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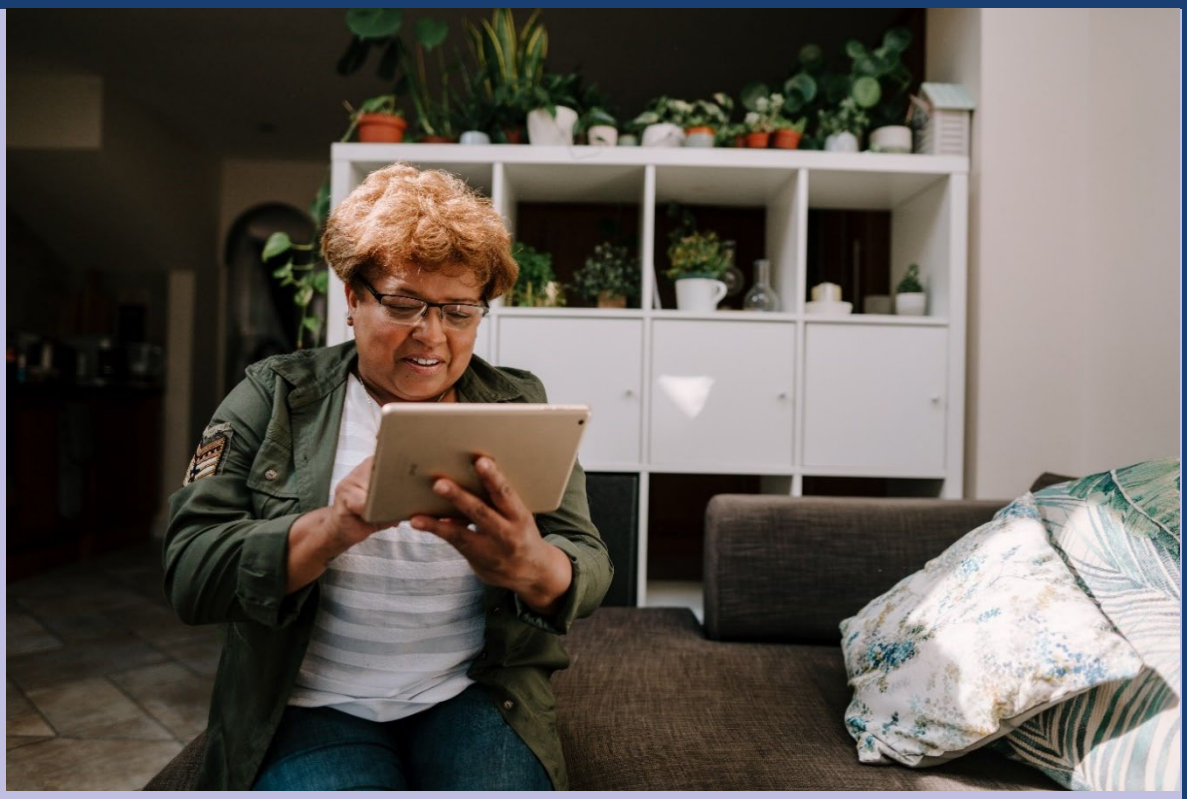

Digital technology to support people living with dementia and carers

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Full Report

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EXECUTIVE SUMMARY

Helping people living with dementia and their carers to live well has been the core policy goal since England's first national strategy in 2009. The *Prime Minister's Challenge on Dementia* 2020 further emphasised consistent access, care and standards in delivering the best services and innovation. Digital technology has the potential to help deliver better and more equitable services for people living with dementia and their carers, although evidence-based policy direction and commissioning are needed to realise such a potential.

This DHSC-commissioned report summarises findings from a rapid evidence review on digital technologies that support people living with dementia and carers at home and in care homes, to answer the following questions:

- What technologies are being used to support independence and safety among people living with dementia at home and in care homes?
- What are the cost benefits and savings for provider organisations and the NHS of using the technology?
- What are the barriers to scaling the technology?

We discuss current research evidence on effectiveness, cost and cost-effectiveness of digital technologies in supporting people living with dementia and carers to live well, with comments on their technology readiness, and describe the main barriers to scaling up.

Findings on effectiveness

A. Technologies used by people living with dementia

- Although assistive technology and telecare (ATT) are more ready (Technology Readiness Level (TRL): validation stage), there is no evidence of effectiveness.
- We found some evidence for virtual care support (TRL: production stage) on carer burden, depression and sense of competence, mainly coming from a US trial ('FamTechCare') of a video-based intervention that provides tailored care strategies to co-resident carers of people living with dementia.
- There are suggestions that applying mobile technologies may be effective in supporting people living with dementia in self-care and daily activities (TRL: production stage), although these technologies currently tend to support more basic (physiological and safety) needs only, and with little effect on higher-level human and psychological needs.
- Prompting and sensing systems (e.g., Development of Responsive Emotive Sensing System, DRESS) are at various TRL stages. We did not find any evidence on effectiveness yet.
- Very preliminary evidence suggests the general use of tablets (TRL: production stage) independently by people with early-stage dementia may have an effect on carer relief.

B. Technologies used with people living with dementia

- Touchscreen technology-based interventions and activities (TRL: production stage) such as digital life storybook may have better outcome than when these interventions and activities are delivered in more traditional way. There is some evidence of better mood and engagement and reduced distressed behaviours, although quality of evidence is low.
- A related group is computer-based/electronic technologies in general (i.e., not limiting to touchscreen technology) for engagement (TRL: validation stage). These include activities delivered through different platforms such as music playlists. Although there is some suggestion of positive outcomes in higher human and psychological needs, evidence varies.

- Modest evidence suggests ICT-based social health and participation (TRL: production stage) may be effective in connecting family members with care home residents.
- Virtual reality (TRL: ideas stage) design that involves people living with dementia and carers showed some potential positive outcomes with qualitative evidence.
- Quality of evidence is uncertain for robotics for supporting engagement (TRL: prototype stage), with some suggestions of effects on loneliness, depression, quality of life, reduced agitation and increased interaction and engagement.
- Despite the potential to reduce staff burden and improve engagement with chatbots and socially assistive robots (TRL: ideas stage), evidence on effectiveness is lacking.

C. Technologies used on people living with dementia

- There is some emerging evidence that digital biomarkers (TRL: ideas stage) may facilitate early identification. There is no evidence in real-world settings yet.
- Digital cognitive tests (TRL: validation stage) may have comparable performance to traditional paper-and-pencil tests, although validation data are lacking.
- Activity sensors (wearable, non-wearable, and smart home devices; TRL: prototype stage) have very limited evidence. There are some suggestions of correlation with apathy, agitation, etc., but the validity of their use for early detection has been questioned.
- Location tracking systems (TRL: protocol stage) has some evidence of benefits such as safety and carers' peace of mind. More evidence is needed, and usability and ethical concerns need to be addressed.

Findings on cost and cost-effectiveness

We found very little economics evidence, although (from published protocols) there are clearly a few RCTs underway with well-designed cost-effectiveness components.

The general paucity of economics evidence is partly because some studies are focused on technologies that are still at an early stage in terms of readiness, and so the evaluations are looking at prototypes or small pilots. However, even when full effectiveness evaluations have been conducted in real-world settings, it is surprising that so few include an economics component.

A further complication in looking at the economics evidence is that most digital technologies are developed in the commercial sector and marketed to public and private purchasers. The cost to the health and social care systems (whether public or private), therefore, is the market price plus whatever staff and other resources need to be deployed to initiate and support implementation. Market prices can go up or down, and so too could the cost of the associated resources.

The economic evidence

- There is some old evidence (from 1998) from a public agency perspective-based evaluation that, with a computer system designed to reduce carer social isolation and increase their confidence in decision-making, the cost has increased but led to better carer confidence. However, it cannot be said whether it was cost-effective.
- The video-initiated intervention FamTechCare was more expensive than telephone support, but also generated better improvements in depression and competence. The improvement in carer mental health is, however, likely to have led to a reduction in carer utilisation of healthcare. It consequently underestimates the economic case for this intervention.

- An exploratory study of homecare assistive devices and safety technologies in Finland showed that patients with Alzheimer's disease were able to stay longer in their own home before going into residential or nursing home care, suggesting reduced costs. However, there was no control group, and so no conclusion can be drawn.
- Compared with an internet-based video conferencing support group, an internet-based chat support group is more effective in improving the mental health of carers of people living with dementia. Costs of professional time allocated to supporting video conferencing did not differ from costs for clinic-based services.
- The Telehealth Education Program (TEP) provides education and support for spouse carers of people with moderate-to-severe dementia. Comparing healthcare service use and costs with usual care, TEP produced cost savings of nearly USD3,000 per person over a 6-month period, which may be due to delayed admission. However, several key limitations with the study should be noted, such as a lack of outcome data and costs for the intervention itself.
- The NIHR-funded ATILLA trial did not find better outcomes with an individualised ATT device compared to smoke and carbon monoxide detectors and a pendant alarm. Over 24 months, there was no evidence of cost-effectiveness.

Barriers to scaling up technology

Drawing on our previous study, our new literature review, and our discussions with a few researchers, we highlight here the main barriers:

- Evidence barriers
- Price barriers
- Design barriers
- Trust barriers and preferences
- Awareness barriers
- Individualisation barriers
- Commissioning barriers
- Societal attitudinal barriers
- Staff skills, awareness and attitude barriers

These barriers are not new, nor unique to dementia care. It is the norm rather than the exception that technologies in health and social care, many of which appear promising, face challenges of non-adoption, abandonment, difficulties in scaling up, spread, and sustainability (the NASSS framework).

Conclusions

To address the above repeating story of slow progress in developing digital technology to support people living with dementia and carers, policy direction and strategies should be in place, using NASSS as a framework in prioritising research funding support in digital technology, on top of existing health technology assessment (HTA) criteria of effectiveness and cost-effectiveness of interventions.

Considering the potential evidence on effectiveness, cost-effectiveness, readiness and scalability, digital technologies that appear relatively more promising include mobile, touchscreen, ICT, and multimedia to support daily functioning, meaningful activities, social engagement, and virtual care that involves tailored dementia-care strategies delivered with a co-resident carer. These technologies have two common features:

- deploying/repurposing existing commercial solutions for people living with mild to moderate dementia; and
- in line with current theory and evidence, they emphasise person-centredness, social connectedness and meaningful engagement.

