Chapter 9
Prospective Memory Failure in Dementia: Understanding and Designing to Support

Laura Ramos, Laurie Miller, and Elise van den Hoven

9.1 Introduction

The increased prevalence and awareness of dementia is driving interest in design for people affected by the condition. This is generating a more nuanced understanding of user needs and contexts, and an interest in looking into the support of prospective memory. Prospective memory allows us to follow through on a future intention; examples include remembering to attend an appointment, take medication at a particular time or buy milk on the way home. For people with dementia, progressive loss of prospective memory function hinders their ability to follow through with everyday tasks. This, in turn, erodes functional independence and results in increased reliance on caregivers or technological aids. Losing the ability to remember following through on some tasks can pose potential risks to their health, safety and well-being. For informal caregivers, juggling additional tasks can contribute to the daily stressors that drive caregiver burden. Loss of memory and autonomy and the transition to

L. Ramos (✉)
School of Computer Science, Faculty of Engineering and Information Technology, University of Technology Sydney, Ultimo, Australia
e-mail: Laura.L.Ramos@student.uts.edu.au

L. Miller
Neuropsychology Unit, Royal Prince Alfred Hospital and University of Sydney, Camperdown, Australia
e-mail: Laurie.Miller@sydney.edu.au

E. van den Hoven
School of Computer Science, Faculty of Engineering and Information Technology, University of Technology Sydney, Ultimo, Australia
e-mail: Elise.VandenHoven@uts.edu.au

Department of Industrial Design, Eindhoven University of Technology, Eindhoven, The Netherlands

Duncan of Jordanstone College of Art and Design, University of Dundee, Dundee, UK

R. Brankaert and G. Kenning (eds.), *HCI and Design in the Context of Dementia*,
Human–Computer Interaction Series,
https://doi.org/10.1007/978-3-030-32835-1_9

dependency in relationships can have further emotional impacts on caregivers and people with dementia.

Therefore, we need to find better ways to support prospective memory among people with dementia. The effectiveness of such support may depend on a wide range of factors including relevance, timeliness, ability to attract attention and suitability to context, as well as individual preferences and control. Although research on design to support dementia is expanding rapidly, specific research on design relating to prospective memory is still relatively new.

This chapter provides an overview of the growing body of research on the design of systems to support prospective memory for people with dementia and their caregivers. It begins with a brief overview of prospective memory function, as well as impacts in older age and among people with cognitive impairment and their caregivers. There are multiple technical and non-technical interventions to support prospective memory; of these, assistive technologies to provide reminders for daily activities have been surveyed in multiple reviews (Ienca et al. 2017; Jamieson et al. 2014; Lorenz et al. 2019; Tulving 2007). In this chapter, three systems that focus specifically on supporting prospective memory for people with dementia (*COGKNOW* (Boer 2010; Davies et al. 2009; Mulvenna et al. 2010), *Robin* (Carroll et al. 2017) and *Living Well with Anne* (de Jong et al. 2018) have been identified; in addition, the *Multi-MemoHome* project (McGee-Lennon et al. 2011, 2012) has focused on the design of a home-based reminder system for a wide range of users, including people with disability, older people and caregivers of people with dementia. A brief exploration of research on support for caregivers has highlighted that reminder systems should coordinate the dual needs of those receiving and providing care adaptive to various situations. Flexibility in how reminders are entered, integrated with other activities and presented is particularly relevant for people affected by dementia. This is due to the progressive nature of the condition, with needs changing over time. Findings point to future directions for research to support people with dementia and their caregivers with prospective memory in everyday living.

9.2 Prospective Memory and Its Impact on People

Multiple aspects of human memory function have been mapped in memory research (Tulving 2007); one type of memory—prospective memory (PM)—is required to remember to take action in the future. PM is often described as remembering of future intentions or delayed intentions (Kvavilashvili and Ellis 1996). Following through with an intention in the future requires remembering events experienced or information learned in the past; the ability to remember things learned in the past is referred to as retrospective memory. PM incorporates retrospective memory, in that one needs to be able to remember what was learned in the past to carry out an intended future action.

