

Original Research Article

Technology and Dementia: The Future is Now

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Keywords

Technology · Dementia · Aging · Big data · Policy

Abstract

Background: Technology has multiple potential applications to dementia from diagnosis and assessment to care delivery and supporting ageing in place. **Objectives:** To summarise key areas of technology development in dementia and identify future directions and implications. **Method:** Members of the US Alzheimer's Association Technology Professional Interest Area involved in delivering the annual pre-conference summarised existing knowledge on current and future technology developments in dementia. **Results:** The main domains of technology development are as follows: (i) diagnosis, assessment and monitoring, (ii) maintenance of functioning, (iii) leisure and activity, (iv) caregiving and management. **Conclusions:** The pace of technology development requires urgent policy, funding and practice change, away from a narrow medical approach, to a holistic model that facilitates future risk reduction and prevention strategies, enables earlier detection and supports implementation at scale for a meaningful and fulfilling life with dementia.

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Introduction

Smartphones and tablets have opened up personal computing to many new audiences and have created increasing interest in how such devices can be used across all aspects of our lives and society. Similarly, wearables, smart home systems (e.g., Amazon Alexa, Google Home Hub), robots, virtual reality (VR), artificial intelligence (AI) and autonomous (i.e., driverless) vehicles are triggering questions about how we can deliver better services, create efficiencies and improve wellbeing, including for those living with dementia. Although research applying technology to dementia has only recently gained mainstream attention, work has been taking place alongside biomedical and health informatics research for many decades. This article produced by members of the Alzheimer's Association Technology Professional Interest Area Executive Committee introduces the main areas of technological focus in dementia and implications for the future. Our views of where technology is going are informed by our direct experience of working with people with dementia with past and present technology.

Diagnosis, Assessment and Monitoring

The longest-standing use of technology in dementia is in assessment. Two touchscreen-based cognitive assessment batteries – Cambridge Neuropsychological Test Automated Battery [1] and Examen Cognitif par Ordinateur [2] were developed in Europe in the 1980s and 1990s. More recently multiple web-based and app-based cognitive assessments have emerged [3] including digitized versions of pen and paper tasks, such as clock drawing [4] including a digital clock-drawing pen [5]. In addition, the manner in which people use technology and changes in their patterns of use has been identified as an early indicator of emerging cognitive impairment [6, 7]. Technological assessment of functional activities extends to tasks such as making tea and toast [8], coffee-making [9], as well as instrumental activities of daily living [10].

In terms of dementia diagnosis, there have been increasing applications of various machine learning approaches, most commonly with imaging data for diagnosis and disease progression [11]. This includes amyloid PET imaging [12], MR imaging [13] and combined PET and MR imaging [14]. Non-imaging studies have generally focused on demographic data and cognitive measures [15], although more recent studies have utilized novel linguistic analysis [16] and unobtrusive monitoring of gait patterns over time [17].

The use of big data in dementia research has also recently emerged. The Big Data for Advancing Dementia Research project initiated by the G8 Health Ministers to explore the use of big data in dementia research, concluded that big data could potentially accelerate dementia research and technology development by helping recognize factors that contribute to dementia, identifying individuals with dementia earlier, promoting better support for dementia care and creating new analysis methods (e.g., data mining) that could result in new research opportunities [18]. Examples of data mining in dementia include working with large, pre-existing data registries and health records to investigate co-morbidities with dementia and other diseases [19], combining different data sources including fluid biomarkers and MRI [20] and Alzheimer's disease drug repositioning [21].

Maintenance of Function

Ongoing monitoring using technology has the potential to both detect progression of dementia over time [22] and to provide prompts and support to individuals to maintain their activities [23]. In 2007, Carrillo et al. [24] identified a gap in knowledge around the delivery of digital prompts, specifically, how best to prompt, what to prompt or when to prompt. A body of work has emerged addressing prompting with Cognitive Assistive Technologies [23]. For example, the Cognitive Orthosis for Assisting aCtivities at Home (COACH) [25] system was created to prompt people with dementia to take them through the hand washing procedures.

COACH combines computer vision for tracking the current stage of activity with AI techniques to decide what prompt is required to deliver verbal and visual prompts when people wash their hands. This highly influential work has informed many subsequent systems and led to the notion of “zero effort technologies” [26], which require little or no effort from the people who use them. Zero effort technologies perform the collection, analysis and application of data about the user and/or his/her context using advanced computing techniques, such as computer vision, sensor fusion, decision-making and planning, machine learning and the Internet of things (IoT). Recent work focusses on integrating models of identity and emotion into prompting systems to make them easier to integrate seamlessly into people’s lives [27].