These features lead us to recommend positioning digital technologies in a supportive/enhancing role in the overall development of non-pharmacological care and interventions for people living with dementia, rather than being a standalone strategy.

The main cost drivers in dementia care are family and social care (rather than medical care). Digital technologies that will have better potential to be effective and cost-effective are those that directly target higher-level, human and psychological needs to preserve personhood, quality of life and wellbeing of the person living with dementia and their carers. The *form* of digital technology, when taken out of its care philosophy and application context, is a less relevant aspect of consideration in prioritising resources.

1. AIMS

The request from DHSC was to look at:

> Assistive and care technologies to support people living with dementia at home and in care homes
>
> - What technologies are being used to support independence and safety among people living with dementia at home and in care homes?
> - What are the cost benefits and savings for provider organisations and the NHS of using the technology?
> - What are the barriers to scaling the technology?

It was agreed with the Department that the focus would be on *digital* technology as relevant to the context in England. We interpret 'digital technology' to include mobile health (mHealth), telehealth, telecare, telemedicine, wearable devices, apps and other approaches that use, for example, computing platforms, connectivity, software and sensors for social and health care purposes.

This report summarises findings from a rapid review over a period of a few weeks. We would be happy to discuss any of the contents, and to undertake further work as needed.

The next section sets the policy context and highlights some aspects of dementia and care that are pertinent to any discussion of digital technology. In Section 3, we consider how best to describe these technologies for the purposes of a review of this kind. In Section 4, we describe our methods. In the final three sections we address each of the above questions in turn: effectiveness in supporting independence and safety (Section 5); costs and cost-effectiveness (Section 6); and barriers to scaling technology (Section 7).

2. CONTEXT

2.1 Policy context

This summary of evidence on digital technologies is intended to inform discussions about a new national dementia strategy. It is therefore helpful to revisit previous strategy documents to provide a reminder of the overarching objectives previously espoused for people living with dementia and carers. (The term 'carers' is used to refer to unpaid family members and others who provide support. As noted below, some technologies would obviously be relevant for paid care staff too, sometimes referred to as 'paid carers'.)

The goal of England's first national strategy, *Living Well with Dementia*, was:

> for people with dementia and their family carers to be helped to live well with dementia, no matter what the stage of their illness or where they are in the health and social care system. The vision to achieve this is a simple one, in three parts, to: encourage help-seeking and help-offering…; make early diagnosis and treatment the rule rather than the exception; and … enable people with dementia and their carers to live well … in the community, in hospitals and in care homes (Department of Health, 2009, p.21).

Three years later, the *Prime Minister's Challenge on Dementia* had this 'ambition' for the period to 2015:

> People with dementia, their families and carers have told us what is important to them and what will help them to live well with dementia. They say they want to receive an early diagnosis and timely, good-quality information that will help them make informed choices about their care. They want the treatment and support they receive to be the best for their dementia and life, regardless of whether they are cared for at home, in hospital or in a care home (Department of Health, 2012, p.5).

The most recent national strategy, the *Prime Minister's Challenge on Dementia 2020*, included this statement of intention:

> People with dementia have told us what is important to them. They want a society where they are able to say:
>
> - I have personal choice and control over the decisions that affect me.
> - I know that services are designed around me, my needs and my carer's needs.
> - I have support that helps me live my life.
> - I have the knowledge to get what I need.
> - I live in an enabling and supportive environment where I feel valued and understood.
> - I have a sense of belonging and of being a valued part of family, community and civic life.
> - I am confident my end of life wishes will be respected. I can expect a good death.
> - I know that there is research going on which will deliver a better life for people with dementia, and I know how I can contribute to it.

Informed by these outcomes, our vision is to create a society by 2020 where every person with dementia, and their carers and families, from all backgrounds, walks of life and in all parts of the country – people of different ages, gender, sexual orientation, ability or ethnicity for example, receive high quality, compassionate care from diagnosis through to end of life care. This applies to all care settings, whether home, hospital or care home. Where the best services and innovation currently delivered in some parts of the country are delivered everywhere so there is more consistency of access, care and standards and less variation. A society where kindness, care and dignity take precedence over structures or systems (Department of Health, 2015, pp.5-6).

These policy visions and ambitions – particularly the 'I' statements – provide an obvious reference point for judging the suitability of any digital intervention. Does it, for example, provide people living with dementia and carers with information on options available to them, and support the process of choosing between them? Does it respond to the circumstances, needs and preferences of the individual – especially as those things change over time – rather than force the individual to fit into what the technology requires? Is it usable by people whose cognitive, sensory and other abilities are deteriorating? Does it help them to feel a valued part of family, community and civic life?

Evaluations of technologies are unlikely to have covered every dimension of effectiveness implicit in the 'I' statements. There are anyway additional criteria for assessing technologies at a broader system level. One is cost-effectiveness: are the costs of delivering (and consequent upon) a technology justified by the outcomes it achieves? Is the technology actually affordable given available budgets? Is it available across all groups within society, bearing in mind the *PM Challenge 2020* objective of supporting 'people of different ages, gender, sexual orientation, ability or ethnicity'?

2.2 Dementia context

There are also contextual factors to consider, linked to the nature of dementia and the structure of the health and social care systems in England.

Dementia is a collection of neurodegenerative conditions which generally do not manifest themselves until many years after onset of the illness. The condition is often progressive – symptoms worsen over time – and so needs for care grow over time, although the speed of symptomatic deterioration varies considerably from individual to individual.

The different types of dementia can lead to different symptom clusters, illness progression and associated needs. Alzheimer's disease is characterised by an insidious onset and gradual progression over many years. The key presentation is memory impairment, but other cognitive function such as judgement, visuospatial, and language ability may also be affected (McKhann et al., 2011). The onset of vascular dementia can follow a recent stroke or abrupt/fluctuating, stepwise deterioration of cognition (Roman et al., 1993). People with vascular dementia may present with gait disturbance, falls, personality and mood changes, psychomotor difficulties and incontinence. Dementia with Lewy body (DLB) and frontotemporal dementia (FTD) are two other major types of dementia, with slow onset and progression (McKeith et al., 2017; The Lund and Manchester Groups, 1994). DLB is characterised by fluctuating levels of attention and alertness, visual hallucinations, Parkinsonism and sleep behaviour (McKeith et al., 2017). People with FTD could experience problems in personal hygiene and grooming, lack of social tact, dietary changes, wandering and mannerisms, and speech disorder. Affective symptoms (such as depression, anxiety and apathy) are highly prevalent at all stages of dementia (Leung et al., 2021).

Dementia prevalence and care needs increase with age. In 2019, there were approximately 748,000 older people living with dementia living in England (Wittenberg et al., 2019). As England's population continues to age, particularly in the group aged 85 years and above, the numbers of older people living with dementia are projected to rise to 900,000 by 2025 and 1,350,000 by 2040. The increase will be particularly sharp in the number of people with severe dementia (Wittenberg et al., 2020). While there will be an increase in the number of older persons who are independent, with more such people in the 85 years or older age group, there will also be more people with higher levels of dependency and co-occurring long-term conditions. Most older people in England living with medium or high dependency and dementia will have at least two other co-occurring long-term conditions (Kingston et al., 2018).

These care needs are mainly supported through three systems: healthcare, social care and unpaid care, which may be delivered in partnership with third sector organisations. Within the healthcare system, NHS England's stated aspirations for dementia include 'equal access to diagnosis for everyone', 'GPs playing a leading role in ensuring coordination and continuity of care for people with dementia', 'every person diagnosed with dementia having meaningful care following their diagnosis', and 'all NHS staff having received training on dementia appropriate to their role' (NHS England, n.d.). In *The Well Pathway for Dementia* (NHS England, n.d.), the standards cover prevention, risk reduction, health information, diagnosis, memory assessment, investigation, provision of information, integrated and advanced care planning, liaison, hospital treatments, integrated service, co-ordinated care, palliative care and pain, and end-of-life care, among others. To achieve these, NHS partners with Alzheimer's Society, Public Health England (now the Office for Health Improvement and Disparities), Department of Health and Social Care, the Association of Directors of Adult Social Services, Care UK, clinical commissioning groups, GP practices and other stakeholders.

The social care system is a major provider of support, with public and private expenditure on social care exceeding NHS expenditure. However, the estimated costs of unpaid care are almost as high as those two expenditure figures combined. In 2015, dementia cost £24.2 billion, with £10.1 billion attributable to unpaid care (Wittenberg, Knapp, et al., 2019). The overall cost is projected to rise by nearly 250% in the 10 years from 2015 to 2025; the rise will be particularly sharp for social care costs, at 300% (Wittenberg et al., 2020). These figures emphasise the pivotal roles of family and other unpaid carers, who often have their own health and support needs. Advances in technologies *could* mean that some care tasks that respond to dependency (e.g., monitoring to prevent health or safety hazards) that are often performed by unpaid carers could be replaced (Kingston et al., 2018). Digital and other technologies can therefore potentially support carers as well as people living with dementia.

The common symptoms of dementia – not just cognitive decline, but agitation, anxiety and the other consequences noted above – can seriously complicate the use of some technologies – for example, if a technology needs its battery recharging on a regular basis, or there is anxiety about technology replacing in-person home visits by a community nurse or care worker, or anxiety about 'big brother' watching you with telecare. On the other hand, novel learning experiences with technologies may have positive impact on people living with dementia (Ingebrand et al., 2020), especially when the technology helps to satisfy their social and emotional needs (Goodall et al., 2021). Some carers are themselves older people with low IT literacy, and similar anxiety and resistance may be seen. Variations in IT literacy among people living with dementia and carers could clearly create challenges in ensuring equity in access: there are wide variations in the use of ICT devices such as smart phones, for example (Guzman-Parra et al., 2020).

With these contextual considerations, digital technologies to support people living with dementia and carers could benefit from participatory design, an approach widely adopted in gerontechnology to tailor to the characteristics and preferences of targeted users and thereby promote acceptance (Bouma et al., 2007). However, if there are communication difficulties, developers may find it challenging to involve people living with dementia in the design process (Merkel & Kucharski, 2019), even though they can be meaningfully engaged as co-creators of the digital technology for better individualisation (Goodall et al., 2021).

Digital technologies are purchased, delivered and managed in complex health and social care systems. Many people living with dementia self-fund their social care. Where local authorities support people living with dementia and carers, local policy and spending priorities will have a bearing on available technologies. Since most formal social care services are delivered by non-state providers (most of them in the private sector), decisions on technologies within care settings (e.g., in care homes) are the responsibility of thousands of independent organisations. Another consideration is that family members of people living with dementia may live some distance away and therefore may not be well-placed to support or monitor the use of privately purchased technologies such as smart phones or alarms. Local authorities may not have the resources or skills to be effective managers of technology. We summarise these and other challenges in the 'Barriers' section below.