PM is critical in everyday living. It is required to perform a wide range of tasks. PM includes both one-off and habitual tasks and plans that are meant to be carried out

around a specific event (event-based) or at a specific time (time-based) (McDaniel and Einstein 2007). Remembering to buy a present for a loved one after going to the hairdresser is an example of an event-based PM; taking medication at a specific hour or paying a bill on time are examples of time-based PM. A meta-analysis of literature on PM among people with mild cognitive impairment and dementia (van den Hoven 2014) confirmed a clear degradation in their ability to carry out both event-based and time-based PM tasks. Reminders to take action may be useful for both event-based and time-based PM, but the nature of that prompt (e.g. a to-do list, a post-it note, an alternative physical reminder or an alarm) is likely to differ depending on whether the action is to be carried out in association with an event or at a certain time. Hence, there may be a need to adapt aspects of different solutions to meet different situations.

Ageing is not always associated with a decline in PM. The evidence on the extent to which PM is impacted by age is mixed, as some older adults have developed excellent strategies and routines to support PM in everyday living (McDaniel and Einstein 2007; Radford et al. 2011). However, memory complaints (including those related to PM) in older people have been associated with lower perceived quality of life and impaired ability to conduct activities of daily living (Montejo et al. 2012).

Research focusing on everyday memory failures (Kliegel and Martin 2003; Ramos et al. 2016; Terry 1988) has found that PM failures are the most frequent type of memory complaint across age groups. Whilst there is only limited research on the affective impacts of declining function in PM, there is some evidence in the literature. First, a study exploring how older people perceive everyday forgetting (Ramos et al. 2016) found that they tended to perceive these failings negatively, but sometimes responded with humour, suggesting their use of humour as a coping mechanism. Second, Lorenz et al. (2019) include a blog post by a person with dementia expressing frustration about alarm noises in her home that might have once been useful; this is because she could no longer associate the noise with the action that it was meant to prompt. The actual blog post includes some additional experiences and ends with the words 'LOL What a day !!! [sic]' (Truthful Loving Kindness 2015).

People with mild cognitive impairment and early dementia experience a clear degradation in PM function, compared to people with no diagnosed memory impairment. This extends to both event-based and time-based PM across multiple studies on PM (van den Berg et al. 2012). In addition to deterioration in memory function, people with dementia commonly experience difficulties with vision and hearing (Cronin-Golomb 2004; Wayne and Johnsrude 2015), which can result in environmental cues being missed or misinterpreted.

PM errors were found to be more frequent than retrospective memory errors among people with dementia (Smith et al. 2000). It also found that carers of people with dementia were more frustrated by PM failings of care recipients than other types of memory lapses, indicating how PM failures might contribute to stress for caregivers. Although a range of factors can impact caregiver burden in the context of dementia, burden could be reduced through tactics and tools to manage forgetting for the person with memory impairment (Miller et al. 2013).

Declining PM function in people with dementia impairs their ability to live independently, sustain health and maintain social connections. Between 70 and 80% of

people with dementia in the United States live in the community (Brodaty and Donkin 2009). As a result, most people supporting someone with dementia are informal caregivers, often spouses, partners, family members and friends who juggle caregiving with other responsibilities. Although there are positive aspects in providing care, the strain of physical, psychological, social and financial impacts of caregiving are well documented. The prevalence and contexts of care and support for people with dementia highlight the need to find better ways to manage and support PM.

9.3 Technical and Non-technical Interventions for PM Support

Along with the growing awareness about the impact of dementia on individuals and their communities, the range of interventions to support cognitive abilities has also increased. These include drug treatments and cognitive-training interventions. However, recent reviews (Bahar-Fuchs et al. 2019; Fink et al. 2018; García-Casal et al. 2017) found limited evidence of positive effects from these approaches on cognitive function in people with dementia.

Interventions to support memory function have focused on retrospective memory, such as systems and therapies to assist people with dementia in reminiscing (De Vreese et al. 2001; Huber et al. 2019). Memory support for wider audiences has included design for *augmented memory systems* (van den Berg et al. 2012). Although these have yielded some positive outcomes, the interventions mentioned in those studies do not specifically address PM.

One study focused on *implementation intention* strategies to support PM for older people with and without mild cognitive impairment (MCI) (Shelton et al. 2016). This consisted of learning to associate a cue with an intended action by verbalising it (e.g. saying that 'if I *see* that it's 4 pm, then I will take my medication'). The study found positive results of the strategy in a laboratory setting where older people with and without MCI went through the Virtual Week task. Whilst researchers acknowledged the importance of PM function in real-world settings, the study had some limitations relating to its relevance outside the lab. In particular, participants were assessed on tasks that might not reflect how they manage PM in their day-to-day lives.

