, although having these skills will not necessarily increase their job satisfaction. In expanding the use of technologies among professional carers it will be important to insure that attention is paid to guidelines on data protection. For institutional care settings the issue seems to be the

lack of awareness of the tools and their potential value in providing quality care for their residents (Alzheimer's Association, 2009).

Without proactive steps to increase awareness by all of these targeted users of the ICT-related tools and applications available, the gap between what is possible and what is actually used will likely continue and indeed grow wider. Because new technology-related tools are emerging at a fairly rapid pace this scenario is likely to change quickly. Consequently, future reviews will be needed to determine their success in addressing the gaps noted here, and in overcoming the barriers to the use of technology-related tools and services delineated in the broader study of which this mapping project was a part (see Knapp et al., 2016, p.91).

Technology certainly offers great promise to help address the needs of people with dementia and their carers, but it is clear that it is not a panacea, and much work needs to be done for technology tools and innovations to live up to the promise.

Limitations

The research project of which this study is part was conducted within tight deadlines. This enabled us to conduct only a rapid review, whereas a full systematic review investigating effectiveness and cost-effectiveness of technologies to support people with dementia and their carers would be necessary to get a full overview over the field. Furthermore, due to time constraints we were unable to obtain ethics approval to gather information from people with dementia and their carers and instead obtained expert opinions of members of a reference group for a related project for which we have full ethical approval.

The experience of dementia is manifold. Dementia is an umbrella term for many different forms of dementia, such as dementia with Lewy Bodies, Alzheimer's disease or Frontotemporal Dementia. In our work we brought together all different dementias, which may have different disease trajectories, leading to different needs together. We also relied on overall descriptions of interventions targeting people with dementia with MCI and mild dementia or people with moderate to severe dementia in different care settings. While the variety of experiences of people with dementia cannot be fully covered in a mapping review, such a review can make an important contribution in raising awareness of the kind of the wide range of technologies available for people with dementia and their carers throughout the dementia care pathway.

Funding

The research on which this article was based was funded by the Department of Health (DH), in part through its funding of the Policy Innovation Research Unit, with some inputs also coming from the MODEM project funded by the Economic and Social Research Council (ESRC) and the National Institute for Health Research (NIHR).

Acknowledgements

The authors would like to thank the individuals who kindly agreed to be interviewed as part of this project. We also thank Margaret Dangoor for her help in accessing valuable experiential evidence.

Conflicts of interest

The authors declare no conflicts of interest.

References

AJDC Team (2013) *Robots in Dementia Care: Australian Journal of Dementia Care* [online]. Available at: <http://journalofdementiacare.com/robots-in-dementia-care> (accessed 1 October 2015).

Alzheimer's Australia (2014) *Testing robots: Professor Rajiv Koshla | Alzheimer's Australia Dementia Research Foundation (AADRF)* [online] Available at: <http://dementiaresearchfoundation.org.au/news/testing-robots-professor-rajiv-khosla> (accessed 1 October 2015).

Alzheimer's Disease International (2012) *Alive Inside! The power of music comes to people with dementia via iPods* [Online]. Retrieved from www.alz.co.uk/icanwill/library/alive-inside-power-music-comes-to-people-with-dementia-via-ipods.

Alzheimer's Society (2014). *Dementia-friendly technology - A charter that helps every person with dementia benefit from technology that meets their need*. London: Alzheimer's Society.

Attainment Company (2016) *VoiceCue | Attainment Company* [Online]. Retrieved from <http://www.attainmentcompany.com/voicecue>.

Ayres S. (2013) How digital technology is supporting people living with dementia [Internet blog] 15 October 2013 Available at <http://www.nominettrust.org.uk/knowledge-centre/blogs/how-digital-technology-supporting-people-living-dementia> (in the 3rd paragraph) (Accessed 20 November 2016).

Barlow, J. & Knapp, M (2014) *Evaluating telehealth and telecare: note for the Medical Research Council*. London: Imperial College Business School and LSE.