3. CATEGORISING TECHNOLOGIES

There are many digital technologies already supporting people living with dementia and/or carers. There is also variety in terminology employed to describe them, including telecare, telehealth, telemonitoring, technology-enabled care, mHealth, home monitoring, telemedicine, assistive technology, smart homes and apps.

For the purposes of this review, it is helpful to categorise digital technologies for people living with dementia to understand aims, evidence and potential future contributions. Numerous different categorisations have been suggested or used previously. In every case, the boundaries between categories tend to be blurred, and many technologies straddle two or more categories.

NICE (2018, p.8) offer a useful broad classification of digital health technologies (DHTs) by function, distinguishing three *tiers*, noting that 'the evidence level needed for each tier is proportionate to the potential risk to users':

- Tier A: system impact:
    - *system services*: DHTs with no measurable patient outcomes but which provide services to the health and social care system
- Tier B: understanding and communicating

    - *inform*: provides information, resources or activities to the public, patients or clinicians; includes information about a condition or general health and lifestyle
    - *health diaries*: includes general health monitoring using fitness wearables and simple symptom diaries
    - *communicate*: allows 2-way communication between citizens, patients or healthcare professionals
- Tier C: interventions
    - *preventative behaviour change*: address public health issues like smoking, eating, alcohol, sexual health, sleeping and exercise
    - *self-manage*: allows people to self-manage a specified condition; may include behaviour change techniques
    - *treat*: provides treatment; guides treatment
    - *active monitoring*: tracking patient location, using wearables to measure, record or transmit data (or both) about a specified condition; uses data to guide care
    - *calculate*: a calculator that impacts on treatment, diagnosis or care
    - *diagnose*: diagnoses a specified condition; guides diagnoses.

In this review, we are mainly concerned with Tier C technologies.

Technologies may be targeted on **different people**: some are primarily for people living with dementia and some for carers. Those designed to support carers could include be aiming to help them manage challenges such as physical strain, sleep disturbance, mental health problems, social isolation and loneliness.

Technologies may also be differentiated by **setting**: are they intended for use in an individual's own home, in a congregate care setting such as a residential or nursing home or elsewhere?

Technologies could, in principle, be described by reference to the **underlying clinical symptoms** of dementia – particularly cognition (memory, judgement, visuospatial and language ability), agitation, personality and mood changes and psychomotor difficulties. In fact, few digital technologies currently available *directly* address dementia symptoms.

A second way to categorise technologies is to link them to how those symptoms manifest themselves in terms of needs for treatment, care and support. How do they support people in the **activities of daily living (ADLs)**: functional mobility, personal hygiene, bathing, toileting, dressing and eating? And do they support individuals in the **instrumental activities of daily living (IADLs)**, such as managing finances, managing transportation, shopping, meal preparation, cleaning and maintaining the home, communication and managing medications? Technologies may be designed to reduce risks (e.g., to detect when the gas has been left on or the door unlocked), detect if the person has had a fall, control the physical environment, or provide customised information and advice.

The need for support with ADLs and IADLs will be influenced in part by an individual's expectations and aspirations for how they live their life (including where and with whom) and by any co-occurring conditions. Those needs will likely grow as dementia progresses. Another way to categorise technologies, therefore, is by reference to the **stages of dementia**. This was the approach taken by Lorenz et al (2019) in their mapping review of technology-based tools and services for people living with dementia and carers: they distinguished two stages (mild cognitive impairment to early stages of dementia; and moderate to severe stages of dementia) and seven different 'functions' of technology: memory, treatment, safety, training, care delivery, social and other.

Technologies may be designed because dementia can sometimes affect the way that the symptoms of **co-occurring conditions** are manifested – for example, cognitive decline may affect ability to express or describe pain – or how they should be managed – such as reminders to take medications for those other conditions. A technology may monitor vital signs. This is another potential way to distinguish technologies.

The categorisation that we use to organise available evidence was suggested by Gibson et al. (2016): technologies used 'by' people living with dementia, 'with' people living with dementia, and 'on' people living with dementia. These are not mutually exclusive categories, and are defined as follows by those authors:

1) Devices used **'by'** people living with dementia. These were devices that could be used independently by the person with dementia and were usually supportive and responsive products which helped people in completing their everyday activities in some way, by making activities easier (e.g. medication dispensers), by providing prompts (memory aids; simple signage) or by raising alerts (e.g. reminder alarms).
2) Devices used **'with'** people living with dementia. These were collaborative devices which fostered interaction between a person with dementia and other people or between the person and the technology. In most cases these devices encouraged, supported or enabled communication (e.g. reminiscence aids), or helped a person engage with others through interactive forms of 'play' (e.g. puzzles and games, sensory play).
3) Devices used **'on'** people living with dementia. These devices could intervene in some way in a person's life, but operated without the active or direct participation of the person with dementia. Such products could monitor people's movements or activities, alerting a carer or tele-operator in an emergency (e.g. telecare), could give quick access to a person (e.g. keysafes) or could lessen or prevent the risk of harm from individual (e.g. fall detectors), internal (e.g. gas or smoke alarms) or external sources (e.g. telephone blockers). Although not exclusively so, the majority of these products sought to manage, lessen or mitigate risks to the person with dementia receiving them (Gibson et al., 2016, pp.686-7).

4. METHODS

The useful review by Gibson et al. (2016) offers an overall description of potential and actual technologies, whereas our focus is narrower: we are interested in those technologies that are already in use and have been demonstrated to be effective by reference to outcomes for people living with dementia and/or their carers. Even so, there are already hundreds of digital technologies that could support people living with dementia and/or their carers. There are thousands of published papers, conference abstracts, reports and blogs on these technologies. The World Dementia Council (2021), for example, recently published a collection of 'essays from international leaders in dementia' on digital technologies, although perhaps focusing more on detection and digital biomarkers than on care and support.

Given the short timescale for preparing this report, we could not look at every technology in detail, nor assess every study. We focussed initially on available reviews of the evidence – rapid online searching, checking other reviews – and then looked for any individual evaluative studies published since those reviews stopped searching. The quality of evidence included in the reviews varies, and we have provided some details about the methods of these reviews in Table 1 to facilitate interpretation. We also had discussions with some researchers currently active in the field.

Our forward time horizon for this review was the next five years, as this is the period expected to be covered by the new national dementia strategy.

We have excluded reviews and studies that look at a general population, or even at an *older* population, unless they specifically separate evidence for people living with dementia. There are far too many dementia-specific challenges and other considerations to have any confidence in the relevance of those broader reviews and studies.

4.1 Technology readiness

It is helpful to refer to Technology Readiness Levels (TRLs), first suggested by NASA in the 1970s and developed and adapted many times subsequently. The version reproduced in Table 2 was adapted for a recent EU Horizon 2020 project, CloudWATCH2 (www.cloudwatchhub.eu). Evaluation questions and the designs needed to answer them will differ to some extent from one TRL level to another. At the 'Idea' stage (levels 0 to 3, when initial concepts are being formulated), there is not yet any evidence available and it is highly unlikely that a technology at this stage will emerge to have any meaningful impact on the lives of people living with dementia or carers in the next five years. At the prototype stage (levels 4 and 5), there will only have been laboratory testing and no meaningful implementation in real-world services, let alone any *evaluation*. Again, these are unlikely to be relevant in the next five years. Some digital interventions may never move beyond the 'idea' or 'prototype' stage anyway, because they just do not work.

At the validation stage (levels 6 and 7), there might already be some emerging evidence of efficacy, and – if the barriers to implementation are overcome (see below) – it is conceivable that these technologies could be introduced into health, social care, housing or other systems in England to the potential benefit of people living with dementia and/or carers. (Efficacy here means that there is evidence of performance of an intervention under ideal, controlled circumstances, whereas the need is for effectiveness, which is evidence of performance in the 'real world' conditions.)

Technologies at the production stage (levels 8 and 9) should already be in wide enough use to support full investigation of effectiveness, cost-effectiveness and possibly also system-wide criteria too. Of course, technological development in this area could be quite rapid, suggesting that research designs might need to be nimble and responsive to changing opportunities and contexts, although the generally slow speed of implementation makes that less urgent. Nevertheless, there is an inherent tension between the need for evidence that goes beyond the immediate, short-term outcome or budgetary impacts of introducing a technology and the complication that a technology may have become obsolete (and/or the context within which it is delivered or used may have changed markedly) before the research evidence can be assembled and disseminated.

4.2 Quality of evidence

The quality of available evidence varies widely and, to a degree, is correlated with the stage of development: more recently developed technologies have not yet been subjected to rigorous evaluation. Some studies have worked with carefully selected small samples, or failed to include any controls. Better established, more widely available technologies might have been evaluated in (independently commissioned and conducted) randomised controlled trials (RCTs) or large-sample observational studies. The most robust studies will have used mixed-methods approaches, integrating quantitative and qualitative data and methods (Skivington et al., 2021) to explore real-life experiences of people living with dementia and/or carers and their utilisation (or not) of digital technologies.

It was not possible to carry out a full quality assessment of each of the studies we found, although where there have already been *reviews* of accumulated evidence, the review teams have often provided some quality monitoring. Given the proprietorial nature of most

technologies in this area, it is important to note who funded and conducted the studies, and what conflicts of interest there might be.

When looking at the evaluation evidence, it is especially important to look at interventions in their wider service, economic and societal contexts. They should not be thought of solely in terms of the physical devices that are deployed, since most of them will need organisational and service delivery support underpinned by interactive and non-interactive transmission of digital data. From the perspective of the person with dementia or carer, the impact that technology might have on face-to-face service contacts also needs to be factored in. Indeed, there are a host of contextual considerations to take into account (see 'Barriers' below).

5. FINDINGS ON EFFECTIVENESS

As requested, our review focused on technologies 'to support independence and safety among people living with dementia at home and in care homes'. We were only interested in evidence from good quality studies conducted in contexts relevant to England. Those technologies could, in principle, focus on early help-seeking, diagnosis, treatment or living well with dementia: some technologies have more than one such purpose. We also searched for evidence on the economic impacts of digital technologies with these same aims.