When it comes to PM function, most solutions for people with memory impairment rely on external memory aids rather than mnemonic strategies like implementation intention. The most easily available memory aids are paper-based tools, including notebooks, diaries and calendars. Their use is noted in multiple studies (McGee-Lennon et al. 2011; Ramos et al. 2016). Memory aids designed for people with memory impairment are increasingly relying on digital technology and systems. Some people with cognitive impairment can still learn how to use commercially available memory aids such as calendars and reminders on mobile handheld devices; however, this may not be possible for people with more severe impairment. The MEMOS system (Thöne-Otto and Walther 2003) was designed to support people

with severe head injury and their caregivers to manage PM tasks. The system proved slightly more effective than commercially available systems in a small trial; this was attributed to greater flexibility in handling tasks and a requirement to confirm task completion (Walthe et al. 2004).

The number of published studies focusing on assistive technologies to support PM among people with dementia has grown significantly since the early 2000s (Ienca et al. 2017). One study (Oriani et al. 2003) found that, among people with mild to moderate Alzheimer's disease, using an electronic memory aid was more effective for helping them to remember to perform a series of tasks than using a written list of the tasks to be performed. That system allowed users to voice record a task reminder and associate the task with a particular time; it then generated an audio prompt at the assigned time. Still, the system was limited to time-based reminders and was evaluated only within a laboratory environment.

Researchers working on robotics to assist older people in an institutional care setting have developed software to handle scheduling and follow through of daily tasks (Pineau et al. 2003). As part of this work, the *Autominder* software was integrated in a trial robot to provide reminders and increase awareness of scheduled tasks to minimise growing dependency on nursing home staff (Pollack et al. 2003). This work was designed to provide cognitive support for older people and their formal carers in a nursing home setting. *Autominder* is one example of a broader range of cognitive assistant systems that provide assurance, guidance and assessment of tasks in care (Pollack 2005).

More recent research has honed in on more granular features. A systematic review of literature on *cognitive prosthetic technology* for people with memory impairment (Jamieson et al. 2014) noted the emergence of micro-prompting devices. This refers to systems that position prompting on a specific action and place. An example of this is the *COACH* system to remind people to wash hands in the bathroom (Mihailidis et al. 2008). The increased availability of wearable technologies and electronic sensors creates opportunities for new ways of imagining micro-prompting systems. Resulting applications of these technologies might take the form of a jacket that provides navigational directions that the user would sense whilst wearing it or a doormat that receives weather information and issues a reminder to household residents to take an umbrella, because it is going to rain (Uhlig et al. 2018). Systems can also track activity that could be integrated into other reminder systems. One example of this is a wearable device that can sense whether the user had brushed their teeth adequately to encourage better dental care among older persons (Cherian et al. 2017).

9.3.1 Home-Based Systems for People with Dementia

There is a clear opportunity to apply new technologies to serve people with dementia, so that they can maintain well-being and independence whilst living at home. The *COGKNOW*, *Robin*, *Living Well with Anne* and *MultiMemoHome* projects support PM for that purpose.

