Neuropsychological Rehabilitation

An International Journal

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/pnrh20

Remind Me To Remember: A pilot study of a novel smartphone reminder application for older adults with dementia and mild cognitive impairment

Katherine Hackett , Sarah Lehman , Ross Divers , Matthew Ambrogi , Likhon Gomes , Chiu C. Tan & Tania Giovannetti

To cite this article: Katherine Hackett , Sarah Lehman , Ross Divers , Matthew Ambrogi , Likhon Gomes , Chiu C. Tan & Tania Giovannetti (2020): Remind Me To Remember: A pilot study of a novel smartphone reminder application for older adults with dementia and mild cognitive impairment, Neuropsychological Rehabilitation, DOI: 10.1080/09602011.2020.1794909

To link to this article: https://doi.org/10.1080/09602011.2020.1794909

Published online: 20 Jul 2020.

NEUROPSYCHOLOGICAL REHABILITATION
https://doi.org/10.1080/09602011.2020.1794909

Routledge
Taylor & Francis Group

Check for updates

Remind Me To Remember: A pilot study of a novel smartphone reminder application for older adults with dementia and mild cognitive impairment

Katherine Hackett [a], Sarah Lehman[b], Ross Divers[c], Matthew Ambrogi[a], Likhon Gomes[b], Chiu C. Tan[b] and Tania Giovannetti [a]

[a]Department of Psychology, Temple University, Philadelphia, PA, USA; [b]Department of Computer and Information Sciences, Temple University, Philadelphia, PA, USA; [c]Department of Psychology, Louisiana State University, Baton Rouge, LA, USA

ABSTRACT

The SmartPrompt is a smartphone-based reminder application informed by a neuropsychological model of functional disability. This laboratory-based pilot study examined the SmartPrompt feasibility, efficacy, and subjective usability using a within-participant, counterbalanced, cross-over design. Ten participants (*M* age = 80.3 $\pm$ 8.2; *M* education = 15.7 $\pm$ 2.5; 60% female) with mild cognitive impairment or mild dementia completed the Remember to Drink Test, which required preparing a glass of water at four predetermined times, in a SmartPrompt (SP) and Unprompted condition (UP). Written cues and a clock were available in both conditions; however, in the SP, the smartphone presented auditory alarms and visual reminders to obtain the water at specified times and required photo logging. In a separate session, caregivers were trained and tested on configuring the SmartPrompt. Overall, caregivers and participants learned to effectively use the SmartPrompt. Caregivers achieved near-perfect scores on the configuration quiz and responded well to training. Participants completed significantly more Remember to Drink tasks in the SP (93%) than UP (56%); checking the cues/clock decreased by 87% in the SP. Usability ratings were excellent among caregivers and fair among participants. Results indicate that the SmartPrompt holds promise for reducing functional disability in older adults with cognitive difficulties in at-home contexts.

ARTICLE HISTORY
Received 1 April 2020
Accepted 25 June 2020

KEYWORDS
Smartphone; Technology; Cognitive aging; Aging in place; Functional disability

Introduction

In 2019, approximately 50 million individuals carried a diagnosis of dementia worldwide (World Health Organization, 2019). Without current effective pharmacologic treatments (Branca & Oddo, 2017) and an increase in the longevity of

CONTACT Tania Giovannetti tgio@temple.edu Department of Psychology, Temple University, Philadelphia, PA 19121, USA

Supplemental data for this article can be accessed https://doi.org/10.1080/09602011.2020.1794909

medically complex older adults (Bluethmann et al., 2016), this number is expected to increase over time. Functional disability (i.e., the inability to independently complete basic activities of daily living such as eating, dressing and grooming) is a core diagnostic criterion for dementia and significantly contributes to exorbitant health care costs, loss of autonomy and independence, and decreased quality of life (Kelley et al., 2015). Caregivers, who are typically unpaid family members, provide up to 62 hours of care per week and are often responsible for prompting or assisting individuals with dementia in their activities of daily living (Olivari, 2018; Olivari et al., 2020). As such, they face threats to their own quality of life including increased rates of depression, financial burden, general caregiver burden, and changes in health and cognition (Braley et al., 2019; Gaugler et al., 2019).

As older adults become more computer literate, assistive technologies hold promise as an inexpensive solution to improve daily functioning in individuals with dementia, and consequently both promote aging in place and reduce caregiver burden and cost of care (Knapp, 2015). Smartphones in particular represent a promising technological solution as they grow increasingly ubiquitous, even among older adults. In fact, in 2019, approximately 53% of U.S. adults over age 65 owned a smartphone (Mobile Fact Sheet, 2019). As the cost of smartphones continues to fall, their increasing affordability will have important implications for the scalability and accessibility of smartphone-based solutions to wider and more diverse populations. At present, there exist a plethora of computer and smartphone applications for people with dementia that target "brain training," physical rehabilitation, falls, and "wandering" (McCallum & Boletsis, 2013; Sposaro et al., 2010); however, there are relatively few commercially-available applications specifically focused on improving daily function. Numerous electronic reminder and calendar applications have been developed for healthy adults, but they typically involve complex interfaces and provide only limited information (i.e., an auditory alert with a simple text-based label), and are not designed according to known age-related differences in human–computer interaction (Chun & Patterson, 2012; Siek et al., 2005). To address this gap, we designed a novel, smartphone-based reminder application (the SmartPrompt) specifically for individuals with mild cognitive impairment (MCI) and dementia, whose features are informed by neuropsychological theories of everyday action (Giovannetti et al., Under Revision) and prospective memory (McDaniel & Einstein, 2000; Smith & Bayen, 2004).

Our conceptual framework posits that everyday activities are represented as goal hierarchies with intentions (e.g., prepare food) at the highest level and manual gestures (e.g., grab jelly jar) at the lowest level. Activation of superordinate intentions may elicit automatic spreading of activation to lower level goals. Activation of a goal hierarchy also may be "triggered" from objects or environments (e.g., a coffee mug may activate coffee-making goals; Giovannetti et al., Under Revision; McDaniel & Einstein, 2000). Deliberate cognitive control (i.e., executive function) is essential to modulate activations and inhibit inappropriate activation from irrelevant objects in the environment (Giovannetti et al., 2005, 2008, 2010). Without sufficient control over goal activations, interference from competing goals and objects may derail performance and lead to disorganization, off-task behaviours, or mis-sequencing of task steps (i.e., commission errors). In addition to commission errors, individuals with functional disability also frequently fail to complete task goals (i.e., omission errors). Omission failures are strongly associated with caregiver-reports of functional disability and may arise because the intention to perform a task (i.e., highest-order task goal in the hierarchy) is not retrieved or activated due to prospective memory impairment (Huppert et al., 2000; McDaniel & Einstein, 2000; Oriani et al., 2003; Smith & Bayen, 2004) and/or apathy (Boyle et al., 2003; Rog et al., 2014). Our framework also proposes that for people with dementia, omissions may be due to the premature decay of goal activations or degraded task goals/knowledge (Giovannetti et al., Under Revision; Roll et al., 2019). Finally, episodic memory and task monitoring are essential to remember that a task has been performed to prevent recurrent perseveration and enable accurate recall and task tracking (Bettcher, Giovannetti, Klobusicky, et al., 2011; Bettcher, Giovannetti, Libon, et al., 2011; Bettcher et al., 2008; Giovannetti et al., 2010, 2012; Giovannetti, Bettcher, et al., 2007; Giovannetti, Libon, Buxbaum, et al., 2002; Giovannetti, Libon, & Hart, 2002; Giovannetti, Schwartz, et al., 2007).

The SmartPrompt was designed to target five cognitive failures that are associated with off-task errors, omissions and deficient task monitoring. Figure 1 illustrates how our conceptual model informed the features and functions of the SmartPrompt. As shown in Figure 1 Panel A, the reminder alert sounds at a predetermined time with an auditory alarm to orient the participant to the phone, at which point they pick up the phone – this feature targets task initiation failures that may arise due to prospective memory impairment. Once the participant picks up the smartphone, they see a brief message directing them to complete the target task and to click on the large button to indicate when they are on their way – this feature addresses the breakdown of task knowledge in that the alarm text can display brief directions.