Bharucha, A. J., Anand, V., Forlizzi, J., Dew, M. A., Reynolds, C. F., Stevens, S. & Wactlar, H. (2009). Intelligent assistive technology applications to dementia care: Current capabilities, limitations, and future challenges. *The American Journal of Geriatric Psychiatry*, 17, 88-104.

Capstick, A. (2011) Travels with Flipcam: bringing the community to people with dementia in a day care setting through visual technology. *Visual Studies*, 26, 142-147.

Carers UK (2014a) *E-learning for carers - Carers UK* [Online]. Retrieved from www.carersuk.org/help-and-advice/equipment-and-technology/our-products-for-carers/about-me-e-learning.

CARERS UK (2014b) *Jointly App - Carers UK* [Online]. Retrieved from www.carersuk.org/search/jointly-app.

Carretero, S. (2015) Mapping of effective technology-based services for independent living for older people at home. Seville: Joint Research Center, Institute for Prospective Technological Studies, JRC Scientific and Technical Reports Series.

Cheng, H. & Zhuang, W. (2011) Bluetooth-enabled in-home patient monitoring system: early detection of Alzheimer's disease. *Wireless Communications, IEEE*, 17, 74-79.

Chiu T., Mariziali E., Colantonio A., Carswell A., Gruneir M., Tang M., Eysenbach G. (2009) Internet-based caregiver support for Chinese Canadians taking care of a family member with alzheimer disease and related dementia, *Can j Aging*, 28, 7, 323-36.

Clasper, K. (2015a) Keeping people safe after the diagnosis of be dementia or memory problems Pt1. . *MCI and memory problems* [Online]. Retrieved from <http://ken2clasper.blogspot.co.uk/2015/08/keeping-people-safe-after-diagnosisof.html?spref=fb>.

Claper, K. (2015b) The role of social media when you are living with neurological problems. *MCI and memory problems* [Online]. Retrieved from <http://ken2clasper.blogspot.co.uk/2015/08/the-role-of-social-media-when-you-are.html>.

Comans, T. A., Martin-Khan, M., Gray, L. C. & Scuffham, P. A. (2013) A break-even analysis of delivering a memory clinic by videoconferencing. *Journal of Telemedicine & Telecare*, 19, 393-396.

Comas-Herrera, A., Knapp, M., Wittenberg, R., Banerjee, S., Bowling, A., Grundy, E., Jagger, C., Farina, N., Lombard, D., Lorenz, K & McDaid, D. (*In Press*) "MODEM: A comprehensive approach to modelling outcome and costs impacts of interventions for dementia. Protocol paper" *BMC Health Services Research, In Press*

Consultancy.uk (2016) Technology and automation has created more jobs than lost [internet blog] 01 March 2016 Available at: <http://www.consultancy.uk/news/3347/technology-and-automation-has-created-more-jobs-than-lost> (Accessed 20 November 2016).

Deloitte (2015) From brawn to brains: The impact of technology on jobs in the UK, London: Deloitte LLP. Available at: <https://www2.deloitte.com/uk/en/pages/growth/articles/from-brawn-to-brains--the-impact-of-technology-on-jobs-in-the-u.html> (Accessed 20 November 2016).

Dementia AT (2015) *At dementia – information on assistive technology for people with dementia* [Online]. Retrieved from www.atdementia.org.uk.

Finderday (2015) *Welcome to finerday* [Online]. Retrieved from www.finerday.com.

Inoue T (2014) Communication Robot for Persons with Dementia-Based on Field-based Innovation. Presentation at the Global Dementia Legacy event in Japan, November 2014. Available at: www.ncgg.go.jp/topics/dementia/documents/Topic3-5TakenobuInoue.pdf (accessed 6 October 2015).