The *COGKNOW* project built on prior research on cognitive prosthetics and electronic memory aids to support PM in people with cognitive impairment (Mulvenna et al. 2010). The project team focused on four key areas to improve quality of life for people living with dementia—remembering tasks, facilitating social contact, engaging in enjoyable activities and safety. The researchers applied participatory design methods in group workshops in Amsterdam, Ireland and Sweden. In each workshop, 5 or 6 older people with mild to moderate cognitive impairment due to dementia discussed how a new system could help them to improve autonomy and quality of life. The ideas generated in the workshops were synthesised ideas into a series of functional requirements. The resulting *COGKNOW Day Navigator* system consisted of a stationary 17-in. touch screen device connected to a desktop computer and a handheld portable device with a 2.8-in. screen. The system included a door sensor in the participant's home and a server that allowed caregivers to enter schedules and reminders for participants remotely. System components were connected via home-based and mobile networks. The system was tested in field trials in the homes of 16 participants (Davies et al. 2009). Video of the *Day Navigator* showed how a user engaged with the touch-screen device to receive reminders inside the home and with the handheld portable device to help her navigate outdoors (Boer 2010). Project researchers evaluated the user-friendliness and usefulness of the *COGKNOW* Day Navigator, as well as the product's effectiveness in supporting memory, increasing social contact and safety, and the evaluation yielded mixed results (Meiland et al. 2012). Although people with dementia reported that the product was easy to use and easy to learn, researchers noted that users with dementia had to be reminded how to use the system repeatedly, and that around half of the reminders were ignored when there was no researcher present. Users reported minimal difference in their perceived quality of life, sense of autonomy and ability to cope with their dementia after trialling the system (Meiland et al. 2012). Hence, results from this research suggest that the system may not be effective in terms of fully compensating for declining PM. However, the system can be useful to support well-being by reminding people with dementia to engage in enjoyable activities and social contact; it can also provide some relief for caregivers. In addition, more time for teaching the use of the device might be necessary. Given that alarm cues were found to be often ignored, exploring how to make these more attention-grabbing or more information-rich might be useful.

The *Robin* system (Carroll et al. 2017) used existing technology to support people with mild to moderate dementia. Based on feedback from experts and carers three use cases were identified for PM support by *Robin*—where an intervention is necessary (e.g. medication reminder), when guidance is required so a user can complete a task, and where quality of life for the person with dementia could be improved (e.g. suggesting an enjoyable activity). The designers created new functions on a commercially available voice-controlled assistant (Amazon Alexa), so that users could receive appropriate reminders. Whilst this is a novel use of a more recent and relatively low-cost commercial technology, the lack of involvement of people with dementia in the design process and limited evaluation data cast doubt on the potential effectiveness of the system in assisting with PM.

More recently, the *Living Well with Anne* project (http://livingwellwithanne.eu) has been developing a system to support both people with dementia and their caregivers using a virtual agent and machine learning algorithms on a tablet device. The system also relies on sensors around the home of the person with dementia. The system features easy-to-read daily schedules, supported by a virtual agent with a conversational interface. The system provides several advantages to paper-based calendars by incorporating reminder prompts and feedback mechanisms, as well as the voice-activated assistant to support system usage. Similar to the *Robin* project, the design was informed by engaging professional and informal carers; however, research participants have raised the need to adapt the system to maintain usability during different stages of dementia. In this way, the project is significant in that it considers how the system can remain accessible to people with dementia as their needs and abilities change over time (de Jong et al. 2018). As the product is in the early stages of development, there is limited evidence of potential effectiveness.

Whilst these studies are deliberately oriented to supporting PM needs of people with dementia, the *MultiMemoHome* (*MMH*) project demonstrates the complexities of meeting user needs in a real-world setting. Researchers used mixed methods (questionnaire, focus groups, and home tour interviews) to explore over a year the development of a multimodal reminder system for at home (McGee-Lennon et al. 2012). The system was designed for multiple age groups and people of different abilities, for caregivers as well as people receiving care. Although there were no participants in the *MMH* project with major cognitive impairment, the research included a broad range of older participants, some of which had memory problems. The researchers considered the needs of informal caregivers and acknowledged the potential for user needs changing in response to declining cognitive ability (McGee-Lennon et al. 2011).

By focusing on the home setting, researchers on the *MMH* project explored the importance of place and physical characteristics of memory aids that participants used in everyday life. Researchers identified what types of activities participants needed reminding about, what memory aids they employed to help them remember, and different user preferences for and expectations about reminder systems (McGee-Lennon et al. 2011). They found that the memory aids could be grouped into five categories: (1) Paper artefacts, such as diaries or calendars; (2) technology or manufactured items, such as digital calendars or alarms; (3) integrated into daily routines or an external schedules, such as using the timing of a radio programme to follow through on a separate action; (4) interactions with other people, thereby relying on others to provide a reminder and (5) physical placement of objects around the home, for example, placing an item by the door to remind the person to take action related to the item.