We organise the technologies by whether they are primarily used by, with or on people living with dementia (following Gibson et al., 2016), and include technologies targeted more on carers in the relevant subsections Where we can, we also note Technology Readiness Level (TRL) for each technology.

5.1 Technologies used by people living with dementia

Assistive technology and telecare [TRL 6/7 Validation Stage]

Referring to a combination of digital approaches such as monitored alarms and sensors (Howard et al., 2021), telecare is intended to support people to live independently. An earlier meta-analysis did not find assistive technology and telecare (ATT) effective in delaying care home entry (Brims & Oliver, 2019), although the number of studies included were small (two RCTs).

A more recent RCT, the ATTILA study (Assistive Technology and Telecare to maintain Independent Living At home in people with dementia), explored whether 'a full package of ATT increase the length of time that people with dementia were able to live safely and independently in their own homes, compared to provision of a very basic package?' (Howard et al., 2021, p.888). The study found no evidence of effectiveness in delaying institutionalisation or cost-effectiveness, while there was some evidence suggesting *reduced* self-rated quality-adjusted life years. The trial compared an assistive technology and telecare (ATT) needs assessment (of the individual and their circumstances), followed by installation of ATT devices and response services, with an ATT needs assessment followed by installation restricted to only smoke and carbon monoxide detectors and a pendant alarm (if indicated by the assessment). One of the long-standing and frequently mentioned difficulties in the area of assistive technology (digital or otherwise) is that the technology is not suited to the needs and circumstances of the individual and any other support they may have. One finding of the ATTILA study was of limited fidelity of technology recommendation to the individual needs assessment (Forsyth et al., 2019), which is a common barrier in adult social care in England.

Analysis in the ATTILA study focusing on carer burden and psychological wellbeing (which were secondary outcomes in the RCT) also did not find any benefits of ATT (Davies et al., 2020). In an ethnographic study embedded in ATTILA to understand how and why people

living with dementia and their carers used technology, Lariviere et al. (2021) highlighted the need to consider the changing lives of people living with dementia and their carers in relation to the context of ATT provision. The complex and evolving nature of their care and daily routines shape how ATT devices are incorporated. They also noted that even temporary use of ATT may have an impact on complex care needs and crises, and therefore policymakers and care providers should look beyond engagement and duration of direct response in considering success in uptake or effect.

Virtual care support [TRL 8/9 Production Stage]

Virtual care support is an area with rapid application in response to COVID-19, with evidence on effectiveness and cost-effectiveness awaited. An example is the adoption of Alcove Video Carephones in supporting the NHS Covid-19 response. It is designed to enable vulnerable or isolated people, including people living with dementia, who may have limited access to mainstream technology to participate in virtual consultations with health professionals and other interventions (e.g., rehabilitation sessions, planned reviews). The 'dementia concern' package includes sensors and telecommunication to provide medication prompts, check-ins, and connection to family, friends and an emergency call centre (London Councils, 2021). Some testimonies and case study stories are available online as supporting evidence (Alcove, 2021).

For carers, there is some initial evidence suggesting *possible* benefits of videoconferencing as a platform for support programmes. In a recent Hong Kong study comparing carer support delivered via telephone versus videoconferencing during COVID-19 pandemic, the latter appeared to show better protection of cognition and quality of life in people living with dementia, and carer burden reduction (Lai et al., 2020). These are interesting findings, but the study has limitations: it employed non-randomised allocation for a relatively small sample (n=60) and looked at changes over just a 4-week period. The Hong Kong context is also different from that in England. Consequently, the findings should be viewed with caution.

There is strong evidence from a recent American RCT of a video-initiated intervention, FamTechCare, which provides tailored dementia-care strategies to co-resident carers of people living with dementia. Carers submit video recordings of 'challenging care situations', uploaded to a secure website for review by an interdisciplinary team of dementia care experts (Williams et al., 2019, 2021; Shaw et al., 2020). That team then develops tailored responses which are communicated to carer by telephone. This was compared with telephone support based on carers' retrospective recall ('attention control'): carers received the same support from the multidisciplinary team through weekly scheduled phone calls, but without tailored feedback based on review of video recordings. The control intervention is itself considerably more than carers in England would receive.

This well-conducted RCT compared outcomes and costs between the two groups, with follow-up assessments at 1 and 3 months. There were significant differences between the intervention and control groups (favouring the FamTechCare group in each case) in carer burden, carer depression and carer sense of competence. There were no inter-group differences in carer sleep disturbance, 'desire to institutionalise' or carer reaction to symptoms of the person with dementia (memory, depressive or disruptive) (Williams et al., 2019). A second paper showed that carers receiving FamTechCare were more likely than the control group to find the support helpful and effective. However, carers of people with more severe dementia in the FamTechCare group expressed concerns that the video-recording intruded on their privacy (Williams et al., 2021). The research team also concluded that FamTechCare was cost-effective (Shaw et al., 2020; see Section 6 below).

Applying mobile technologies for self-care and daily activity support [TRL 8/9 Production Stage]

Koo and Vizer (2019) conducted a scoping review of 24 papers that focused on evaluating the effectiveness of mobile technologies in supporting people living with dementia in daily

activities, social interaction, memory, leisure activities, location tracking and health monitoring. (Further details of this and other reviews included in this report are given in Table 1.) Using thematic analysis from the perspective of personhood and human needs, Koo and Vizer found that mobile technologies and Bluetooth earphones were effective in providing support for performing daily activities, by acting as memory aid devices (e.g., providing audio and visual assistance for complex sequential tasks) that are portable and allowing the storing of information for future use. By facilitating recognition of familiar people, providing information about events and aiding in daily tasks such as getting dressed, taking medications and navigating, these technologies could help maintain social relationships, aid communication and autobiographical memory, and support agency, independence, and esteem. However, by mapping the needs fulfilled by these technologies against the hierarchy of needs as defined by Maslow and Kitwood, the authors concluded that current technologies tend to support more basic (physiological and safety) needs, and development is needed in technologies that address higher-level, human and psychological needs to preserve personhood.

In a recent literature review on whether and how people living with dementia can (re)learn to use mobile devices and apps by Kerkhof et al. (2021), all 16 studies included suggested positive learning effects, in a range of training contexts (e.g., effortful or errorless learning) and user characteristics (e.g., dementia severity). However, no firm conclusion can be drawn as the studies reviewed were mainly case studies without a robust experimental design. Again, further details of the design and coverage of the review are given in Table 1.

Prompting and sensing systems [TRL various]

In a recent scoping review that aims to evaluate technology-based promoting systems that enable people living with dementia or cognitive impairment to perform daily tasks (Lancioni et al., 2021), 30 reports were identified between 2010 and 2020. These include (1) context-aware, automatic or (2) mediated computer prompting; (3) teleoperated robot prompting; (4) self-operated augmented reality prompting; and (5) self-operated computer or tablet prompting; and (6) time-based (preset) computer, tablet, or smartphone prompting (see Table 1). The authors concluded that it is difficult to judge the level of readiness for (4), and that (5) and (6) are simper technologies and have a higher level of readiness for application in daily use. They also cautioned that, with most studies lacking a clear experimental design and with small samples, it is not yet possible to draw conclusions on the effectiveness of these prompting technologies to support independence.

The Development of Responsive Emotive Sensing System (DRESS) is an example of a system of mobile technologies used by people living with dementia to help them dress independently. DRESS provided dressing guidance through individualised audio and visual task prompting, by first detecting correct and incorrect dressing behaviours through Microsoft Kinect and then providing the right instructions through an iPad on top of the dresser. Findings from the testing of the technology demonstrated ‘family caregiver acceptability of the proposed system’ and ‘the successful interoperability of the built system’s components’ (Mahoney et al., 2014). Since this 2014 prototype paper, Burleson et al. (2018) have provided initial laboratory evidence of the DRESS prototype’s ability to detect dressing events in healthy participants and suggested this as a viable solution for maintaining independence and privacy of people living with dementia with automated dressing support. Direct evidence in people living with dementia is awaited.

General use of tablets [TRL 8/9 Production Stage]

Lim et al. (2013) explored the extent to which people with early-stage dementia were able to use a tablet computer independently. The in-home tests demonstrated that the majority of participants were able to use the tablet on their own: 48% of participants spent around 24 minutes per day using the tablet without supervision which was used to quantify the positive effect it had on carer relief.

5.2 Technologies used with people living with dementia

Touchscreen technology[2] in care settings [TRL 8/9 Production Stage]

A recent scoping review looked at both qualitative and quantitative reports on the impact of using touchscreen technology-based interventions (e.g., iPad) on supporting social connections and reducing distressed behaviours in care settings such as care homes (Hung et al., 2021; details in Table 1). These interventions include digital memory books, multimedia computer systems (e.g., videos, music) to facilitate reminiscence, game apps and training sessions on how to use videoconferencing tools. Taken together, there is qualitative evidence of these touchscreen technology-based interventions on improving positive engagement (e.g., as evidenced by better eye gaze), and initial evidence (from one quantitative study) of greater improvement in mood and engagement using touchscreen activities over traditional activities.

There is also some evidence suggesting touchscreen-based intervention is more effective than non-touchscreen-based activities (e.g., newspapers and magazines) in reducing distressed behaviours such as agitation and anxiety. There is some before-and-after single-group evidence suggesting positive impact of digital reminiscence and life storybook in reducing depressive mood, improving sense of confidence and self-esteem, and enhancing communication. Challenges noted include reflective glare, internet connectivity, battery life, users' concern over confidentiality, and physical ability to hold the device. However, evidence of this kind is methodologically weak.

While the authors noted great progress in this area since a previous review was published in 2008 (Topo, 2008) in that most of the reviewed studies actively involved people living with dementia in the individualisation process as co-creators, they cautioned against the quality of evidence, with small sample size and lack of standardised outcome measures.

Computer-based/electronic technologies for engagement [TRL 6/7 Validation Stage]

In a recent systematic review of digital technologies designed to create individualised, meaningful activities for people living with dementia (Goodall et al., 2021), 29 studies were identified, covering four areas: reminiscence or memory support, behaviour, stimulation, and conversation / communication (details in Table 1). Activities were delivered through different platforms such as apps, music playlists and social media.

Among these, digital life storybook appears to have a positive impact on autobiographical memory, and Biography Theatre also seems to improve self-identity. Wearable cameras, which take pictures to help people recall their activities during the day, enabled recalling of recent events and improve self-identity, although it is also noted that they potentially create confusion when the person cannot recall any of the events featured in the pictures. The AnswerBoard (public ambient display) and AnswerPad (mobile phone app) devices have positive impact on reducing distressed behaviours.