SmartPrompt alerts are delivered on a time-based model – as compared to location-based or context-aware systems as described in Seelye et al. (2012) – in that prompts are delivered based on a prespecified time. Time-based intentions are more difficult to remember because there are no external cues to trigger their activation; however, location-based prompts, which are delivered when an individual is at a location where an action should be performed, may be more effective because the cues are delivered at an optimal moment when supplies are available and task completion may be more convenient. To address this potential limitation of time-based cues, we have built in the option for participants to defer alerts until they are ready to perform the task. Figure 1 Panel B shows “nudges” that are displayed in the event that the

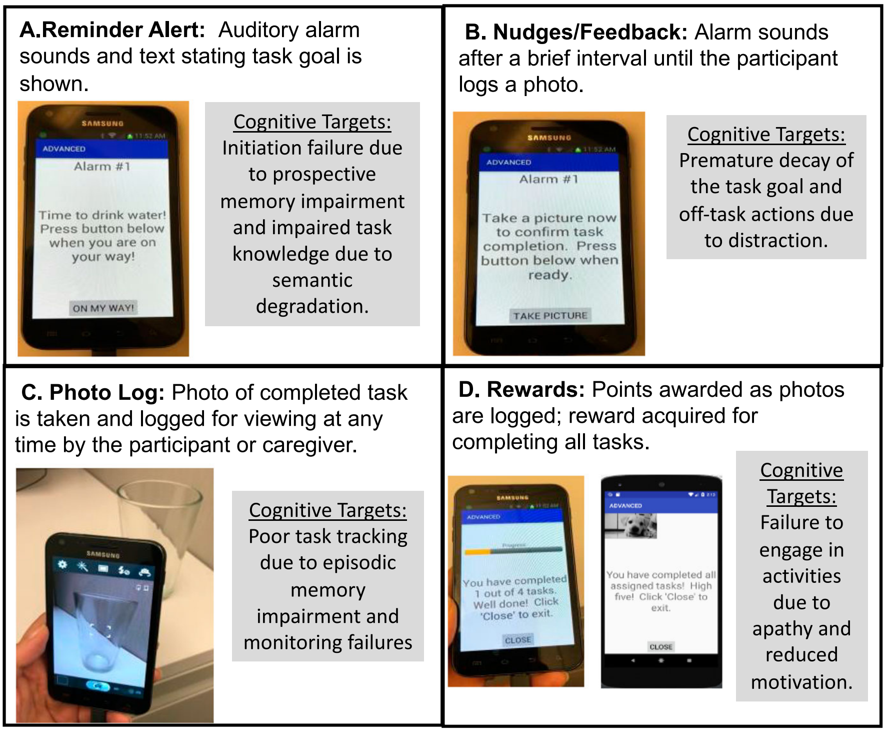


Figure 1. SmartPrompt features and cognitive targets.

participant defers the initial prompt, does not hear the initial prompt, or becomes distracted after hearing the prompt and before completing the target task. An auditory alarm continues to sound every minute until the task is completed – this feature targets poor control over goal activations (off-task behaviors), premature goal decay, and poor monitoring.

The SmartPrompt also includes a task logging feature and rewards to motivate users. As shown in Figure 1 Panel C, after the participant presses the "take picture" button (Panel B), a screen instructs them to take a photo of the completed task (through the photo capture feature which is integrated into the app), thereby logging photo evidence that the task has been completed - this feature circumvents episodic memory failures regarding task completion, enabling participants and/or their caregivers to review the photo log to confirm task completion. As shown in Figure 1 Panel D, points are assigned as each task is successfully logged and are displayed using a progress bar, and if all target tasks are successfully logged within the day, participants receive a video-based reward – this feature addresses problems with motivation and apathy by attempting to make completion of tasks with the SmartPrompt engaging. Finally, we emphasized simple interfaces and explicit instructions when designing the SmartPrompt to minimize training demands and promote efficacy and usability (Seelye et al., 2012).

There are very few systematic pilot studies on reminder applications for individuals with dementia, and even fewer that incorporate a theoretical model to guide development (Seelye et al., 2012). Most research on reminder applications has been conducted on single cases without objective outcome data or control conditions (Gibson et al., 2015; Ienca et al., 2017; Imbeault et al., 2014; Nauha et al., 2018; Oriani et al., 2003; Szymkowiak et al., 2004). Over the years, our research team has used a range of laboratory-based, everyday tasks to evaluate the efficacy of strategies to improve task completion by increasing the number of task steps accomplished (Brennan et al., 2009; Giovannetti et al., 2015), reducing sequence and object-selection errors (Giovannetti, Bettcher, et al., 2007; Giovannetti et al., 2010), and increasing the proportion of errors detected (Bettcher, Giovannetti, Libon, et al., 2011). The current pilot study extends the existing literature on everyday function impairment and associated interventions in several ways. First, the SmartPrompt delivers cues through commercially-available smartphones (Android or iOS), allowing for future generalizability and scalability. Second, multiple cueing strategies that target a variety of cognitive failures based on our conceptual framework are delivered at once to optimize performance. Third, the study design includes a control condition for stronger inferences to be made about outcomes. Finally, qualitative data were collected from participants and caregivers to more directly involve the end users in the design of future iterations of the SmartPrompt.

This laboratory-based pilot study evaluated the SmartPrompt on three dimensions: (1) feasibility – whether people with dementia and their caregivers could be trained to use the SmartPrompt; (2) efficacy[1] – the extent to which the SmartPrompt efficiently improved participants' everyday task performance; and (3) subjective usability – participants/caregivers' perception of the SmartPrompt's design and ease of use. We developed an experimental task called the Remember to Drink Test to directly test the efficacy of the SmartPrompt in the laboratory. The Remember to Drink Test involves obtaining a glass of water at predetermined times (as outlined in more detail in the Methods section). It was chosen as a standardized, laboratory-based example of an everyday task because drinking water represents a low-risk activity that is also highly relevant for health outcomes among older adults. Dehydration, or failure to remember to drink adequate amounts of water, is common among older adults and is associated with numerous negative health outcomes including acute confusion, urinary and respiratory infections, medication toxicity, falls, cognitive dysfunction, and more (Mentes, 2006). Therefore, we reasoned that retrieving a drink of water was familiar and relevant to all participants, making it a highly suitable task to evaluate with and without the SmartPrompt. We hypothesized that participants and caregivers would easily learn to use and operate the SmartPrompt. We also hypothesized that during the Remember to Drink Test, participants would accomplish more tasks at the right time and engage in fewer checking behaviours (i.e., seeking written cues and/or clock) when they were able to rely upon the SmartPrompt as compared to without the SmartPrompt.

We also were interested in exploring individual features that might influence the efficacy and perceived utility of the SmartPrompt among both participants and caregivers to begin to develop a framework that could be useful for matching individuals with dementia with specific SmartPrompt features in future studies. We considered participants' demographics, cognition and mood, because older adults vary widely on these features and prior work from our laboratory indicated that participants' cognitive and clinical profiles were associated with task improvement following the delivery of cues at the end of a task (Giovannetti et al., 2015). We also included measures of proficiency and attitudes towards technology, as technology experience and self-efficacy has been associated with the efficacy and experience of using assistive technologies in older adults (Cohen-Mansfield et al., 2005; Czaja et al., 2006; Harris et al., 2020).

Materials and methods

Participants

Participants were recruited from a range of outreach efforts, including local community and senior centres, flyers and email distributions, referring providers, and a research database of previous participants who consented to future contact. A relatively small sample size ($N = 10$) was recruited for this pilot study, yet the sample size range falls within that of the typical pilot or phase 0 studies involving preliminary assessment of an experimental device within clinical populations (Billingham et al., 2013; Marchetti & Schellens, 2007), and also suffices for usability testing (Faulkner, 2003). Participants met the following inclusion criteria: (a) 65 years of age or older, (b) diagnosis of MCI or dementia (or cognitive scores falling within this range at the study visit) according to widely used clinical diagnostic criteria (Albert et al., 2011; McKhann et al., 2011), (c) experiencing difficulty with at least one everyday task due to cognitive problems, (d) fluent in English, (e) availability of an informant/caregiver with knowledge on the participant's everyday cognition. Exclusion criteria were as follows: (a) sensory or motor difficulties that would preclude walking or cell phone use, (b) lifetime history of major neurologic disorder (e.g., schizophrenia, epilepsy, major head trauma), (c) current B12 deficiency, renal failure, cancer, major depressive disorder, or anxiety disorder. All participants gave written informed consent as part of a protocol approved by the Institutional Review Board of Temple University.