Other examples of Cognitive Assistive Technologies combine sensors with AI and machine learning embedded in living environments to create “smart homes,” which can detect and analyse health [28] and other events. These first emerged in the late 1990s and have evolved to address the needs of people with dementia, informal (family) caregivers, formal (clinical) caregivers and social (i.e., nonmedical) caregivers [29]. The Gloucester Smart Home [30], an early prototype for individuals with dementia coupled bath and cooker monitors with an automated nightlight, item locator and digital message board to provide visual and verbal prompts such as “time for your medication.” More recent examples leverage advances in sensor technology, AI and machine learning to support cooking [31], dressing [32] and reduce demands for caregiving [29]. In addition, smart home technologies are becoming available for individuals to install themselves [33], creating huge potential for conducting scalable clinical trials at home [34, 35].

The availability of cloud computing allows dementia researchers and practitioners to utilize powerful computing resources without the need for specialized computing backgrounds. The result is that research is less expensive and faster to produce results. For these reasons, many novel research projects investigating cloud-based solutions to dementia care, treatment and diagnosis have recently emerged. Examples include supporting aging-in-place and activity monitoring [36], providing location tracking [37], and supporting analysis and interpretation of neuroimaging data [38].

Leisure and Activities

Supporting social and leisure activities is another area of technological focus in dementia. Musical memory is relatively spared in dementia [39] and multiple technology projects have leveraged this including the one-button radio [40], simple music-making interface [41] and collaborative music making [42]. Enjoying art has also led to programmes such as House of Memories¹, an interactive art installation for care homes [43], making art as an enjoyable pastime [44] and a more focused art therapy programme [45, 46].

Participating in activities outside the home remains important for persons with dementia. Navigation and route-finding can, however, become challenging and numerous technological solutions have been developed to support these activities [47] and enable “safe walking” [48, 49]. Smart phones with GPS and map functions, offer functionality to support wayfinding [50], including identifying indicators of disorientation to support navigation prompting [51]. For those who have difficulty getting out or participating in regular exercise, virtual cycling [52] and navigating virtual environments [53] can offer enjoyable alternatives.

Socialising is another key activity that people want to do that is important for their well-being and maintenance of cognitive function. CIRCA (Computer Interactive Reminiscence and Conversation Aid) [54], a multimedia touchscreen application promotes social interaction which benefits caregiving relationships [55] and improves cognition and quality of life of people with dementia [56]. Socialising through storytelling has been demonstrated with

¹<http://www.liverpoolmuseums.org.uk/learning/documents/house-of-memories-evaluation-report.pdf>

“StoryTable” (de Waag Society) [57], and remote socialising with family and friends using videoconferencing technologies (e.g., Skype, FaceTime) increases positive emotions [58] and reduces agitation [59].

Games and other digital pastimes have also been widely explored [60], with both bespoke, for example, Eldergames [61], Living in the Moment [62] and consumer products (e.g., gaming consoles, tablets) utilised for people with dementia. The potential of digital activities for brain training either to reduce dementia risk has attracted much popular attention. However, while there is consistent evidence of improvement in the aspect of cognitive function that is trained (e.g., processing speed), to date there is no substantial evidence for dementia prevention or delaying decline [63]. However, the FINGER trial has demonstrated that computerised cognitive training can be beneficial in reducing dementia risk as one part of a multidimensional lifestyle intervention [64].

From a leisure and pleasure perspective, mainstream mobile applications can be accessible for people with dementia [65] and motion-based gaming systems (e.g., Nintendo Wii and Xbox Kinect) can provide enjoyable group activities [66]. VR for dementia has also attracted recent attention [67], not just as a leisure activity, but also an assessment tool [68] and for delivering cognitive training [69]. The potential of VR and augmented reality, so-called mixed reality technologies, to support people with dementia in everyday activities, is currently being explored [70].

Caregiving and Management

Caregiving is another key target of dementia technology. While the potential of robots to complement or even replace human caregivers has attracted much recent attention, research has been underway for many years (e.g., [71, 72]). Recent projects have coupled social presence robots with remote monitoring using sensors and videoconferencing (via tablets) to deliver “virtual visits” [73]. Other robotics-based applications that have been explored for persons with dementia include supporting food preparation [25], eating [74] and participation in recreational activities [75] in care homes.