Part of the scoping review by Koo and Vizer (2019) mentioned above focused on social interaction and leisure activities, such as viewing art on a tablet computer. The authors suggested that mobile technologies could facilitate positive person work, such as play, occupation and collaboration, to fulfil human and psychological needs.

Neal et al (2020) conducted a scoping review to explore the use of technologies in supporting engagement of people living with dementia in care homes. They found six studies that used multimedia computer programmes, which reported positive impact on meaningful

[2] This category includes technologies that overlap with the following category 'Computer-based and electronic technologies for meaningful engagement'. Here the focus is on the *form* of technology (i.e., touchscreen) whereas the next category focuses on the *content* (i.e., meaningful activities) of the technology, which includes but is not limited to touchscreen technology-based activities.

engagement of people living with dementia. It should be noted, however, that while there is some evidence suggesting positive behaviours (e.g., increased human-to-human interaction), one of the studies also noted no difference between technology-supported versus traditional leisure activities.

ICT-based applications to improve social health and social participation [TRL 8/9 Production Stage]

A systematic review from 2017 identified six reports that provided initial evidence from four qualitative studies and a mixed-methods study of the benefit of ICT-based interventions in promoting social health and participation (Pinto-Bruno et al., 2017; see Table 1). Again, the lack of specific outcome measures and studies that were only modest in quality limited the conclusions that could be drawn. In a more recent scoping review by Hung et al. (2021), positive impacts of videoconferencing to connect family members with care home residents were noted, although challenges including physical frailty and cognitive impartment persisted in more recent studies, on top of internet connectivity and acceptance issues by persons living with dementia and care home staff noted in earlier studies (in 2012 and 2014) included in the review (see Table 1).

Virtual reality [TRL 0-3 Ideas Stage]

In a study involving collaborative workshops to explore the initial reactions of people living with dementia and their carers to virtual reality, and to provide in-depth information about how to ensure aesthetically engaging and pleasant experiences, Hodge et al. (2018) engaged a small group of people living with dementia in a scoping workshop, followed by a design and iteration process, and evaluated the designed virtual environment with a dyad. Using thematic analysis, the authors suggested several directions for further development of virtual reality and dementia, including personalisation, using all senses, and making room for sharing. The latter point, in particular, can be interpreted in relation to the finding that participants saw virtual reality as an opportunity to be together in meaningful ways with their loved ones. This is in contrast with the common perception that virtual reality is an isolating experience, as the virtual reality system in this study was by design intended as a talking point and for social interaction. Other themes identified in the study include reports from people living with dementia that virtual reality made them feel ‘foolish and free’ and happy to be sharing a new experience, and the careful design of the virtual reality environment to allow a familiar experience in a new setting.

Robotics for supporting engagement [TRL 4/5 Prototype Stage]

In a scoping review on technologies and engagement, Neal et al. (2020) and found 14 studies where the technology used falls in the category of robotics. Overall, the authors noted conflicting findings, and concluded that meaningful engagement is only possible for people with moderate-to-advanced dementia if the technology focused on facilitating social interaction with other people. While positive effects of robotics were observed – such as serving as a common focus of interest, increasing residents’ awareness of each other and promoting interaction, and more interaction, smiling and laughter – the quality of evidence is uncertain, given a lack of standardised measure of activity, interaction and engagement. There is also the potential ethical issue of infantilisation of older persons living with dementia, negatively impacting on their dignity, depending on how these robotics are being used. Neal et al. concluded that these technologies should focus on promoting human-to-human interactions, while considering individual preferences and person-centred principles.

Abbott et al. (2019) systematically reviewed qualitative and quantitative evidence on the effect of robopets on older adults (including but not limited to people living with dementia) in residential care. Based on their qualitative evidence synthesis, they described positive experiences on resident loneliness, depression and quality of life. There was some quantitative evidence of reduced agitation, with support from the narrative synthesis of quantitative evidence on increased interaction and engagement. However, the authors noted

the currently prohibitively expensive price of some robopets, and that this kind of intervention is not for everyone as some residents may be annoyed, bored or over-attached to the robopet. Importantly, the studies included in the review were noted to be diverse, complex, and of low-to-moderate quality.

A recent systematic review (Chan DKY et al., 2021) similarly provided mixed findings on the effects of robotics on improving distressed behaviours (e.g., agitation) in people living with dementia, with modest or questionable benefits over those of plush toys, and the potential risk of increased hallucinations or delusions. Although there are methodological issues with existing evidence, the possible unfavourable risk/benefit ratio and low probability of cost-effectiveness should be noted.

Chatbots and socially assistive robots [TRL 0-3 Ideas Stage]

Ruggiano et al. (2021) reviewed six chatbot apps targeted on the topic of dementia: one text-based mobile app and five Alexa Skills voice apps. They assessed the quality of these apps by reviewing their features and content. Overall, a lack of evidence-based chatbots with user evaluation is highlighted, but the authors also identify many potential applications of chatbots in dementia care. For example, chatbots may provide treatment management and moral support. For health care systems using telehealth, well-designed chatbots could be a cost-effective way to collect patient data, facilitate patient education, improve engagement with patients, and allocate resources more efficiently. For people living with dementia and their carers – who are known to be at increased risk of social isolation, especially those in long-term care settings – the potential for chatbots has been evident during the COVID-19 pandemic. Integrating chatbots into dementia clinical settings could also potentially reduce the burden on staff by offering vetted information to patients and caregivers, which could reduce calls and questions for clinical staff. These are all *potential* benefits: they have not yet been proven. A key challenge with this technology is developmental needs, including the need for specific pronunciations, and to support diverse populations, such as people who speak different dialects, to ensure acceptability. Another challenge is that people living with dementia might find the disembodied voices to be confusing.

A recent review aimed to identify design trends and applications of social robots and AI voice technology (e.g., ubiquitous smart home speakers) for older persons, including those with dementia. It concluded that there were some promising applications in social and clinical contexts (Lima et al., 2021). As with other robotics, however, there is currently very little robust evidence on efficacy or utility of these conversational systems. There is also limited evidence on long-term compliance, effectiveness in home settings, clinical translation, and implementation in real-world (e.g., home) instead of controlled (e.g., laboratory) environments. The authors of this review also commented on the role of user-centred approaches (e.g., handling communication breakdowns).

5.3 Technologies used on people living with dementia

Digital biomarkers [TRL 0-3 Ideas Stage]

The focus of this report is on assistive and care technologies to support people living with dementia at home and in care homes, but we note here two recent contributions on digital approaches to biomarkers and cognitive testing that may be relevant at the healthcare interface. Digital biomarkers are physiological and behavioural data collected through digital devices; in theory, they allow objective and ecological continuous assessment to detect changes in symptoms (Piau et al., 2019).

In a systematic review, Piau et al (2019) examined the use of digital biomarker technologies for the detection and follow up of people with MCI or mild Alzheimer's disease in home-based settings. Based on 26 included studies, they noted a lack of research in real-world settings, with most of these technologies removed from everyday life experiences. These

technologies can be categorised into four groups, namely embedded or passive sensors, wearable sensors, technological solutions such as games and nondedicated technological solutions such as computer mouse movements. Among these, embedded passive sensors represent a relatively mature area, although the authors concluded that digital biomarkers on a whole is a new research area and there is no evidence of superiority of any of the digital biomarkers.

Apart from continuous assessments for symptom changes in known cases of MCI or dementia, there is some initial evidence suggesting the potential application of digital biomarkers to facilitate early identification of people with cognitive impairment and dementia. In a model using a smartphone/tablet App to engage people in instrumental activities of daily living tasks using augmented reality (the Altoida IADL test), a person's behaviours (e.g., screen touch frequency, reaction time) was used to classify people with neuropathology of Alzheimer's disease and to predict onset of dementia (Buegler et al., 2020).

Digital cognitive tests [TRL 6/7 Validation Stage]

A recent systematic review on the performance of digital cognitive tests for the identification of people living with dementia or mild cognitive impairment showed that most of these tests have performance comparable to traditional paper-and-pencil tests (Chan JYC et al., 2021), although a lack of validation studies was noted.

Activity sensors [TRL 4/5 Prototype Stage]

These are wearable, non-wearable, and smart home devices that are being used to monitor distressed behaviours and medication side effects for early intervention. A case series of these unobtrusive activity-sensing technologies suggested how some everyday activities (e.g., couch usage, number of transitions between spaces, limb movements) can be used as indicators of apathy, agitation, and side effects on bodily movements (Au-Yeung et al., 2022).

In a synthesis review by Husebo et al. (2019), acceptability and feasibility of these sensors for monitoring distressed behaviours and treatment response were evaluated. Half of the studies reviewed provided a proof of concept, and half suggesting validity of temporarily dense data on motion as proxy for behaviours. In an earlier systematic review on the validity of sensor data for detection and early intervention of distressed behaviours (Khan et al., 2018), however, the authors concluded that while actigraphy may be correlated with agitation and aggression, validity of using multimodal sensors to detect such behaviours needs further evaluation.

Location tracking systems [TRL 4/5 Prototype Stage]

Location monitoring services are among the devices which are used **on** and **by** people living with dementia at the same time. Most such devices are mainstream ICTs (mobile phones and computers) and use Global Positioning System (GPS) to position the person with dementia geographically. GPS can also be incorporated in parts of clothing such as belts, especially for people living with dementia. In an early pilot study of use of GPS devices in 33 dyads of people living with dementia and carers, Pot et al. (2012) suggested that the device made people living with dementia feel more independent and their carers less worried, although there seems to be no impact of feelings of role overload. Some GPS devices are provided as part of ATT, although an earlier scoping review (Gibson et al., 2016) found that only three out of 245 local authorities mentioned the devices as part of their service. They also noted the availability of tailored GPS devices, which are more expensive than standardised GPS requiring monthly subscription costs.

Lorenz et al. (2019), in their mapping of technology onto dementia care pathways, noted that some carers reported a sense of freedom and peace of mind by drawing on discussions with people living with dementia about GPS devices. Koo and Vizer (2015) found that, although tracking and locating devices can provide meaningful benefits, there are usability and ethical

concerns. In their more recent review, Koo and Vizer (2019) concluded that location functions with GPS devices can meet safety needs of people living with dementia, as they allow carers to remotely monitor a person's movements, although in the review a key conclusion is the need to safeguard and promote personhood with technologies. Another recent systematic review investigated the appropriateness of using wearable GPS sensors and Internet of Things (IoT) to allow carers to track the location of people living with dementia, to reduce life risks and improve social life (Ray et al., 2019). The authors proposed an IoT-based sensor system to evaluate the effectiveness of such devices in tracking people living with dementia.