Procedures

All study activities occurred within the timeframe of June 2018 – August 2019. Participants and their caregivers completed the study during a single session lasting approximately three hours at the Temple University Cognitive Neuropsychology Laboratory. The session began with a brief screening and interview with the participant and their informant/caregiver (*hereafter referred to as caregiver*) to obtain demographic data (e.g., age, sex, level of education) and to confirm inclusion/exclusion criteria. Next, participants and caregivers were brought into separate testing rooms to complete different study procedures. Participants completed a brief cognitive assessment and questionnaires about their mood and computer experience. Following completion of the cognitive assessment and questionnaires, participants were guided through a brief training protocol covering use of the SmartPrompt. To evaluate the efficacy of the SmartPrompt, participants then completed an experimental prospective memory task, called the Remember to Drink Test, which was modelled after the commercially-available Memory for Intentions Test (MIST; Raskin & Buckheit, 2004). Following SmartPrompt testing using the Remember to Drink Test, participants completed a usability questionnaire about the SmartPrompt. Caregivers were administered questionnaires and asked to review, configure, and evaluate the SmartPrompt in a separate testing room. Study measures are described in further detail below.

Participant measures

SmartPrompt efficacy testing

Remember to Drink Test. Participants were seated at a table and provided with instructions on the Remember to Drink Test. Participants were told that they would be expected to get up from the table to obtain a glass of water from the laboratory kitchen at four specific, predetermined times. Participants then followed the examiner into the laboratory kitchen (which was down the hall from the experimental test room), and practiced pouring a glass of water into a cup to confirm they were physically able to complete the Remember to Drink Test. Once they returned to the experimental test room, participants were told that they would be engaged in brain games (i.e., other cognitive testing) with the examiner, which served to mimic everyday distractions that occur outside of the laboratory. However, they were instructed to prioritize obtaining each glass of water at the four predetermined times and not to prioritize the brain games. The list of times was written in large, high-contrast font on a piece of paper which was posted behind the participant to their left side (list cue), whereas a digital clock depicting the current time was placed behind the participant to their right side (clock cue; See Figure 2). Participants were asked to look behind them to their left and right and read aloud (a) the list of times, and (b) the current time to confirm that they were able to perceive and read the cue stimuli. Efficacy outcome variables included task accomplishment and checking behaviour. Task accomplishment was operationalized as the percent of drinks successfully obtained from the laboratory kitchen (i.e., X out of 4), with successful completion meaning participants exited the testing room, entered the laboratory kitchen and poured a glass of water within 3 minutes of the predetermined time. Checking behaviour was operationalized as the

Figure 2. Depiction of the Remember to Drink Test set-up with the list of times behind the participant to their left and a digital clock cue behind the participant to their right.

number of times participants looked behind them to check either the list cue or the clock cue while they were engaged in distraction testing. The Remember to Drink Test was administered under two different conditions (SmartPrompt and Unprompted), which were counterbalanced across participants to control for potential practice effects. Instructions for the Remember to Drink Test are included in Supplemental Materials.

SmartPrompt condition. Before beginning the Remember to Drink Test under the SmartPrompt condition, participants underwent a brief (10–15 minute) training according to a detailed and standardized script and handout that included familiarization with the laboratory smartphone (Android; Samsung Galaxy S2), familiarization with the SmartPrompt application, and a test run (see Supplemental Materials for the SP training script and handout). During the test run, the participant was verbally guided through the functionality of the SmartPrompt. Each participant enacted his/her response to the initial SmartPrompt reminder alarm and to the successive prompts to complete the target task. Training covered each of the SmartPrompt features first through successive pictures on a handout and then with the actual smartphone. SmartPrompt training included instructions for the participant to photograph the end product of their efforts on each task (i.e., photo log). Extensive feedback was provided by the study team during the enactment. The training was "hands-on" and highly interactive, and participants were not prevented from making errors during enactment. However, all errors were corrected and all questions were answered until the participant was successful in using the SmartPrompt and completing the target task during the test run. Participants were offered a lanyard carrying case for the smartphone to facilitate ease of transporting the phone to and from the laboratory kitchen.

Once participants demonstrated capability in responding to the SmartPrompt alarm and logging a photo of the glass of water in the laboratory kitchen during the test run, the experimenter proceeded to set the four predetermined alarms at 12-minute intervals (e.g., 2:00, 2:12, 2:24, 2:36) and commence the SmartPrompt condition. As mentioned earlier, participants were engaged in cognitive testing to mimic everyday distractions, but were instructed to interrupt the cognitive testing and to prioritize obtaining the water. For the present study, technical specifications of the smartphone were configured such that no additional applications were active during the study visit, preventing irrelevant pop ups or other communications from disrupting the alarms. If the alarm was not acknowledged by the participant, or if the participant chose to defer the alarm, then a second alarm was delivered after one minute. A total of three alarms were delivered for each task. The alarm/response logic used to programme the SmartPrompt application is depicted in the supplemental materials.

Control condition. Participants were asked to complete the Remember to Drink Test, but they were not given the SmartPrompt to facilitate task completion (e.g., no alarms sounded, no instructions requiring photo logging, laboratory smartphone was not present). Participants were told to prioritize the water task and to interrupt their ongoing cognitive testing to obtain the water at the right time. Dependent variables were obtained just as they were for the SmartPrompt condition, including the number of times the participant successfully completed the task (number of drinks obtained, out of 4) and the number of times they checked the list and clock cues.

SmartPrompt subjective usability testing-participant perspective. At the end of the Remember to Drink Test, participants completed a modified "participant" version of the System Usability Scale [P-SUS (Brooke, 1996; Lewis & Sauro, 2009)]; the P-SUS was modified to include language that is specific to the prompting application. Ten items (e.g., "I found the SmartPrompt was easy to use") were evaluated on a 1 (strongly disagree) to 5 (strongly agree) point scale. After correction (−1 for odd items and −5 for even, reverse-scored items), the total is multiplied by 2.5 to yield a total score ranging from 0 (poor usability) to 100 (excellent usability).

Cognitive testing. Before SmartPrompt testing, participants completed a subset of cognitive tests so that cognitive abilities could be evaluated using measures that were not compromised due to prioritizing the Remember to Drink Test. Participants completed measures of global cognition (Mini Mental State Exam; Folstein et al., 1975), word reading/estimated IQ (Hopkins Adult Reading Test; Schretlen et al., 2009), verbal memory/list learning (Hopkins Verbal Learning Test; Brandt & Benedict, 2001), processing speed, and executive functioning (Trail Making Test Parts A and B; Reitan, 1958). These measures were selected for their psychometric properties, association with functional abilities in dementia, and availability of demographically-corrected norms (Schretlen et al., 2010). Demographically-corrected *T*-scores (controlling for age, education and sex) were calculated for all cognitive tests. Demographically-corrected *T*-scores for tests of verbal memory, processing speed, and executive functioning were averaged to create a cognitive composite score.

Depression and anxiety. Depression symptoms were evaluated with the Geriatric Depression Scale (GDS; Yesavage, 1988), and general anxiety symptoms were evaluated with the Geriatric Anxiety Inventory (GAI; Pachana et al., 2007). Both the GDS and GAI require participants to reply *yes* or *no* to a series of questions regarding depression/anxiety symptoms (e.g., Do you feel your situation is hopeless). The number of symptoms endorsed is summed, with higher scores reflecting more symptoms.

Participant computer proficiency and attitudes questionnaires. Participants completed two questionnaires pertaining to their computer experience and attitudes. The Computer Proficiency Questionnaire (CPQ; Boot et al., 2015) requires participants to rate their ability to perform a variety of computer-based tasks (e.g., using a printer, emailing, performing internet searches) on a 5-point scale (e.g., 1 = *Never tried*, 2 = *Not at all able*, 3 = *Not very easily able*, 4 = *Somewhat easily able*, 5 = *Very easily able*). An overall proficiency score was calculated as the average rating (possible range = 1–5), with higher scores reflecting greater overall computer proficiency. The Attitudes Towards Computers Questionnaire (ATCQ; Jay & Willis, 1992) includes subscales related to comfort, self-efficacy, anxiety, interest, and perceived utility of technology. Statements (e.g., Computers make me nervous) are rated on a 5-point scale (e.g., 1 = *strongly agree*, 2 = *agree*, 3 = *neither agree nor disagree*, 4 = *disagree,* and 5 = *disagree strongly*), with higher scores reflecting more favourable attitudes towards computers and technology.