Khosla R (2015) *Emotionally intelligent robots for social innovation, Research, La Trobe University*, [online]. Available at: www.latrobe.edu.au/research/research-impacts/researchers/videos/emotionally-intelligent-social-robots-for-social-innovation (accessed 1 October 2015).

Knapp, M., Barlow, J., Comas-Herrera, A., Damant, J., Freddolino, P., Hamblin, K., Hu, B., ... Woolham, J. (2016) The case for investment in technology to manage the global costs of dementia. Policy Innovation Research Unit: Personal Social Services Research Unit at the London School of Economics and Political Science.

LeBlanc B. (2015) Saved by Siri. *Alzheimer's The Journey...A peek inside* [Internet blog] 4 July 2015. Available at: <https://abitofbriansbrilliance.com/2015/07/04/saved-by-siri/> (Accessed 28 September 2015).

Leuty, V., Boger, J., Young, L., Hoey, J. & Mihailidis, A. (2013) Engaging older adults with dementia in creative occupations using artificially intelligent assistive technology. *Assistive Technology*, 25, 72-79.

Lewis, V., Bauer, M., Winbolt, M., Chenco, C. & Haney, F. (2015) A study of the effectiveness of MP3 players to support family carers of people living with dementia at home. *International Psychogeriatrics*, 27, 471-479.

Living Made Easy (2015) *Talking Photo Album* [Online]. Retrieved from www.livingmadeeasy.org.uk/loanlibrary/memory-prompts-p/talking-photo-album-0044375-3854-information.htm.

Loc8tor Healthcare (2014) *Loc8tor for Healthcare UK - The World's Best Trackers & Finders* [Online]. Retrieved from www.loc8tor.com/uk/healthcare.

Lundberg S (2014) The results from a two-year case study of an information and communication technology support for family caregivers. *Disabil Rehabil Assist Technol*, 9, 353-8.

Marziali, E., Damanianakis, T. & Donahue, P. (2006) Internet-based clinical services: virtual support groups for family caregivers. *Journal of Technology in Human Services*, 24, 39-54.

Marziali, E. & Garcia, L. J. (2011) Dementia caregivers' responses to 2 internet-based intervention programs. *American Journal of Alzheimer's Disease & Other Dementias*, 26, 36-43.

Memory & Company (2015) *Re:member* [Online]. Retrieved from <http://memoryandcompany.com>.

MODEM (2016) *Modelling outcome and cost impacts of interventions for dementia* [Online]. Retrieved from <http://www.modem-dementia.org.uk/>.

Moyle, W., Cooke, M., Beattie, E., Jones, C., Klein, B., Cook, G. & Gray, C. (2013) Exploring the effect of companion robots on emotional expression in older adults with dementia: a pilot randomized controlled trial. *J Gerontol Nurs*, 39, 46-53.

MyBrainbook (2015) *MyBrainBook - MyBrainBook* [Online]. Retrieved from <http://mybrainbook.com/login>.

NHS Choices Health Apps Library (2013) *NHS Health and Symptom Checkers - Health Apps Library* [Online]. Retrieved from <http://apps.nhs.uk/app/nhs-health-and-symptomcheckers>.

Nichols, L. O., Martindale-Adams, J., Burns, R., Graney, M. J. & Zuber, J. (2011) Translation of a dementia caregiver support programme in a health care system - REACH VA. *Arch Intern Med*, 171, 353-9.

Nijhof, N., Van Gemert-Pijnen, J. E. W. C., Burns, C. M. & Seydel, E. R. (2013a) A personal assistant for dementia to stay at home safe at reduced cost. *Gerontechnology*, 11, 469-479.

Nijhof, N., Van Gemert-Pijnen, L. J. E. W. C., Woolrych, R. & Sixsmith, A. (2013b) An evaluation of preventive sensor technology for dementia care. *Journal of Telemedicine and Telecare*, 19, 95-100.