Whilst users reported different preferences to the modality of the reminder (e.g. visual or audible prompts), the majority of users (83%) reported that they would prefer receiving reminders from multiple devices throughout the home (e.g. on their mobile phones, desktop computer and on screens placed in the hallway or kitchen). The research identified user expectations of an effective reminder system, including adaptability, ability to personalise and the need for reminders to be discrete in the household. It also illustrated the challenges of balancing competing demands

to address user diversity, context, task urgency, autonomy, shared spaces and optimal care (McGee-Lennon et al. 2011). Later work in the *MMH* project focused on whether synthetic speech could provide reminders that could be easily understood by older people who might have age-related hearing impairment that could impact comprehension (Wolters et al. 2014). Whilst this is a very specific aspect of usability, it shows the extent to which designers need to carefully consider how users engage with a system.

The *COGKNOW*, *Robin*, *Living Well with Anne* and *MMH* systems are examples of PM support within the home and in independent-living settings. The systems are not for the exclusive use of people with cognitive impairment; multiple parties may need to be involved with the creation of and follow through with reminders. As a result, these systems aim to cater for a very wide range of abilities, needs and expectations. It is worth noting, however, that these systems are often not relevant for people in more advanced stages of cognitive impairment who require ongoing assistance from caregivers for daily activities.

9.3.2 Systems to Support Caregivers with Everyday PM Support

Researchers exploring design for caregivers are also finding opportunities to support PM. Two studies focusing on caregiver needs highlight memory support as a shared function between caregivers and care recipients. This places increased strain on the caregiver and creates new design challenges.

Research exploring the needs of caregivers (Chen et al. 2013) used semi-structured interviews with carers to understand their experiences in caregiving. They found that as caregivers spend more time attending to tasks to support the person who needs care, balancing tasks related to their own lives created increasing stress for the caregiver. The researchers identified a need to cater for personal as well as caregiving activities. An integrated care system could include prompts to remind caregivers to take time for self-care activities or to seek other supports to manage stress related to caregiving. By suggesting integrated management of everyday personal and caregiving tasks with reminders to practice self-care, Chen et al. (2013) opened an innovative approach to design for PM among caregivers.

In Europe, a case study of the TOPIC (The Online Platform for Informal Caregivers) project highlighted the use of ethnographic methods to generate a nuanced understanding of the information and communication needs of informal caregivers (Schinkinger and Tellioğlu 2014). The authors noted how non-technological tools, such as paper-based calendars and whiteboards, were used frequently for task coordination between caregivers and care recipients in home settings. They used culture probes to surface a wide range of technologies that caregivers relied upon to provide informal care tasks, including smart watches, healthcare recording and distributed scheduling systems. The researchers identified the need to integrate data from these

various systems in a common platform that would be available to informal and formal caregivers. The need for coordination of caregiving tasks among family members as dementia progresses has also been noted in a recent review of multiple technologies to support people with dementia and their carers (Lorenz et al. 2019). The TOPIC case study further found that an integrated platform for caregivers would need to be easily accessible in the home setting, support multimodal interactions (e.g. voice, text and touch) and would also need to respect privacy.

Although these studies did not focus exclusively on caregivers of people with dementia, they are very relevant for that context in two ways. First, most people with dementia live at home and will require increasing levels of care over time from informal caregivers (Brodaty and Donkin 2009). As part of this, caregivers will manage more tasks for and on behalf of the care recipient. Transitioning that responsibility to caregivers would require shared and visible access to reminders, whilst somehow giving the care recipient a sense of privacy and control (Schinkinger and Tellioğlu 2014). In addition, whilst caring for a person with dementia contributes to higher levels of stress for the caregiver (Chiao et al. 2015), systems that support caregivers should acknowledge the complexities and context of providing care. This might require helping the caregiver schedule and manage personal tasks, including self-care, more easily and intuitively (Chen et al. 2013).

9.4 Involving People with Dementia in Design Practice

Researchers have been applying a range of methods and practices to engage with people with dementia, as well as with their formal and informal carers, throughout the design process. Participatory design and co-design practices have been used widely to learn and share expertise about what should be included in design (Vines et al. 2013). Understanding user needs and developing solutions for them has been done through various formats (interviews, focus groups, group workshops and home tours) (Bourazeri and Stumpf 2018; Chen et al. 2013; McGee-Lennon et al. 2012; Schinkinger and Tellioğlu 2014). In addition, researchers have co-designed personas with people with dementia and Parkinson's disease to explore technology choices and evaluate prototypes (Bourazeri and Stumpf 2018). Research to develop an assistant for people with dementia that leveraged mobile phone technology (Mayer and Zach 2013) has found that personas can be useful to encourage people with dementia to express concerns that they may be reluctant to mention if they were speaking about themselves.