Caregiver measures

Functional abilities. Caregivers completed two questionnaires about participants' everyday functioning: the Functional Activities Questionnaire (FAQ; Pfeffer et al., 1982) and the Everyday Cognition Scale (ECog; Farias et al., 2008).

Caregiver computer proficiency and attitudes questionnaires. Caregivers completed questionnaires on their own computer proficiency (CPQ), attitudes towards computers (ATCQ), and open-ended questions about general technology use.

SmartPrompt configuration and evaluation. Caregivers were guided through a brief 10–15-minute training during which they were familiarized to each of the SmartPrompt features and were verbally guided through the steps required to programme and respond to alarms. Unlike participant training, caregiver training was not interactive, as caregivers were not given the opportunity to touch the smartphone during the training. Following the research team's demonstration of programming and responding to a test alarm, caregivers were provided with conceptual background on the design of the SmartPrompt to fill a 10–15-minute delay (see Supplemental materials). Following the delay, caregivers were handed the smartphone and asked to complete an eight-item performance-based quiz to evaluate retention of the training (see Supplemental materials). Each step in the SmartPrompt configuration procedures was reflected as an item on the quiz, which was scored as correct vs. incorrect.

SmartPrompt subjective usability-caregiver perspective. Caregivers also completed a modified "caregiver" version of the System Usability Scale [Caregiver (C)-SUS] and an open-ended structured interview to qualitatively inform SmartPrompt modifications.

Analyses

Feasibility/training completion

To explore whether participants and caregivers could reasonably learn to use the SmartPrompt, we maintained a record of any study discontinuations resulting from inability to engage with the SmartPrompt, as well as percent completion rates for the participant and caregiver training protocols. We also recorded caregiver scores on the performance-based training quiz.

Efficacy

To investigate the hypothesis that the SmartPrompt is efficacious at promoting everyday task completion, we plotted and compared task accomplishment and checking behaviours from the Remember to Drink Test in the SmartPrompt condition (SP) versus the Unprompted (Control) Condition (UP). Despite our small sample size, we conducted ancillary analyses using Related Samples Wilcoxon Signed Rank Tests because the SP task accomplishment and SP checking variables were not normally distributed. The magnitude of the differences between the conditions (i.e., effect size) was estimated by calculating r (.10 = small; .30 = medium, .50 = large).

Subjective usability

Descriptive analyses were performed for subjective usability outcomes, including average scores on the P-SUS and C-SUS. C- and P- SUS scores of at least 70 suggest adequate usability (Bangor, 2009). Other variables were used to evaluate usability qualitatively, including open-ended usability and feedback questionnaires.

Exploratory associations

To evaluate participant and caregiver features that may be associated with SmartPrompt efficacy and subjective usability ratings, bivariate correlation analyses were used to explore relations with the following variables: participant age, sex, education, overall level of cognitive and functional impairment, mood, and caregiver and participant computer proficiency and technology attitudes. Supplemental analyses examined associations between efficacy variables and individual cognitive tests (in addition to an overall cognitive composite). Pearson correlations were used when both variables were normally distributed, whereas Spearman's rank order correlations were used when one or both variables were non-normally distributed.

Results

Participant and caregiver demographics

Individual-level data including key participant features, accomplishment rates, and checking behaviours for each study participant are provided in Table 1. All participants meeting eligibility criteria at screening were included in the study and completed all study procedures. As shown in Table 2, participants were on average 80 years old, and the majority identified as white and female, with at least a high school education. Estimated IQ ranged from average (102) to very superior (137). Caregivers were on average 68 years old and were of similar demographics. The majority of caregivers were spouses of the participant (40%), followed by adult children (30%). The remainder of caregiver relationships included a paid caregiver, a friend, and a sibling.

Participants' cognitive abilities were variable, with total Mini Mental State Exam (MMSE) scores ranging from 17 (moderate dementia) to 30 (no dementia). See Tables 1 and 2. Age, sex and education-adjusted *T*-scores of domain-specific cognitive tests ranged from 19 (impaired) to 77 (very superior), with an average global cognition *T*-score of 40 (average) and ranging from 23 (impaired) to 57 (average). Caregiver-reported FAQ scores ranged from 0 (no functional difficulties) to 23 (functional disability) and overall reports of changes in everyday cognition (ECog) suggested mild decline and ranged from typical cognitive aging to the range of MCI or mild dementia (Farias et al., 2011). Reported symptoms of anxiety (GAI) and depression (GDS) were variable but fell within the average range overall.

Results of computer proficiency (CPQ) and technology (ATCQ) questionnaires are shown in Table 3. Both participants and caregivers reported that they were capable of using computers, though participants on average reported significantly lower computer proficiency than caregivers [M CPQ = 3.74 for participants vs. 4.77 for caregivers; $t(9) = 3.30$, $p = .01$]. Caregivers also expressed more favourable attitudes towards computers [M ATCQ = 4.45 for caregivers vs. 3.84 for participants; $t(9) = 4.14$, $p = .003$], though both participants and caregivers reported positive attitudes towards computers on average.

Table 1. Participant individual level data: demographics, cognition, function, mood, accomplishment and checking.

ID	Age	Edu	Sex	Avg. Cognition (*T*)†	FAQ	ECog (total)	GDS (*T*)†	GAI	% Accomplish (SP)	Checking (SP)	% Accomplish (UP)	Checking (UP)
1	76	16	F	40	12	2.8	56	0	100	7	75	15
2	82	12	M	31	12	2.6	49	0	100	1	50	9
3	93	16	F	51	3	1.7	75	3	100	1	33	8
4	82	20	F	23	23	3.7	38	0	25	0	0	2
5	72	14	F	57	0	1.4	75	16	100	4	100	25
6	88	17	F	35	15	1.4	65	18	100	0	0	0
7	67	16	F	37	8	2.4	80	9	100	0	75	23
8	82	17	F	35	21	2.0	74	6	100	2	100	34
9	73	20	M	38	6	2.9	62	0	100	4	100	18
10	88	16	M	47	1	2.5	65	6	100	0	25	12

†*T* scores are corrected for age, sex, and education.

FAQ = Functional Activities Questionnaire; ECog = Everyday Cognition Questionnaire; GDS = Geriatric Depression Scale; GAI = Geriatric Anxiety Inventory; SP = Prompted Condition; UP = Unprompted Condition.

Table 2. Descriptive characteristics ($N = 10$ Participants, $N = 10$ Caregivers).

	Mean (SD)	Range	Maximum Score
Participant Demographics			
Age	80.3 (8.2)	67–93	–
Education	16.4 (2.4)	12–20	–
Sex (% female)	70%	–	–
Race (% White)	80%	–	–
Caregiver Demographics			
Age	68.0 (8.4)	57–84	–
Education	16.4 (3.1)	12–21	–
Sex (% female)	60%	–	–
Participant Cognition & Everyday Function			
Calibration Estimated IQ*	119.2 (10.8)	102–137	140
MMSE- Raw	26.1 (4.2)	17–30	30
MMSE-$T^{\dagger}$	45.7 (17.6)	23–72	80
HVLT (Imm. Recall) – Raw	13.9 (5.0)	5–22	36
HVLT (Imm. Recall) – $T^{\dagger}$	30.9 (8.5)	19–44	80
HVLT (Delayed Recall) – Raw	3 (2.9)	0–10	12
HVLT (Delayed Recall) – $T^{\dagger}$	34.3 (9.1)	23–57	80
HVLT (Retention %) – Raw	49.2 (40.6)	0–125	1200
HVLT (Retention %) – $T^{\dagger}$	41.2 (15.7)	28–77	80
HVLT (Recog. Discriminability) – Raw	8.2 (3.6)	1–12	12
HVLT (Recog. Discriminability) – $T^{\dagger}$	42.9 (14.3)	19–62	80
Trail Making Test Part A (sec)	73.2 (32.4)	34–132	150
Trail Making Test Part A – $T^{\dagger}$	40.9 (14.1)	22–63	80
Trail Making Test Part B (sec)	209.0 (89.2)	65–300	300
Trail Making Test Part B – $T^{\dagger}$	40.8 (12.9)	29–71	80
Overall Cognition – Average $T^{\dagger}$	39.5 (9.9)	23–57	80
FAQ	10.1 (8.0)	0–23	30
ECog	2.3 (0.7)	1.4–3.7	4
Participant Mood and Anxiety Symptoms			
Geriatric Depression Scale (GDS)	8.6 (5.9)	0–18	30
Geriatric Anxiety Inventory (GAI)	5.8 (6.7)	0–18	20

MMSE = Mini Mental State Exam; HVLT = Hopkins Verbal Learning Test; FAQ = Functional Activities Questionnaire; ECog = Everyday Cognition Questionnaire.
*Note: Calibration Estimated IQ is based on Age, Sex, Education, and Hopkins Adult Reading Test.
$^{\dagger}T$ scores are corrected for age, sex, and education. *T*-scores between 40 and 60 are considered to fall within the average range.