Supporting informal caregiving (e.g., [76–78]), and delivering care remotely (e.g., [79, 80]) are major challenges that can be addressed at least in part through dementia technology. Across the world, the majority of people with dementia live at home cared for by family members [81]. This caregiving activity represents approximately USD 1 trillion per annum [81] and takes a greater toll on caregiver mental and physical health than caring for other conditions [82]. Unsurprisingly, a large part of caregiver Internet use relates to the demands of caregiving and managing their own health [83]. Despite a large amount of Internet-based interventions being developed and launched for caregivers, there is lack of systematic, large-scale studies examining their efficacy [84]. Further, research that unobtrusively assesses caregiver burden is in the early, but promising, stages (Thomas et al., this issue [95]).

In terms of care management, the IoT facilitates the connection between items in the real world and computer systems, providing data more easily, efficiently and economically. IoT in dementia research [85] includes early detection through in-home sensors [86], wearable monitoring [87] and integration of devices for healthcare management [88].

Future Scoping

Future directions in dementia therapy are predicted to include nanotechnology either to “repair” brain damage [89] or for drug delivery [90]. While there are still many obstacles to resolve, work on nanoparticle and implantable therapeutics to locally deliver chemotherapy for treating brain tumours [91], opens up huge possibilities for delivering new types of interventions for people either with dementia or ideally, before dementia develops. New means of

data collection, ubiquitous monitoring technologies, population surveillance, data mining and modelling may all play a key role in accelerating the development pipeline of preventive therapeutics for dementia.

Discussion/Conclusion

Alongside the rapid pace of innovation, policy and practice move much more slowly. To maximise the current and future benefits of technology for dementia, urgent change is needed in services and policies. This includes radically rethinking what people with dementia need in order to live with this condition now and in the future, and how this is going to be provided. Continuing to view dementia as purely a clinical matter addressed with medication and, to a limited extent direct healthcare, is no longer an option as it fails to address the majority of concerns, needs and wishes of people with dementia in their everyday lives. Existing technology can collect prospective data, model risk and provide supportive monitoring. Mainstream devices have the potential to empower people with dementia in many activities and pursuits; however, adoption rates remain low, in part due to lack of awareness or challenges in accessibility (including financial) and support. Harnessing the power of everyday (i.e., off the shelf) technologies raises major questions about funding and finance, not only in insurance-based healthcare systems, but also in publicly funded systems, as many consumer devices (e.g., smart phones) are not classified as medical devices and therefore cannot be “prescribed” by clinicians. While specific software, such as cognitive assessments could be so classified, the use of standard functions of a smart device for maintaining social interaction (through calls, texts, videoconferencing) or cognitive stimulation (through playing games) may not be classified as a medical intervention.

Expanding our view of dementia beyond healthcare can be understood as akin to physical and intellectual disabilities that influence all aspects of a person’s life. Taking this view as a starting point, policies are needed that provide people with dementia and their caregivers access to devices, services and other tools to live as well as possible with their condition. This includes creating direct funding streams for technology, providing maintenance and updating support services, delivering new types of digitally enabled services with tech-savvy staff for people with dementia, harnessing big data to predict patterns of need and proactively identify people at risk, and supporting rapid development, testing and deployment of next-generation technological interventions. Supporting the technology-enabled provision of preventive and care interventions also requires a number of ethical issues to be addressed, including privacy, data ownership, sharing and usage, risk, rights, responsibilities and relationships (including data sharing) between private corporations and statutory bodies [92, 93].

With the current research and commercial technology, we have the tools to tackle many of the perceived problems currently associated with dementia. First, technology can be used to target lifestyle factors that are associated with the risk of developing dementia [94]. For those who are diagnosed with dementia, providing them with technology (e.g., apps, wearables, smart home systems), from the point of diagnosis we can monitor the progression of their condition, identify problems emerging, deliver interventions and avoid unnecessary emergency admissions and hospital stays. Such technology can also provide prompts and reminders both within and outside the home to support maintenance of cognitive, social and physical functioning as well as continued completion of daily activities. Technology can also contribute both directly and indirectly to caregiving, reducing demands on families and formal services, which are major contributors to the economic costs of dementia.

Statement of Ethics

The authors have no ethical conflicts to disclose.

Disclosure Statement

The authors declare that they have no conflicts of interest to disclose.

Author Contributions

A.J.A. drafted the article, N.B., J.H., A.L., C.N., A.M., and J.M.R. all contributed to the development of the concepts and revised the manuscript.

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