O'Connel M.E., Crossley M., Cammer A., Morgan D., Allingham W., Cheavins B., Dalziel D., Lemire M., Mitchell S., Morgane E (2014) Development and evaluation of a telehealth videoconferenced support group for rural spouses of individuals diagnosed with atypical early-onset dementias. *Dementia: The International Journal of Social Research and Practice*, 13, 382-395.

Oysta Technology (2012) *Creating Safety Solutions* [Online]. Available: www.oysta-technology.com.

Padala, K. P. (2008) *Wii-Fit for Improving Activity, Gait and Balance in Alzheimer's Dementia* / National Institute on Aging [Online]. Retrieved from

www.nia.nih.gov/espanol/alzheimers/clinical-trials/wii-fit-improving-activity-gait-and-balance-alzheimersdementia.

Pilotto, A., D'Onofrio, G., Benelli, E., Zanesco, A., Cabello, A., Margeli, M. C., Wanche-Politis, S., ... & Kiliass, D. (2011) Information and communication technology systems to improve quality of life and safety of Alzheimer's disease patients: A multicenter international survey. *Journal of Alzheimer's Disease*, 23, 131-141.

Pitts, K., Pudney, K., Zachos, K., Maiden, N., Krogstie, B., Jones, S., Rose, M., ... & Truner, I. (2015) Using mobile devices and apps to support reflective learning about older people with dementia. *Behaviour & Information Technology*, 34, 613-631.

Pot, A. M., Willemse, B. M. & Horjus, S. (2012) A pilot study on the use of tracking technology: Feasibility, acceptability, and benefits for people in early stages of dementia and their informal caregivers. *Ageing & Mental Health*, 16, 127-134.

Prince, M., Wimo, A., Guerchet, M., Ali, G.-C., Wu, Y-T, Prina, M. (2015) „*World Alzheimer Report 2015 – The Global Impact of Dementia – An analysis of prevalence, incidence, cost and trends*“ London: Alzheimer's Disease International

Rally Round (2015) *Rally Round - start an account to organise care for someone who needs help* [Online]. Retrieved from www.rallyroundme.com/welcome.

RED Embedded Systems (2014) *RED Embedded Systems: visual care systems* [online] Available at: <http://www.redembedded.com/systems> (accessed 22 September 2015).

Riikonen, M., Mäkelä, K. & Perälä, S. (2010) Safety and monitoring technologies for the homes of people with dementia. *Gerontechnology*, 9, 32-45.

Riskman (2012) *Riskman - RisMan.Net* [Online]. Retrieved from www.riskman.net.au/Services/RiskMan-Net.

Rower, M. A., Kairalla, J. A. & McCrae, C. (2010) Sleep in dementia caregivers and the effect of a nighttime monitoring system. *J Nurs Scholarsh*, 42, 338-47.

Salford, U. O. (2015) *Dementia: Care and the Enabling Environment MSc/PgDip/PgCert - Postgraduate Taught Courses - University of Salford, Manchester* [Online]. Retrieved from www.salford.ac.uk/pgt-courses/dementia-care-and-theenabling-environment.

Sony-Aibo (2015) *Sony Aibo website for all models of Sony Aibo ERS-7, ERS-210, ERS-220, ERS-11x* [Online]. Retrieved from www.sony-aibo.co.uk.

Spink, K. (2015) Technology can make a difference. *Social Care Blog*, Department of Health, England, 10 June 2015. [internet blog] Retrieved from <https://socialcare.blog.gov.uk/2015/06/10/technology-can-make-a-difference-2>.

Staffordshire Cares (2015) *Me, Myself and I* [online]. Available at: <http://www.memyselfandigame.co.uk> (accessed 28 September 2015).

Tedim Cruz, V., Pais, J., Alves, I., Ruano, L., Mateus, C., Barreto, R., Bento, V., Colunas, M., Rocha, N. & Coutinho, P. (2014) Web-based cognitive training: patient adherence and intensity of treatment in an outpatient memory clinic. *Journal of Medical Internet Research*, 16, e122-e122.