Feasibility/training completion

All participants were able to successfully use and interact with the SmartPrompt during the brief training procedure. None of the participants discontinued their

Table 3. Technology questionnaire responses.

	Participant		Caregiver	
Computer Proficiency Questionnaire (CPQ – average score; max = 5)				
	Mean (SD)	Range	Mean (SD)	Range
	3.74 (.82)	2.3–4.8	4.77 (.33)	4.0–5.0
Attitudes Towards Computers Questionnaire (ATCQ-average score; max = 5)				
	Participant		Caregiver	
	Mean (SD)	Range	Mean (SD)	Range
Overall	3.84 (.51)	3.1–4.9	4.45 (.46)	3.8–4.9
Comfort subscale	3.14 (1.04)	1.4–4.8	4.40 (.63)	3.0–5.0
Efficacy subscale	4.16 (.53)	3.6–5.0	4.46 (.52)	4.0–5.0
Computer Anxiety subscale	3.40 (.91)	2.4–5.0	4.20 (.71)	3.0–5.0
Interest subscale	4.22 (.53)	3.4–5.0	4.46 (.45)	4.0–5.0
Utility subscale	4.28 (.37)	3.8–5.0	4.74 (.51)	4.0–5.0

CPQ response options ranged from 0 (not at all proficient) to 5 (very proficient); ATCQ responses ranged from 0 (negative attitudes), 3 (neutral) to 5 (positive attitudes).

participation in the study, and all were able to engage in the study procedures with 9 out of 10 participants correctly responding to all alarms (100%) in the SP condition and all 10 participants responding correctly to at least one alarm (≥25% task accomplishment rate in the SP condition). Of note is that the participant with the lowest task accomplishment in the SP condition (25%) also had the lowest level of cognitive ability in the study sample, with overall average cognitive test scores falling nearly three standard deviations below average (Participant #4, Table 1).

All caregivers successfully completed the SmartPrompt training procedures. On the performance-based quiz, caregivers earned an average score of 97.6%, with only two caregivers omitting the final step to hit the close button after saving the alarms (i.e., one quiz step out of 8 total steps), resulting in a score of 88% for these two caregivers and 100% for the remainder. These results indicate that all caregivers were able to successfully programme the SmartPrompt independently after a single training session lasting less than 20 minutes.

Efficacy: Accomplishment, checking, and associations between accomplishment and checking

Accomplishment scores and total checking behaviours for each participant in the SP and UP conditions are reported in Table 1. None of the 10 participants obtained a lower accomplishment score on the Remember to Drink Test in the SP condition as compared to the UP condition. Three participants obtained a perfect score (100%) in the UP condition and showed no difference between the UP and SP conditions, likely due to ceiling effects. All other participants ($n = 7$) who obtained less than perfect accomplishment scores in the UP condition obtained a higher accomplishment score in the SP condition. An ancillary Wilcoxon signed-rank test indicated that a significantly higher percentage of tasks were accomplished in the SP condition ($Mdn = 100$) as compared to the UP condition ($Mdn = 62.50$), $n = 10$, $Z = 2.38$, $p = .017$, as displayed in Figure 3. Calculation of the effect size also showed the magnitude of the accomplishment score difference between the SP and UP conditions was large ($r = 0.53$).

Checking behaviours (i.e., total number of checks to the list and clock cues) showed a similar pattern. All participants, except one who exhibited no checking behaviour in the UP condition, exhibited less checking in the SP condition. In fact, checking behaviours reduced by 87% in the SP condition, as shown in Figure 4A. An ancillary Wilcoxon signed-rank test showed the difference between checking behaviour in the SP ($Mdn = 1$) and the UP ($Mdn = 13.5$) was statically significant ($n = 10$, $Z = 2.67$, $p = .008$), and the effect size was large ($r = 0.60$). Further, as shown in Figure 4B, the distribution of checking behaviours within each condition (SP and UP) indicated that participants made a greater proportion of checks to the clock cue as opposed to the list cue in both conditions.

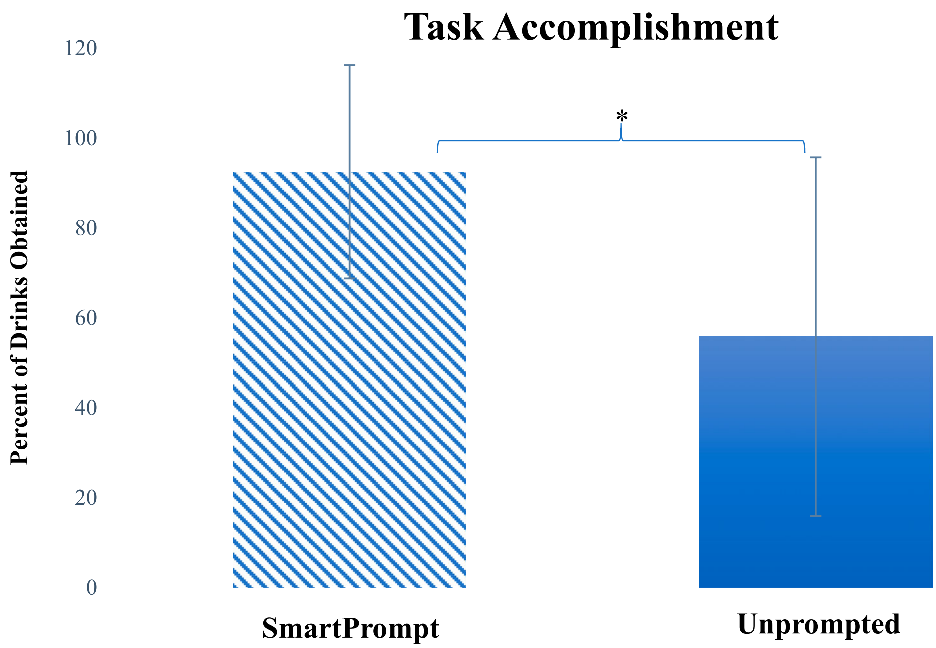


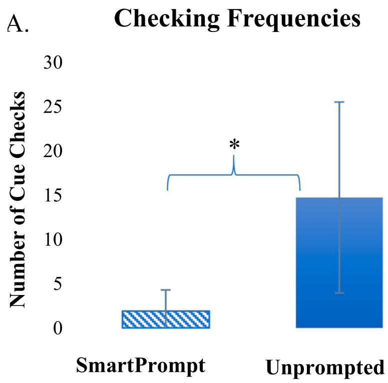
Figure 3. Average percent accomplishment in the SmartPrompt (SP) versus Unprompted (UP) condition.

Notes: Error bars reflect 95% confidence intervals. *related-samples Wilcoxon Signed Rank test: $n = 10$, $Z = 2.38$, $p = .017$, $r = 0.53$.

Correlations were conducted to first examine whether checking behaviours were helpful in obtaining higher task accomplishment. There was a significant and strong association between checking and task accomplishment in the UP condition ($r = .89$, $p < .001$) such that individuals who engaged in more checking behaviour in the UP achieved higher task accomplishment in the UP. This relation was not observed in the SP condition- checking behaviour was not associated with task accomplishment when participants were using the SmartPrompt ($r_s = .36$, $p = .305$). Further, the difference between the SP and UP checking x accomplishment correlation coefficients was statistically significant ($z = 2.31$, $p = .01$).