Fall monitoring devices

There is a separate paper from OPF PRU that summarises the evidence that technology can reduce falls and fall risk for people living with dementia (Eost-Telling & Todd, 2022). We have not included any details here, but reproduce the conclusion from that paper:

> Although digital technologies have the potential to reduce risk of falls for older people living with dementia and thus help them to live longer in their own home, there is currently not enough good quality evidence to recommend which technology is best placed to do this. Despite the fact that people living with cognitive impairment or dementia have a higher risk of falls, and could benefit from fall prevention technology, they are often excluded from such studies.
>
> Some evidence has shown that people living with dementia can find the use of technology systems unsettling and may become distressed or refuse to use the technology. Therefore, it is paramount that digital technologies for people living with dementia and other cognitive impairments are designed and tested with the end user in mind, preferably through co-design to ensure it meets their needs, and has high usability and acceptability.
>
> Utilising digital technology to enable older people living with dementia to remain independent in their own home for longer, or to prevent falls amongst older people in residential or nursing care, has been posited to improve quality-of-life and provide cost reductions to health and social care support. However, to date there is a lack of robust evidence supporting this, as both effectiveness and cost-effectiveness of technological approaches to fall prevention for people living with dementia have yet to be established. (Eost-Telling & Todd, 2022, p.3).

We would just add one finding from a very recent ethnographic study by Lariviere et al. (2021); this was linked to the ATTILA study summarised above. This found that fall monitoring devices such as pendants or wristbands were often not activated automatically when falls happened. In many cases, the fall monitoring equipment needed to be manually triggered by people living with dementia in case of a fall, which required carers to train them on how to act in case of a fall. Carers are themselves probably not well trained in how to do this. In one of the studied cases, the individual's fall was not automatically reported but she remembered to press the alarm which notified her carer in time and allowed her to receive appropriate care shortly after the fall. It has, of course, long been known that alarm systems are often not used by older people (e.g., Fleming & Brayne 2008).

Personalised multimedia device [TRL 4/5 Prototype Stage]

Davison et al. (2015) tested the effectiveness of a personalised multimedia device to treat agitated behaviour and improve mood in people living with dementia in a small-scale RCT (n=11). The system tested is called Memory and is accompanied by a simplified interface to help people living with dementia access material independently. In 8 weeks, compared with a control condition (equivalent contact with research staff), the system seemed to be able to reduce agitation, and improve symptoms of depression and anxiety. The authors concluded that the system is promising in facilitating improvement in wellbeing and cognitive function in people with agitation. Hung et al. (2018) also reported iPad-facilitated video simulated

presence (VSP) to have positive impact on improving behaviour and mood of people living with dementia in a hospital setting, although over-stimulation with too much video content also seems to trigger anxiety.

Artificial intelligence-based technologies [TRL 4/5 Prototype Stage]

There are multiple definitions of artificial intelligence (AI). The one that is considered most applicable to health and social care (Joshi & Morley, 2019) is that AI is "the science of making machines do things that would require intelligence if done by people" (Minsky, 1968).

Xie et al. (2020) conducted a systematic literature review on 30 papers on artificial intelligence (AI)-based technologies to support dementia carers (details in Table 1). They found that the majority of these studies reported use of AI to assist in daily living activities, but there are also technologies intended for carer education and provide interventions for the person living with dementia. There appears to be some evidence on feasibility and user satisfaction. However, as most of these studies were qualitative and observational with small samples, and because the label 'AI' was used rather broadly, no firm conclusions could be drawn, and the authors of the review called for more systematic designs and evaluations.

In a simulated modelling study, Machado et al (2021) tested the use of context histories from IoT data to generate simulated scenarios and specify a prediction model of distressed behaviours such as aggression and agitation. They concluded that the prediction model has a high accuracy for identifying potentially dangerous behaviours, and provided lessons learned, such as the importance of data on vital signs, especially heart rate, in analysing distressed behaviours.

6. FINDINGS ON COSTS AND COST-EFFECTIVENESS

The second question we were asked to look at was: 'What are the cost benefits and savings for provider organisations and the NHS of using the technology?' We can rephrase the question to clarify the economic issues that need to be considered: What are the direct costs (prices) of the digital interventions? What are the broader costs of their implementation? Does utilisation of an intervention lead to savings? And, if there are no savings, are the outcomes from utilisation of the intervention sufficient to justify the higher costs?

6.1 Availability of economics evidence

We did not find much economics evidence, although (from published protocols) we can see that there are a few RCTs underway in (at least) the UK and Netherlands that have well-designed cost-effectiveness components. These are evaluating exergaming (van Santen et al., 2019), a tablet-based intervention to improve self-management and social participation of community-dwelling people living with dementia (Neal et al., 2021) and e-WHELD, the online version of the effective and cost-effective WHELD intervention in care homes that delivers person-centred using social interaction, personalised activities and exercise to improve care (see Romeo et al., 2019, for cost-effectiveness findings for the non-digital version).

A comprehensive review of the cost-effectiveness of assistive technology to support people living with dementia was conducted by Bowes et al. (2013), looking at technology offered through formal health or social care services, as well as technology for private or personal use. (Some of the material in the report was subsequently included in Dawson et al., 2015, but the focus was rather different.) These authors helpfully offer quality assessments of the studies found in their review. Of the 59 types of studies in the Bowes review, some were not digital interventions and only a small handful had empirical information on costs or cost-effectiveness. We looked at all the studies found by Bowes and colleagues. Those they rated as 'low' quality do indeed look to be inadequate for our purposes. Some were tentative explorations of technology (e.g., in small samples without a control group). Pilot studies at

that time (up to November 2012) appear not to have led to full evaluations, which suggests that the technologies were either never developed to 'production' (or even 'validation') level of readiness or have been rolled out with (reported) evaluation. Given the interval of almost ten years since the Bowes et al. review, it is highly unlikely that any of those interventions have been found to be effective or cost-effective without being picked up by others in searches for evidence.

The general paucity of economics evidence is partly because some studies are focused on technologies that are still at an early stage in terms of readiness, and so the evaluations are looking at prototypes or small (and usually not generalisable) pilots. However, even when full effectiveness evaluations have been conducted in real-world settings, it is surprising that few include an economics component. The recently completed ATTILA study of, which (as described above) found no effectiveness or cost-effectiveness case for the assistive technology and telecare interventions evaluated, is an example of what should be included in an economics study in this area. (That last sentence is written cautiously because the economic evaluation was co-designed by one of us.)

A further complication in looking at the economics evidence is that most digital technologies are developed in the commercial sector and marketed to public and private purchasers. The cost to the health and social care systems (whether public or private), therefore, is the market price plus whatever staff and other resources need to be deployed to initiate and support implementation. Market prices can go up or down, and so too could the cost of the associated resources. (The WSD trials of telehealth and telecare, although not looking at people living with dementia, included comprehensive economic evaluations which endeavoured to adjust for the economies of scale that would likely result from scaling-up outside a trial context; see Henderson et al., 2014.)

6.2 Summary of economics findings

We summarise here the little economic evidence that we have been able to find. We do not think that we have missed anything of importance, but will keep searching. A general caveat to note is that economic evidence from studies conducted outside the UK is unlikely to be immediately transferable to the UK context. This is because there are inter-country differences in the structure and funding of health and social care systems, which could lead to differences in incentives and governance arrangements, which in turn can generate differences in absolute and relative costs of resources and services. In contrast, evidence on effectiveness is less likely to be so context-bound.

An old study by McGuire (1998) evaluated ComputerLink, a computer system designed to reduce carer social isolation and increase their confidence in decision-making. The evaluation was conducted from a public agency perspective (in the United States). The intervention increased cost but led to better carer confidence, but there was no analysis of how these might be traded off, so it is not known whether this intervention would be considered to be cost-effective.

More recently, another carer-focused study found that FamTechCare, a video-initiated intervention, improved the health and well-being of carers compared to regular telephone support. Significant differences were reported in a US trial in terms of carer burden, depression and sense of competence, and carers found the intervention both helpful and effective (Williams et al., 2019, 2021). The RCT included a cost-effectiveness analysis (Shaw et al., 2020), but it only measured the costs of the interventions (FamTechCare and control) and did not look at any of the other services or supports received by sample members with dementia or carers. The video-initiated intervention was more expensive than the telephone support (USD48 per dyad per week greater), but also generated better improvements in depression and competence. The authors then argue that the incremental cost-effectiveness ratio compares favourably with a willingness-to-pay threshold that had

been determined before intervention delivery but provide no details on what that was or how it was arrived at. However, the significant improvement in carer mental health is quite likely to have led to a reduction in carer utilisation of healthcare, as was found in the (non-digital) START intervention for carers in England which also reduced carer mental health problems (Knapp et al 2013, Livingston et al 2014). Consequently, the published analysis almost certainly underestimates the economic case for this video-initiated intervention.

Riikonen et al. (2010) carried out an exploratory study of homecare assistive devices and safety technologies in Finland, looking at 29 different technologies (risk prevention, assistive technology and emergency technology): choice of technology was based on each individual's needs. Costs of devices are reported, and there is a suggestion that the sample members (each of them with Alzheimer's disease) was able to stay longer in their own home before going into institutional care. However, there was no control group, and so no conclusion can be drawn.

Marziali and Garcia (2011) compared an internet-based chat support group with an internet-based video conferencing support group, finding the latter to be more effective in improving the mental health of carers of people living with dementia. Although this Canadian study did not include an economic evaluation, the authors note that the costs of professional time allocated to supporting video conferencing did not differ from time allocated to clinic-based services, and that carers can continue to benefit from these interventions through a mutual self-help format at no cost to the healthcare system.

The Telehealth Education Program (TEP) provides education and support for spouse carers of people with moderate-to-severe dementia in the Veterans Administration system (USA). Wray et al. (2010) examined healthcare service use and costs compared to usual care using an RCT design. TEP produced cost savings of nearly USD3,000 per person over a 6-month period, although these savings were not maintained at the 12-month follow-up. Looking at component costs, the only significant element was nursing home costs, because the intervention delayed admission. Surprisingly, the study appears not to have collected any outcome data. Another limitation is that the study did not include costs for the intervention itself, but, by comparing with similar interventions, the authors argue that inclusion of the intervention costs would not reduce the observed cost savings by more than a small amount.