The design of systems to support people with dementia is relatively new. As a result, there is still limited research on how to involve people with dementia in design and research practices to understand whether their needs are being met. Research from Gibson et al. (2016) specifically focused on identifying which established usability testing methods (questionnaires, *think aloud* protocol and observation) provided the greatest amount of user feedback to support system evaluation. They found that observation of task completion (including completion rate and time spent on

task) was a more reliable measure of effectiveness than questionnaires or relying on the *think aloud* protocol. People with dementia might have difficulty understanding questions and verbalising their thoughts; however, they can still engage with new systems with adequate support and their behaviour can be observed and assessed. Further research to develop methods to assess emotional impacts of system use is required.

A common concern across these studies is how to involve individuals with dementia in a meaningful and respectful way throughout the design process, whilst working within constraints imposed by cognitive impairment and the increased reliance on caregivers. Researchers will need to continue adapting design practices to the specific context and need of the research. A sensitive and tailored approach to design practice will be essential when working with both people with dementia and their carers (Hendriks et al. 2014; Lazar et al. 2017; Lindsay et al. 2012)

Another critical perspective on designing for people with dementia (Madjaroff and Mentis 2017) challenges the notion of memory impairment as a problem to be fixed with technology. This is because the use of technology among people with cognitive impairment could be impacted by the relationship with caregivers, as well as physical context and individual preferences. One of the researchers who worked on the *MMH* project (Wolters 2014) reflected that people make active choices and combine multiple strategies to remember; these strategies build in physical, sensory, digital and non-digital cues to prompt PM. As they do this, they also factor in other people within their environment—and possibly the strategies that these other individuals use. In trying to create a supportive system, designers may be layering complexity on an already complicated environment.

The notion that PM challenges can be solved with technology points to an underlying tension in the research in this area. Much of the research reviewed here that new technology-based systems and interventions can provide a better substitute to the existing analogue or offline solutions, as well as existing digital systems for mass market audiences. Critically assessing this assumption is not without merit: there is ample evidence that traditional reminder systems can fail and cause frustration (McGee-Lennon et al. 2011, 2012; Ramos et al. 2016; Truthful Loving Kindness 2015). To date, however, new systems in this area (Carroll et al. 2017; Davies et al. 2009; García-Casal et al. 2017; Jamieson et al. 2014; Mulvenna et al. 2010; Oriani et al. 2003) have produced relatively limited benefits for users in memory function or overall well-being and quality of life. The challenges of engaging with people with dementia in research to understand their perceptions in relation to new systems have also been noted (Gibson et al. 2016; Hendriks et al. 2014). This might prompt questioning the value of researching and designing new solutions to support PM. However, growing numbers of people and communities require better options to enjoy life with the day-to-day realities of dementia. This already involves a range of technologies to support reminding, prompting and overall PM. And continuing this line of work to make these more accessible, useful and relevant, and finding new angles of support through research and design is therefore necessary.

9.5 Conclusion: Lessons Learned for Future Design Research

There are at least two reasons to continue our effort in design to support PM in everyday life for people with dementia and their caregivers. First, there is a growing body of research with increasing relevance to this area, evidenced by reviews on electronic memory aids (King and Dwan 2017), intelligent assistive technology (Ienca et al. 2017) and technologies that map the dementia care pathway (Lorenz et al. 2019). Second, there is a continued willingness to engage with people with dementia and with their caregivers throughout the design and delivery process—and to share learnings to support further work (Bourazeri and Stumpf 2018; Hendriks et al. 2014; Lindsay et al. 2012; Madjaroff and Mentis 2017; Mayer and Zach 2013). Increasing maturity in methods to engage users across the design, development and evaluation cycle will result in a better understanding of the diversity of user needs and contexts, including the complexities of designing for changes in cognitive ability and increased dependency on caregivers over time.