Associations between participant features and efficacy outcomes

Correlation analyses were performed to determine whether participant demographic and clinical features (Supplemental Table 1) and cognitive abilities (Supplemental Table 2) were associated with performance on the Remember to Drink Test in the SP and UP conditions. There were no statistically significant associations between participant features and task accomplishment in the SP condition. However, in the UP condition, a significant association was found between task accomplishment and age ($r = -.68$, $p = .029$), as well as episodic memory abilities ($r = .81$, $p = .005$), such that older adults and those with poorer episodic memory



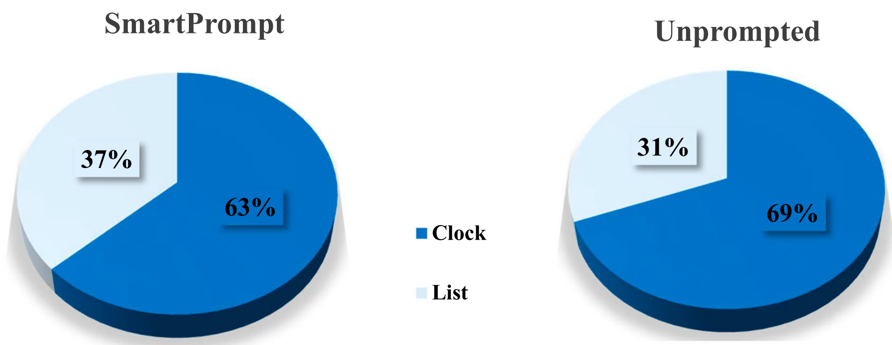


Figure 4. Panel A. Total checking count in the SmartPrompt (SP) versus Unprompted (UP) condition. Notes: Error bars reflect 95% confidence intervals. Panel B. Proportion of checking behaviour to the clock and the list in the SmartPrompt (SP) and unprompted (UP) conditions. *related-samples Wilcoxon Signed Rank test: $n = 10$, $Z = 2.67$, $p = .008$, $r = 0.60$.

abilities accomplished fewer tasks in the UP condition only. A significant association also was found between checking behaviours and episodic memory abilities in the UP ($r = .76$, $p = .012$), such that participants with stronger episodic memory engaged in more checking behaviour.

We also were interested in understanding whether computer proficiency and attitudes influenced performance with the SP. These relations were not of interest for the UP condition. As shown in Supplemental Table 1, associations between efficacy outcomes in the SP condition and computer attitudes (ATCQ) and proficiency (CPQ) were not statistically significant.

Subjective usability

Participant (P-SUS) and Caregiver (C-SUS) usability questionnaires obtained at the end of the study visit indicated that participants and caregivers viewed the SmartPrompt favourably, with mean Participant-SUS ratings of 67.22 (Good range) and mean Caregiver-SUS ratings of 86.75/100 (Excellent range). Supplemental Table 3 includes individual-level Participant- and Caregiver-SUS ratings.

Correlations were performed to determine whether participant features and/or performance with the SP were associated with usability ratings on the Participant-SUS (Supplemental Table 4). Participant global cognition was significantly associated with Participant-SUS ratings ($r = .66$, $p = .04$), such that participants with higher cognitive functioning assigned higher Participant-SUS ratings. We suspected that participants who were more successful with the SP would report higher usability ratings; however, the relation between the Participant-SUS and SP Accomplishment was not statistically significant, and the relation with SP checking behaviour was in the unexpected direction, such that participants who engaged in more checking behaviour in the SP assigned more favourable usability ratings ($r_s = .70$, $p = .02$). All other correlations with Participant-SUS ratings were not statistically significant.

We also explored relations between Caregiver-SUS ratings and caregiver features (e.g., caregiver age, education, computer proficiency or technology attitudes), but all correlation coefficients were not statistically significant (see Supplemental Table 5).

Supplemental free response data from caregivers collected in response to interview questions including *"Was there anything that you did not like about the SmartPrompt?"* indicated that 6/10 caregivers replied "No," suggesting that the majority of caregivers had no critiques about the SmartPrompt. Of those that did have critiques, comments focused on the alarm sound (e.g., some stated the sound would be annoying and confusing, or simply that the sound was aversive), as well as one caregiver who thought the SmartPrompt was too cumbersome and included too many steps. Other suggestions included increasing the font size for the numbers displayed when setting the alarm times. Responses to other open-ended questions, such as "*Do you have any comments about the SmartPrompt?*" or "*How could we change the SmartPrompt to be more useful to you/the participant?*" included suggestions for increased customization (e.g., personalized alarm sounds, use of favourite colours, phase in levels of support based on level of impairment), remote scheduling of recurring alarms, reward enhancements (e.g., vibrating feedback), and support for iOS (Apple's operating system) and wearable devices. Examples of positive feedback included that the SmartPrompt was "very intuitive" and that the font/buttons were large and clear. One caregiver commented that "the interface is somewhat basic, but this may be a good thing because it is not distracting." Another noted that "with reminders, he [the participant] could do things without error." Some concerns that were raised included consideration of tasks that do not lend themselves to photo logging (e.g., remembering to use catheter) and doubts that older adults with memory difficulties can keep their smartphones charged. Finally, responses to the question "*Are there any tasks, other than drinking, for which the SmartPrompt might be helpful?*" indicated that caregivers believed the SmartPrompt would be useful for the following everyday tasks: checking glucose monitors, checking blood sugar, mealtime, nap time, medications, and appointments.

Discussion

There is a dearth of empirical data on the use of smartphone applications for improving daily functioning for individuals with dementia and reducing burden among their caregivers. The results of this pilot study yielded essential fundamental information on the feasibility, efficacy and subjective usability of smartphone-based reminder applications. Specifically, we demonstrated that the SmartPrompt application, which was designed according to a neuropsychological model of everyday action impairment and was tested following minimal participant and caregiver training, shows promise as a tool to improve everyday task completion and reduce inefficient checking behaviours in older adults with cognitive impairment.

Feasibility testing (i.e., examination of training completion rates) demonstrated that after less than 20 minutes of training, all caregivers learned to configure the SmartPrompt application and all participants learned to respond to the SmartPrompt without demonstrating overt frustration or requesting discontinuation. Efficacy testing using a controlled laboratory task (Remember to Drink) revealed that participants completed significantly more tasks with the SmartPrompt (SP) than without it (UP). In fact, every participant completed the same or a greater number of tasks in the SP vs. UP, indicating that the process of introducing a novel technological device did not detract from task accomplishment among any participant.

Checking behaviour significantly decreased (by 87%) in the SP, suggesting that the SmartPrompt effectively reduced inefficiencies in task completion and allowed allocation of additional cognitive resources to the task at hand. When the SmartPrompt was unavailable to alert, remind and reward participants for task completion (UP condition), checking behaviours assumed a compensatory role and were strongly associated with task accomplishment. On the other hand, checking behaviour was unrelated to task accomplishment in the SP, suggesting that checking was unnecessary to facilitate task completion with the SmartPrompt. We also observed that the SmartPrompt did not change the nature of checking behaviours; in both conditions, participants spent a greater proportion of time checking the clock cue versus the list cue. This observation supports the importance of time-base cues, as participants sought greater assistance with monitoring the time but may have felt more confident about their ability to remember the list of predetermined times.

Subjective usability ratings were fair among participants, and were excellent among caregivers. Qualitatively, caregivers reported overall positive impressions of the SmartPrompt, felt the SmartPrompt would be useful for their loved ones, and provided a range of insightful recommendations. Caregivers achieved near perfect scores on the configuration quiz and responded well to training, suggesting the SmartPrompt could be easily translated to real-world settings where caregivers would independently programme and monitor task completion using the SmartPrompt.

We also aimed to explore whether known factors that influence everyday function were associated with the efficacy of the SmartPrompt. We saw that in the UP condition, age and episodic memory ability were significantly associated with task accomplishment such that older participants and those with poorer episodic memory accomplished fewer tasks without the SmartPrompt. This finding is in line with well-established, age-related declines in everyday functioning and associations between episodic memory and everyday function that we observe even in healthy aging. The significant, specific association between episodic memory and accomplishment in the unprompted condition suggests that the SmartPrompt may be most beneficial for individuals who have difficulties with everyday tasks due to memory impairment (i.e., anterograde amnesia), possibly because they fail to recall the task objectives, lose track of time, have difficulty imaging the future, or some combination of these difficulties.