We have already noted that the NIHR-funded ATILLA trial did not find better outcomes for community-residing people living with dementia if they received an individualised assistive technology and telecare (ATT) device following needs assessment compared to people who received (if indicated by the assessment) smoke and carbon monoxide detectors and a pendant alarm (Howard et al., 2021). Costs were comprehensively measured over 24 months to include health and social care services, costs to the person with dementia and carer (including out-of-pocket payments for home adaptations, ADL equipment and travel to appointments) and opportunity costs of providing unpaid care. ATT costs were a relatively small proportion of the total. 'There was no evidence of cost-effectiveness in terms of days lived in the community, impact on health-related quality of life or QALY … from the health and social care or societal perspective' (Howard et al., 2021, p.887).

7. BARRIERS TO SCALING UP TECHNOLOGY

The final question we were asked to address was: What are the barriers to scaling the technology? In previous work, we identified numerous potential (interconnected) barriers, based on literature reviewing and interviews with a range of stakeholders in the technology, health and care sectors (Knapp et al., 2015). We have not conducted new empirical work for the present report because of time constraints, but we draw on that previous study, our new literature review, and our discussions with a few researchers to highlight the main barriers. In this, we go beyond the kinds of barriers generally discussed previously, which often tend to

focus more on staff and organisational capability, and technical issues such as interoperability (e.g., Institute of Public Care, 2021).

Evidence barriers

For many of the digital technologies being developed there is no evidence yet that they are either effective in enabling people living with dementia and carers to live well or deliver economic gains. This is in part because those technologies are 'too early' in terms of readiness, but there are also technologies at the validation and the production stages for which there appears to be no robust supportive evidence. This is either because they have never been rigorously evaluated (which points to a need for more or better research) or because well-conducted research shows them to be ineffective and/or a waste of money (which points to a need for better delivery/implementation, or abandonment of that specific technology).

Price barriers

The market for technology in dementia care is potentially huge and will grow, given current and projected prevalence and continued heavy reliance on family and other unpaid carers. There are also many different potential technology purchasers. These include NHS and local authority commissioners (public sector), health and social care providers (many in the non-public sectors), community organisations (such as Age UK or the Alzheimer's Society), people living with dementia, carers and family members.

Pricing new technologies at an affordable level – and the interpretation of affordability will vary across and within these purchaser groups – is fundamental to take-up. The development costs of digital technologies may be high, and delivery costs may also be high (especially if monitoring / response back-up is needed) until an economical scale of operation is reached. These are all price barriers to scaling up, at least in the short term, even for interventions that look effective. Current procurement levels may not yet have reached cost-minimising scale for some technologies. Willingness to purchase may also still be low for many older people themselves, but could increase over the coming years with growing IT literacy. However, there is already a wide 'digital divide' (see, for example, Centre for Ageing Better n.d.; Damant et al., 2017); without concerted action, this will continue to exacerbate inequalities (DHSC, 2021).

A related economic issue is the possibility that some monitoring technologies might increase the demand for other services by uncovering previously unrecognised or unmet needs. This is why evaluations need to view technologies in the wider context and, ideally, over a period of years.

Design barriers

Digital technologies need to be designed to be usable by or with people living with dementia and/or older carers whose technological literacy may be modest (linked to negative attitudes towards digital technology perhaps) and whose sensory acuity, manual dexterity and cognition may be deteriorating. Poor broadband or 3G/4G/5G infrastructures in some areas of the country create another kind of 'design' barrier. (The digital switchover in 2025 will mean that some technologies could become obsolete.)

A further design barrier is the potential stigma felt by individuals who are invited to use monitoring services and certain wearable devices: they suggest frailty and dependence. This is why mainstream technologies may be more acceptable, and also why some pendant alarms have been redesigned as brooches, although we are not aware of evidence of effectiveness. Relatedly, intrusive devices and those that require charging every 24 hours may be seen as unacceptable. Technologies that effectively confine people to their own homes because of the need to keep close to a phone/4G signal run counter to the aims of good care.

Another potential barrier is interoperability problems: systems not linking with each other because of proprietary constraints or technical challenges.

Trust barriers and preferences

Some older people are not only less familiar with digital technology – it is not part of everyday life – and so more suspicious of it when suggested at a time when they are beginning to struggle with ADLs or IADLs and are looking for support. They may be distrustful of online services, fearing (with good cause perhaps) identity theft, abuse of personal information and financial exploitation. They may worry about privacy and personal security.

Some technological developments are aimed at enhancing the personal connections between staff and people living with dementia, rather than replacing them, although this is not how they may be perceived or experienced. This is linked to resistance to the use of some telecare or telemonitoring devices: for example, people with care needs perceive them as leading to reduction in in-person contacts with health and social care staff (see Sanders et al., 2012, and Lariviere et al., 2021, for example). Many people living with dementia and carers are already socially quite isolated. A linked reason is that some older people may feel that any reduction or denial of personal contact is denying them access to services to which they feel entitled (after a lifetime of National Insurance contributions).

Awareness barriers

We noted above that the market for digital technologies has a range of potential purchasers, but few may be aware of what works, or be hesitant about direct-to-consumer marketing, especially given the above concerns about digital security. Even the organisational purchasers (public and private) may not have a clear idea about what is and is not acceptable to potential users, effective in improving outcomes or cost-effective (overall or to their own budgets).

Individualisation barriers

A key challenge is the policy aim of ensuring that treatment and care for people living with dementia and support for carers responds to their individual needs, circumstances and preferences. Digital technologies will generally be more effective if tailored to individual needs and they will likely have their greatest wellbeing benefits if they respond to individual preferences. Developing technologies that are responsive in these ways makes sense but is probably more costly (fewer economies of scale, for example) and more risky. It also requires careful assessment and matching, yet health and social care staff may not have sufficient knowledge or time.

Commissioning barriers

There are very wide variations across the country in access to publicly funded digital technologies, with different local authorities and NHS bodies having different policies or priorities, and different providers making their own decisions about what services to offer to secure public contracts or self-funded customers. Whether these variations are acceptable depends on one's views about devolved decision-making, local democracy and social care funding models.

A further barrier to commissioners providing greater access to digital technologies for people living with dementia and/or their carers may be the upfront demand on staff time and budgets, as has occurred with some other service changes. Local authorities might find it challenging to make resources available or to employ extra staff to assess people for digital assistive technology, purchase the technology, teach people how to use it and respond to any queries or problems from technology users.

Another commissioning barrier is linked to budget silos. There may be savings from wider use of a digital technology, but if those savings do not flow to the organisation or individual

expected to pay for the technology then the financial incentive may be insufficient. Integrated care systems and cross-budget compensations are still some distance from reality. (See Knapp and Wong, 2020, for wider discussion of these economic barriers, and some solutions.)

Societal attitudinal barriers

There remain widespread negative, stigmatising attitudes about dementia. Awareness of the condition is far better today than in the past, but it is not yet obvious that technology developers or providers see people living with dementia (or indeed older people in general) as a sufficiently high priority to overcome the other challenges of digital support.

Staff skills, awareness and attitude barriers

There are many aspects to this final barrier. Health and care professionals might be unaware of possible digital solutions or see them as inappropriate ('too difficult') for people living with dementia. Or those staff may not have the necessary skills, confidence, attitudes or time to support the use of digital technologies. Some staff might see digital or other technologies as a threat to their jobs. It is not obvious who the professional 'champions' are for digital interventions in the dementia area. The recent NHSX review of digital skills in the adult social care sector (Blake et al., 2021) explores these issues in considerable detail, although not specifically looking at people living with dementia. The Institute of Public Care (2021) highlighted lack of resource to invest in technology or train staff; lack of leadership from employers and managers; and workforce resistance to using digital technology or staff not having the necessary skills.

8. CONCLUSIONS

Most of the above barriers are not new, nor are they unique to dementia care. It is the norm rather than the exception that technologies in health and social care, many of which appear promising, face challenges of non-adoption, abandonment, difficulties in scaling up, spread, and sustainability (NASSS) (Greenhalgh et al., 2017). The first step in developing digital technology for dementia care to overcome these issues is a clear picture of the levels of complexity surrounding key domains that affect what Greenhalgh et al. refer to as NASSS.

Our main conclusions are:

- There is clearly a lot of work underway to explore how digital technologies might contribute to supporting independence and safety for people living with dementia in their own homes and in care homes. Much of this is still at an early stage of readiness.
- Many of these technologies do not ever reach a stage of readiness that makes it possible to evaluate whether they contribute to better outcomes for people living with dementia or carers, at least outside the unreal environments of the laboratory.
- This is a repeating story. It is unclear whether efforts to develop technologies pay enough attention to the potential for adoption and scalability. Many of the barriers discussed above are especially challenging in the context of dementia care.
- There remains disappointingly little robust evidence of effectiveness or cost-effectiveness, with many studies being too small, too short or too poorly designed to be able to generate findings that can be generalised to a wider context.
- Although things are changing, there is still a lot of room for improvement in terms of involvement of people living with dementia and carers throughout all the stages of technology development.

To address the above repeating story of slow progress in developing digital technology to support people living with dementia and carers, policy direction and strategies should be in

place, using NASSS as a framework in prioritising research funding support in digital technology, on top of existing health technology assessment (HTA) criteria of effectiveness and cost-effectiveness of interventions.

Considering the potential evidence on effectiveness, cost-effectiveness, readiness and scalability, digital technologies that appear relatively more promising include mobile, touchscreen, ICT, and multimedia to support daily functioning, meaningful activities, social engagement, and virtual care that involves tailored dementia-care strategies delivered with a co-resident carer. These technologies have two common features:

- deploying/repurposing existing commercial solutions for people living with mild to moderate dementia; and
- in line with current theory and evidence, they emphasise person-centredness, social connectedness and meaningful engagement.

These features lead us to recommend positioning digital technologies in a supportive/enhancing role in the overall development of non-pharmacological care and interventions for people living with dementia, rather than being a standalone strategy. As such, while independence and safety – the main outcomes of interest for the current review – are important, they represent intermediate points or means toward the end of addressing 'higher-level needs' of enhancing personhood and quality of life.