Overall, it is early days for research to design technology to support PM for people with dementia and their caregivers. A review of research on electronic memory aids to support PM in people with dementia (King and Dwan 2017) found that many studies featured technology solutions that were in an early stage of development, and that this posed issues for evaluating those systems. This also extends to a lack of research on designs that adapt to changes in perception and cognition of people with dementia. The same review also found limited evidence of improved outcomes for users, such as improvements in quality of life or in the ability to carry out activities of daily living. Furthermore, a separate review (Lorenz et al. 2019) noted that technologies to support memory have been primarily developed for people with mild cognitive impairment and early dementia and that their use was intended in the home, rather than residential care environments.

Future research will need to address the progressive and degenerative nature of dementia and increasing caregiver responsibilities over time (King and Dwan 2017). More exploration of changes in the motivations, needs and expectations of people with dementia and their caregivers as cognitive function degrades is critically needed. This will also require further iteration of design over longer timeframes, design of more mature systems, management of increased technical complexity, and establishing the boundaries of where technology can support in this context. This points to four opportunity areas for future research on design for PM and dementia.

First, changes in cognitive ability and perception that people with dementia experience (Chiao et al. 2015; Smith et al. 2000; Wayne and Johnsrude 2015) deserve further research. Following through on an intended action requires scheduling or sequencing an action, prompting at the right moment and supporting in the execution of that action (Pollack et al. 2003; Pollack 2005). However, people with dementia do not always respond or understand prompts (Lorenz et al. 2019; Meiland et al. 2012). Scheduling, sequencing, prompting and supporting functions could be tailored to the changes in individual ability and perception. This might mean personalization of

alarm formats to suit changes in visual and auditory perception, increased guidance on the steps required to complete an action and reassurance on the execution of the intended task. However, not all of these may be required; the user should have the option to choose how much support is needed. Future work should also consider monitoring effectiveness of more personalized reminders.

Second, future research should consider the shifting of responsibilities between people with dementia and their caregivers as the disease progresses. As people with dementia face declining PM function (Smith et al. 2000), informal carers will be increasingly responsible for task scheduling and follow through (Lorenz et al. 2019); formal, paid caregivers may also play a part in this (Schinkinger and Tellioğlu 2014). This results in various opportunities to design reminder systems that support collaboration among people with dementia and informal and formal caregivers. The idea of distributed remembering among couples has been noted in prior research (Harris et al. 2014); this could be extended to a shared PM function. This would require flexible access and privacy controls so that the person with dementia could share and transition scheduling management to a caregiver or other support person. It could also provide better ways for caregivers to manage increasing workloads over time—a requirement previously noted (Chen et al. 2013). Prior research (King and Dwan 2017; Lorenz et al. 2019) has noted the need for design that adapt to the progression of dementia. Longitudinal research is needed to assess changing user needs and the effectiveness of technology solutions over time.

Third, reminder management will require balancing of complex user requirements and interconnected technologies with the need for simple and practical solutions for PM support in the real world. The need for reminders manifests in different places and contexts. This may include interfaces and connectivity across devices and integration into other systems to cater to the different contexts, as well as increasing use of sensors to track actions that prompt a reminder or the execution of an intended action. This is in line with a view of future assistive technologies to support people with dementia in the home that calls out use of assistive robots, biometric sensors, multimodal interactions, augmented reality and intelligent smart home technology (Zanwar et al. 2018). However, the feasibility and viability of technological solutions are critical. For example, the *Autominder* project (Pineau et al. 2003) featured robotics and sensor technologies that supported the scheduling management software; the complexity and expense of the system put it outside of the reach of everyday users. In contrast, the *Robin* project (Carroll et al. 2017) focused on low-cost, commercially available voice-activated technology. Handling increasing technical complexity whilst maintaining ease of use, providing users with a sense of control, ensuring security and managing obsolete system components will be an ongoing topic of research. Furthermore, research should include more evaluation of these technologies as they mature into more robust solutions.

Lastly, there is an opportunity to explore the limits of technology in addressing the needs of persons dealing with declining PM function due to dementia, either as caregivers or recipients of care. Commenting on medication adherence, past research (Wolters 2014) has noted that reminder systems can bring an undesirable level of

complexity, because people already rely on multiple mechanisms to support remembering in everyday life; the best option for them may be to receive a *minimal dose* of technology support. This seems particularly relevant to people with dementia and their carers, who may already be dealing with overwhelming change. Clearly, further work is needed to design more appropriate solutions to help individuals adapt to declining PM function and maintain well-being when it is no longer possible to remember to follow through with an intended action unaided.

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