Importantly, however, we did not observe the associations between age or episodic memory and task accomplishment in the SP condition, suggesting that the supportive features of the SmartPrompt facilitated task performance for all participants, regardless of age and episodic memory ability. However, inspection of individual-level data showed one outlier, with the lowest level of overall cognitive function in the entire sample, who failed to accomplish any tasks without prompting and showed better but still very low accomplishment (25%) with the SmartPrompt. This individual responded correctly to the first alarm in the prompted (SP) condition and used the SmartPrompt application correctly. However, she completely ignored the three subsequent alarms. This failure pattern suggests that individuals with moderate-level cognitive impairment may require additional training with the SmartPrompt or may require a more salient and explicit auditory alert or verbal command in order to orient attention to the smartphone (e.g., "Mary! Look at your phone now"). Salient and explicit alerting alarms may be even more critical in the home setting where multiple electronic devices may make similar sounds and compete for an individual's attention, ultimately leading to a failed SmartPrompt response.

Cognitive abilities were significantly associated with participants' usability ratings, such that participants with higher cognitive functioning assigned more favourable usability ratings. Qualitative analysis of SUS responses showed participants with lower cognitive abilities indicated lower confidence in their ability to use the SmartPrompt independently (i.e., "I think I would need the help of a technical person to use the SmartPrompt"). This may suggest that traditional usability questions are less appropriate for individuals with cognitive impairment who may overestimate or underestimate their true abilities. In sum, although participants with greater cognitive difficulties report lower subjective usability ratings, the efficacy of the SmartPrompt is unrelated to level of cognitive impairment and usability ratings, deeming the SmartPrompt applicable to a wide range of individuals at various levels of cognitive ability and despite their subjective impression of the application.

Also surprising was the lack of significant associations between computer proficiency/attitudes and SmartPrompt efficacy and usability outcomes, as we expected more experience with computers and more favourable attitudes towards technology to predict greater task accomplishment and higher usability ratings on the SmartPrompt (Evans et al., 2020; Roque & Boot, 2018). As the older adult population gains increasing exposure to technology (Mobile Fact Sheet, 2019; Wagner et al., 2010), concerns about low technology proficiency and negative or suspicious attitudes towards technology will be less concerning for intervention devices. Nonetheless, the current population of older adults includes those who are new computer and smartphone users, who did not grow up with this technology. For these individuals, it is important to continue to learn about potential barriers to successful adoption of tools like the SmartPrompt so we can continue to modify and make them more amenable. Efficacy data such as these, showing the benefits of assistive technologies even among individuals with cognitive difficulties and low computer proficiency, might be helpful in convincing skeptical individuals to adopt new and unfamiliar devices.

It is important to acknowledge several study limitations. First, the SmartPrompt was tested in a highly controlled setting with a single, prototype (Android) smartphone; consequently, the effectiveness of the SmartPrompt in individuals' home settings with their own personal smartphones remains unknown. Second, the sample size was small, and although appropriate for pilot studies and usability testing (Billingham et al., 2013; Faulkner, 2003; Marchetti & Schellens, 2007), offered limited power to detect effects in correlation analyses, which should be interpreted as exploratory and require replication. Finally, the SmartPrompt alarm and reward features were the same for all participants; even greater efficacy and subjective usability might have been achieved if the SmartPrompt was customized for each person.

It is also worth highlighting several notable strengths of the SmartPrompt design and the present study, which differentiate the SmartPrompt from other available phone-based reminder applications. First, the SmartPrompt design is grounded in an empirically based framework which, as Seelye et al. (2012) note, is lacking in the prompting technology literature. These theoretically-driven features address multiple cognitive targets simultaneously (e.g., lack of motivation, prospective and episodic memory, etc.) and to our knowledge have not been incorporated into existing alarm applications. These include repeated prompts until the user acknowledges the alarm, requirement to log photo proof of task completion, and motivational rewards upon task completion. The second strength of the SmartPrompt is that it can be used with commercially-available smartphones, eliminating the need to learn to use an unfamiliar device and also likely leading to increased adoption among older adults who might be concerned about social stigma associated with obtrusive adaptive devices, privacy, and cost (Beringer et al., 2011; Courtney, 2008; Hedman et al., 2016; Kenigsberg et al., 2019). Relying on individuals' personal smartphones in the next phase of our study also should decrease training time associated with learning unfamiliar, basic phone controls (e.g., volume, power, etc.). In an attempt to address a common barrier of technology use among older adults, namely complex interfaces (Kenigsberg et al., 2019), the SmartPrompt design consists of a very simple interface with large text and "buttons," which is believed to result in higher efficacy and acceptance levels (Seelye et al., 2012). The current study design also has several strengths, including a control condition, which allowed us to examine the incremental effect of the SmartPrompt on behaviour. The use of a real-world, important everyday task (i.e., hydration) to test the SmartPrompt increases the ecological validity of the results. Finally, the collection of qualitative free-response data, consideration of individual features that may influence outcomes, and feedback from both participants and caregivers yielded valuable information that is being used to improve the design of the SmartPrompt for a future larger scale study.

Future directions include continued investigation of the SmartPrompt in a longitudinal intervention study with a larger sample size (Stage I Feasibility with AB/BA crossover design) that will take place in participants' homes using their own personal smartphone devices. Importantly, participants and their caregivers will identify a custom everyday task that is relevant to their lives and which participants currently have difficulty completing independently, thereby extending the task repertoire of the SmartPrompt beyond hydration to other ecologically valid and personally meaningful tasks that, if completed independently, are more likely to promote self-esteem and quality of life. Similar outcomes of efficacy and subjective usability will be explored. In addition, we are interested in learning whether the SmartPrompt alleviates caregiver burden over the extended study duration, whether participants' procedural knowledge of how to use and respond to the SmartPrompt can be sustained over a longer study period, and whether the SmartPrompt can successfully facilitate task accomplishment as it did in a controlled laboratory setting but within a home environment where everyday distractions are more abundant. Preliminary testing of a touchscreen prompter used by individuals with dementia and their caregivers in the home has shown promising results (Harris et al., 2020); however, it is unclear whether the design of this particular prompting device included the important elements of nudges and photo logging, which may prove vital in everyday contexts that are less structured and more unpredictable. Increasingly rigorous methods of analyzing qualitative interview data from participants and caregivers, such as Thematic Analysis, will be used (Evans et al., 2020), and we will continue to incorporate user feedback into the ongoing development and evaluation of the SmartPrompt according to a user centred approach (Schulz et al., 2015). In fact, our team has already made substantial changes to the design of the SmartPrompt based on participant and caregiver feedback from the present study, including further customization of the interface and rewards. With personalization as a major priority, we have incorporated the option for customized rewards (e.g., participant's favourite song to play when they accomplish all daily tasks), as well as customized audio and visual alarm features (i.e., custom audio recording using a familiar voice in place of a standardized alarm sound, and display of a personal photo depicting the participant's everyday task objects to provide additional semantic and visual cues). These suggested modifications are in line with principles of cognitive rehabilitation theory and are likely to better capture the attention of users and improve the effectiveness of the prompt (Seelye et al., 2012). In addition, we have integrated more overt flexible response options so that the participant will have the ability to defer task completion to a later timepoint (i.e., 10–15 minutes) if they are currently engaged in another task, which we believe will reduce the potentially disruptive nature of SmartPrompt alerts within the home and increase the chances that target tasks are carried out when participants are not distracted.

Additional future directions farther down the line include translating the guiding functionality of the SmartPrompt from primarily time-based to context-aware, as we move from testing of a simple predetermined task in the lab to more complex tasks within the home. This may possibly involve integrating with global positioning service (GPS) and other smart-home sensors to deliver prompts at increasingly nuanced and crucial timepoints based on contextual information (Seelye et al., 2012). Additional customization in terms of graduated levels of assistance is another area of consideration, where the content provided by the SmartPrompt would depend on the degree of cognitive and functional impairment. This approach would avoid the erosion of skills and abilities through disuse and would facilitate cognitively effortful engagement that may be more effective for individuals with less severe cognitive impairment, enhance subjective usability, and further promote individual autonomy and dignity (Le Dorze et al., 2014; Schulz et al., 2015; Seelye et al., 2012).

Note

1. The term efficacy is used as recommended in the clinical trial literature, where efficacy refers to testing the result of an intervention under ideal circumstances (i.e., laboratory setting), whereas effectiveness refers to testing in the "real world" (Gartlehner et al., 2006). However, our use of the term "efficacy" is consistent with the International Organization for Standardization (ISO) definition of "effectiveness," which refers to the accuracy, completeness and lack of negative consequences with which users achieved the specified goals of a device or technology (Bevan et al., 2016).