This position will also help put in context a key finding of the OPF PRU rapid review on fall monitoring devices: alarm systems may reduce fall risk but at the same time be 'unsettling' for people living with dementia. The technology per se does not determine its effectiveness and cost-effectiveness, but whether and how it is applied to facilitate or hinder achievement of better quality of life and wellbeing is key.

The main cost drivers in dementia care are family and social care (rather than medical care). From the best economics studies in this field, we also know that the cost of technology itself is a relatively small proportion of the total. Taken together, digital technologies with the greatest potential to be effective and cost-effective will be those that directly target higher-level, human and psychological needs to preserve personhood, quality of life and wellbeing of the person living with dementia and their carers. These should be prioritised. The *form* of digital technology, when taken out of its care philosophy and application context, is a less relevant aspect of consideration in prioritising resources.

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Table 1: Overview of Recent Review Studies Included in this Report

Author	Topic/Objectives	Type of Review	Methods	Remarks on quality of evidence
Abbott et al., 2019	To synthesise research focussed on the experiences and effects of pet- or animal-like robots (robopets) in older adult residential care settings	Systematic review	• Data source: MEDLINE, EMBASE, PsycINFO, SPP, CINAHL, AgeLine, CDSR, CENTRAL, DARE, ASSIA, Web of Science Core Collection, SCOPUS and ProQuest Dissertations and Thesis Global with no date or language restrictions; forward and backward citation chasing of included article • Time frame: from earliest available dates to 2018 • Included studies: 19 (10 qualitative, 2 mixed-methods, 7 randomised trials) • Report standard: Enhancing Transparency in Reporting the Synthesis of Qualitative Research (ENTREQ) guidelines and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines	Authors noted paucity of evidence on sustainability of robopets, but suggested that future, cheaper robopets may allow more robust research
Chan DKY et al., 2021	To assess the evidence of digital technology in fall prevention and management of BPSD in long-term care facility	Systematic review	• Data source: MEDLINE, EMBASE, Scopus, Web of Science, PSYCINFO • Time frame: 2000 to 2020 • Included studies: 17 papers (8 RCTs, 8 quasi-experimental, 1 mixed-methods) • Report standard: PRISMA; Downs and Black checklist	Authors noted small sample sizes, heterogeneity in methodology including measurements and varied outcomes limited meaningful conclusion. Only 9 out of 17 studies were of good quality
Chan JYC et al., 2021	To evaluate the diagnostic performance of digital cognitive tests for MCI and dementia in older adults	Systematic review	• Data source: OVID databases of MEDLINE, EMBASE, PsycINFO, PubMed • Time frame: from earliest available dates to 2020 • Included studies: 56 observational studies (23 head-to-head comparison of a digital version versus traditional paper-and-pencil test) • Report standard: Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and guidelines from the Cochrane Diagnostic Test Accuracy Working Group	Authors noted 5 studies with high risk of bias on participant selection, 3 high risk on index test execution, 2 high risk on reference standard execution, 13 high risk in patient flow and timing presentation
Goodall et al., 2021	To identify and explore types of digital technologies used in creating	Systematic review	• Data source: CINAHL, Embase, PubMed, and Scopus • Time frame: 2005 or later • Included studies: 29 reports (12 qualitative,13 mixed-methods, 4 quantitative). Majority (12) were case studies; only 2 RCTs; remaining field trials and explorative	Authors noted small sample sizes and lack of standardised outcome measures

Author	Topic/Objectives	Type of Review	Methods	Remarks on quality of evidence
	individualized, meaningful activities		• Report standard: PRISMA	
Hung et al., 2021	To summarise existing knowledge about the impact of touchscreen tablets in social connections and distressed behaviours in care settings	Scoping review	• Data source: MEDLINE, AgeLine, Cumulative Index to Nursing and Allied Health, Cochrane, PsycINFO and IEEE; Google for grey literature • Time frame: 2009 to 2019 Included studies: 17 articles (all designs including quantitative, qualitative, small feasibility pilots, user experiences) • Report standard: scoping review guidelines developed by the Joanna Briggs Institute	No assessment on quality of evidence
Husebo et al., 2019	To synthesise research on sensing technology to assess distressed behaviours and to monitor treatment response	Systematic review	• Data source: Embase, Medline, Cochrane library and Web of Sciences • Time frame: up to 2019 • Included studies: 34 studies; majority (11) cross-sectional, 5 case series, 5 feasibility studies, 2 qualitative, 2 RCTs, 2 longitudinal, 1 case-control, 1 mixed-methods, 1 retrospective database • Report standard:	Authors noted majority of the studies included were open-label early-stage studies
Kerkhof et al., 2021	To identify which training interventions work best to help people with mild dementia (re)learn how to use technologies including touchscreen devices	Literature review	• Data source: PubMed, APA PsycInfo (EBSCO), CINAHL (EBSCO) • Time frame: up to 2020 • Included studies: 16 studies (3 RCTs, 2 quasi-experimental, 11 case studies) • Report standard: Higgins and Green	Authors noted that many studies included were single-case studies and the need of more robust study designs such as RCTs to evaluate the effectiveness of training interventions
Koo and Vizer, 2019	To provide an overview of the current research on mobile technologies through the lens of personhood and human needs	Scoping review	• Data source: MEDLINE, Web of Science, PsycINFO, CINAHL, EMBASE, CENTRAL • Time frame: unspecified, presumably up to 2018 • Included studies: 24 articles. Individual study designs not reported but include case studies and untested prototype • Report standard: unspecified	No assessment on quality of evidence
Lancioni et al., 2021	To review studies that evaluated technology-based prompting	Scoping review	• Data source: PubMed, PsycINFO, Web of Science, IEEE; and Google Scholar “cited by” search • Time frame: 2010-2020	Authors noted that no definite conclusions about effectiveness can be

Author	Topic/Objectives	Type of Review	Methods	Remarks on quality of evidence
	systems for supporting people living with dementia or acquired cognitive impairment in performing multistep daily tasks		• Included studies: 30 studies (including 14 experimental) • Report standard: PRISMA-ScR	formulated due to small sample sizes and a lack of clear experimental designs in many of the studies included
Lima et al., 2021	To review design trends and current applications of conversational affective socially assistive robots for ageing and dementia support	Qualitative review with a horizon scanning of AI voice technology for healthcare	• Data source: "scientific publication databases such as IEEE, Xplore, ACM, PubMed, Google Scholar" • Time frame: 2000-2021 (for conversational robots); 2015-2021 for voice assistants and smart speaker technology • Included studies: 30 studies on human-robot interaction using distinct conversational robots; including questionnaire surveys, interviews, and observational studies • Report standard: n.a.	Authors noted that majority of studies reviewed had small sample sizes (defined as n=6-20), short-term exploratory trials, not conducted in real-world environments
Neal et al., 2020	To investigate the use of computer-based and electronic technologies for enhancing meaningful engagement of adults with dementia living in residential aged care	Scoping review	• Data source: Ageline, AMED, CINAHL, Cochrane Database of Systematic Reviews, Embase, Medline, OT Seeker, PsycINFO and Scopus • Time frame: 2008-2018 • Included studies: 20 studies, including 12 quantitative, 5 mixed-methods, 2 descriptive, 1 qualitative • Report standard: Arksey and O'Malley 2005	No assessment on quality of evidence; authors noted narrow definition of engagement as interacting solely with the technology as a limitation
Piau et al., 2019	To review the evidence for real-life, home-based use of technologies for early detection and follow-up of MCI or dementia, and to investigate what transformation might clinicians expect in their everyday practices	Systematic review	• Data source: PubMed, Cochrane, and Scopus • Time frame: up to 2018 • Included studies: 26 observational studies, including 10 comparative • Report standard: PRISMA	Authors noted a lack of home-based, real-life evaluations

Author	Topic/Objectives	Type of Review	Methods	Remarks on quality of evidence
Pinto-Bruno et al., 2017	To assess the utility of ICT in promoting social health and active ageing in people living with dementia	Systematic literature review	• Data source: PsycInfo, PubMed, CINAHL with full text and Scielo • Time frame: up to 2016 • Included studies: 10 studies (4 qualitative) • Report standard: Critical Appraisal Skills Programme (CASP) guidance	Authors noted that the methodical quality of the studies reviewed was poor, and the need of high-quality research with specific outcome measures
Ruggiano et al., 2021	To identify the types of current commercially available chatbots that are designed for use by people living with dementia and their carers and to assess their quality in terms of features and content	Systematic review	• Data source: Google Play Store, Apple App Store, Alexa Skills, and the internet • Time frame: 2019-2020 • Included studies: 6 chatbots • Report standard: Radziwill and Benton (2017) framework for evaluating chatbots	Authors noted the need of more evidence-based chatbots that have undergone end user evaluation to evaluate their potential
Xie et al., 2020	To identify and examine literature on AI that provides information to facilitate dementia management by cares	Systematic literature review	• Data source: PubMed, Cumulative Index to Nursing and Allied Health Literature Plus with Full Text, PsycINFO, IEEE Xplore Digital Library, and the ACM Digital Library • Time frame: presumably up to 2019 • Included studies: 30 papers (majority qualitative, followed by cross-sectional surveys with small convenience sample) • Report standard: PRISMA	Authors noted a low level of evidence in all of the studies reviewed due to small convenience sample (ranging from 6 to 106) and exploratory/descriptive nature. They called for more systematic designs and evaluations of the feasibility and efficacy of AI-based interventions for carers.

Table 2: Technology Readiness Levels

0	**IDEA**: Unproven concept, no testing has been performed.	IDEA
1	**BASIC RESEARCH**: You can now describe the need(s) but have no evidence.	
2	**TECHNOLOGY FORMULATION**: Concept and application have been formulated.	
3	**NEEDS VALIDATION**: You have initial 'offering'; stakeholders like your slideware.	
4	**SMALL SCALE PROTOTYPE**: Built in a laboratory environment ('ugly' prototype).	PROTOTYPE
5	**LARGE SCALE PROTOTYPE**: Tested in intended environment.	
6	**PROTOTYPE SYSTEM**: Tested in intended environment close to expected performance.	VALIDATION
7	**DEMONSTRATION SYSTEM**: Operating in operational environment and pre-commercial scale.	
8	**FIRST OF A KIND COMMERCIAL SYSTEM**: All technical processes and systems to support commercial activity in ready state.	PRODUCTION
9	**FULL COMMERCIAL APPLICATION**: Technology on 'general availability' for all consumers.	

Adapted by the CloudWATCH2 project (www.cloudwatchhub.eu)

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