Tobiasson, H. (2010) *Game over or play it again and again... participatory design approach withing special housing*. Linköping University. Retrieved from <https://www.diva-portal.org/smash/get/diva2:291681/FULLTEXT02.pdf>.

Topo, P., Maeki, O., Saarikalle, K., Clarke, N., Begley, E., Cahill, S., Arelind, J., Holthe, T., Morbey, H., Hayes, K. & Gilliard, J. (2004) Assessment of a music-based multimedia program for people with dementia. *Dementia*, 3, 331-350.

Torkamani M., McDonald L., Saez Aguayo I., Kanios C., Katsanou M.N., Madeley L., Limousin P.D., Lees A.J., Haritou M., Jahanshahi M (2014) A randomized controlled pilot study to evaluate a technology platform for the assisted living of people with dementia and their carers, *J Alzheimers Dis*, 41, 2, 515-523.

Truthful Loving Kindness (2015) Sound DisOrientation as Dementia Symptom. *Truthful Loving Kindness, Patient with dementia symptoms* [Internet blog], 11 August 2015. Retrieved from <http://truthfulkindness.com/2015/08/11/sound-disorientation-dementia-symptom>.

Tunstall Healthcare (UK) LTD. (2012a) *MyAmie pendant* [Online]. Retrieved from [www.tunstall.co.uk/Uploads/Documents/MyAmie datasheet 0414.pdf](http://www.tunstall.co.uk/Uploads/Documents/MyAmie%20datasheet%200414.pdf).

Tunstall Healthcare (UK) LTD. (2012b) *Telehealthcare solutions: key information for health and social care professionals and carers - Dementia Care* [Online]. Retrieved from www.tunstall.co.uk/Uploads/Documents/TelehealthcareSolutions-DementiaCare.pdf

Upton, D., Upton, P., Jones, T., Juttla, K. & Brooker, D. (2011) Evaluation of the impact of touch screen technology on people with dementia and their carers within care home settings. Worcester: University of Worcester.

University of Salford (2015) *Dementia: Care and the Enabling Environment MSc/PgDip/PgCert – Postgraduate Taught Courses – University of Salford, Manchester* [online]. Available at: <http://www.salford.ac.uk/pgt-courses/dementia-care-and-the-enabling-environment> (Accessed 23 September 2015).

Van Mierlo, L. D., Meiland, F. J. & Droes, R. M. (2012) Dementelcoach: effect of telephone coaching on carers of community-dwelling people with dementia. *Int Psychogeriatr*, 24, 212-22.

Virtual College (2015) *Assisted Living on the App Store* [Online]. Retrieved from <https://itunes.apple.com/gb/app/assisted-living/id687336068?mt=8>.

Wada, K., Shibata, T., Musha, T. & Kimura, S. (2005) Effects of robot therapy for demented patients evaluated by EEG. *IEEE/RSJ International Conference, 2-6 August 2005*.

Weiner, M. F., Rossetti, H. C. & Harrah, K. (2011) Videoconference diagnosis and management of Choctaw Indian dementia patients. *Alzheimers Dement, 7*, 562-6.

Wray, L. O., Shuland, M. D., Toseland, R. W., Freeman, K. E., Vásquez, B. E. & Gao, J. (2010) The effect of telephone support groups on costs of care for veterans with dementia. *The Gerontologist, 50*, 623-631.

York Health Economics Consortium (2013) *Telecare for People with Dementia: Evaluation of Refrewshire Project - Final Evaluation Report*. University of York: York Health Economic Consortium.

Zettler, J. (2008.) Effectiveness of simulated presence therapy for individuals with dementia: a systematic review and meta-analysis. *Aging Ment Health, 12*, 779-85.

Appendix

Abbreviations used

GPS – Global Positioning System

ICT – Information and Communication Technology

MCI – Mild Cognitive Impairment

NHS – National Health Service