Acknowledgements

This project was supported by the National Institute on Aging (Grants R21AG060422, R01AG062503, R21AG066771 to TG). A portion of the study was presented at the 2020 North American meeting of the International Neuropsychological Society.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the National Institute on Aging [grant number R01AG062503, R21AG060422, R21AG066771].

ORCID

Katherine Hackett http://orcid.org/0000-0002-3595-1418
Tania Giovannetti http://orcid.org/0000-0001-5661-152X

References

Albert, M. S., DeKosky, S. T., Dickson, D., Dubois, B., Feldman, H. H., Fox, N. C., Gamst, A., Holtzman, D. M., Jagust, W. J., Petersen, R. C., Snyder, P. J., Carrillo, M. C., Thies, B., & Phelps, C. H. (2011). The diagnosis of mild cognitive impairment due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's & Dementia*, *7*(3), 270–279. https://doi.org/10.1016/j.jalz.2011.03.008

Bangor, A. (2009). Determining what individual SUS scores Mean: Adding an Adjective Rating Scale. *Journal of Usability Studies*, *4*(3), 10. https://doi.org/10.5555/2835587.2835589

Beringer, R., Sixsmith, A., Campo, M., Brown, J., & McCloskey, R. (2011). The "acceptance" of ambient assisted living: Developing an alternate methodology to this limited research lens. In B. Abdulrazak, S. Giroux, B. Bouchard, H. Pigot, & M. Mokhtari (Eds.), *Toward useful services for elderly and people with disabilities* (pp. 161–167). Springer. https://doi.org/10.1007/978-3-642-21535-3_21

Bettcher, B. M., Giovannetti, T., Klobusicky, E., Wambach, D., Eppig, J., & Libon, D. J. (2011). To err is human, to monitor divine: Environmental adaptations reduce everyday errors but do not improve monitoring. *Journal of Clinical and Experimental Neuropsychology*, *33*(10), 1049–1058. https://doi.org/10.1080/13803395.2011.595395

Bettcher, B. M., Giovannetti, T., Libon, D. J., Eppig, J., Wambach, D., & Klobusicky, E. (2011). Improving everyday error detection, one picture at a time: A performance-based study of everyday task training. *Neuropsychology*, *25*(6), 771–783. https://doi.org/10.1037/a0024107

Bettcher, B. M., Giovannetti, T., Macmullen, L., & Libon, D. J. (2008). Error detection and correction patterns in dementia: A breakdown of error monitoring processes and their neuropsychological correlates. *Journal of the International Neuropsychological Society*, *14*(2), 199–208. https://doi.org/10.1017/S1355617708080193

Bevan, N., Carter, J., Earthy, J., Geis, T., & Harker, S. (2016). New ISO standards for usability, usability reports and usability measures. In M. Kurosu (Ed.), *Human-computer interaction. Theory, design, development and practice* (pp. 268–278). Springer International Publishing. https://doi.org/10.1007/978-3-319-39510-4_25

Billingham, S. A., Whitehead, A. L., & Julious, S. A. (2013). An audit of sample sizes for pilot and feasibility trials being undertaken in the United Kingdom registered in the United Kingdom clinical research Network database. *BMC Medical Research Methodology*, *13*(1), 104. https://doi.org/10.1186/1471-2288-13-104

Bluethmann, S. M., Mariotto, A. B., & Rowland, J. H. (2016). Anticipating the "silver tsunami": Prevalence Trajectories and comorbidity burden among older cancer survivors in the United States. *Cancer Epidemiology Biomarkers & Prevention*, *25*(7), 1029–1036. https://doi.org/10.1158/1055-9965.EPI-16-0133

Boot, W. R., Charness, N., Czaja, S. J., Sharit, J., Rogers, W. A., Fisk, A. D., Mitzner, T., Lee, C. C., & Nair, S. (2015). Computer Proficiency Questionnaire: Assessing low and high computer proficient seniors. *The Gerontologist*, *55*(3), 404–411. https://doi.org/10.1093/geront/gnt117

Boyle, P. A., Malloy, P. F., Salloway, S., Cahn-Weiner, D. A., Cohen, R., & Cummings, J. L. (2003). Executive dysfunction and apathy predict functional impairment in Alzheimer disease. *The American Journal of Geriatric Psychiatry*, *11*(2), 214–221. https://doi.org/10.1097/00019442-200303000-00012

Braley, R., Fritz, R., Van Son, C. R., & Schmitter-Edgecombe, M. (2019). Prompting technology and persons with dementia: The significance of context and communication. *The Gerontologist*, *59*(1), 101–111. https://doi.org/10.1093/geront/gny071

Branca, C., & Oddo, S. (2017). Paving the way for new clinical Trials for Alzheimer's disease. *Biological Psychiatry*, *81*(2), 88–89. https://doi.org/10.1016/j.biopsych.2016.10.016

Brandt, J., & Benedict, R. H. (2001). *Hopkins verbal learning test–revised: Professional manual*. Psychological Assessment Resources.

Brennan, L., Giovannetti, T., Libon, D. J., Bettcher, B. M., & Duey, K. (2009). The impact of goal cues on everyday action performance in dementia. *Neuropsychological Rehabilitation*, *19*(4), 562–582. https://doi.org/10.1080/09602010802405623

Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability Evaluation in Industry*, *189*(194), 4–7.

Chun, Y. J., & Patterson, P. E. (2012). A usability gap between older adults and younger adults on interface design of an internet-based telemedicine system. *Work*, *41*(Suppl. 1), 349–352. https://doi.org/10.3233/WOR-2012-0180-349

Cohen-Mansfield, J., Creedon, M. A., Malone, T. B., Kirkpatrick, M. J., Dutra, L. A., & Herman, R. P. (2005). Electronic memory aids for community-dwelling elderly persons: Attitudes, preferences, and potential utilization. *Journal of Applied Gerontology*, *24*(1), 3–20. https://doi.org/10.1177/0733464804271277

Courtney, K. L. (2008). Privacy and senior willingness to adopt smart home information technology in residential care facilities. *Methods of Information in Medicine*, *47*(1), 76–81. https://doi.org/10.3414/ME9104

Czaja, S. J., Charness, N., Fisk, A. D., Hertzog, C., Nair, S. N., Rogers, W. A., & Sharit, J. (2006). Factors predicting the use of technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and Aging*, *21*(2), 333–352. https://doi.org/10.1037/0882-7974.21.2.333

Evans, N., Boyd, H., Harris, N., Noonan, K., Ingram, T., Jarvis, A., Ridgers, J., & Cheston, R. (2020). The experience of using prompting technology from the perspective of people with dementia and their primary carers. *Aging & Mental Health*, 1–9. https://doi.org/10.1080/13607863.2020.1745145

Farias, S., Mungas, D., Harvey, D. J., Simmons, A., Reed, B. R., & DeCarli, C. (2011). The measurement of everyday cognition: Development and validation of a short form of the Everyday Cognition scales. *Alzheimer's & Dementia*, *7*(6), 593–601. https://doi.org/10.1016/j.jalz.2011.02.007

Farias, S., Mungas, D., Reed, B. R., Cahn-Weiner, D., Jagust, W., Baynes, K., & DeCarli, C. (2008). The measurement of everyday cognition (ECog): Scale development and psychometric properties. *Neuropsychology*, *22*(4), 531–544. https://doi.org/10.1037/0894-4105.22.4.531

Faulkner, L. (2003). Beyond the five-user assumption: Benefits of increased sample sizes in usability testing. *Behavior Research Methods, Instruments, & Computers*, *35*(3), 379–383. https://doi.org/10.3758/BF03195514

Folstein, M., Folstein, S., & McHugh, P. (1975). "Mini-Mental-State": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Gartlehner, G., Hansen, R. A., Nissman, D., Lohr, K. N., & Carey, T. S. (2006). *Criteria for distinguishing effectiveness from efficacy trials in systematic reviews*. Agency for Healthcare Research and Quality (US). https://www.ncbi.nlm.nih.gov/sites/books/NBK44029/

Gaugler, J., James, B., Johnson, T., Marin, A., & Weuve, J. (2019). 2019 Alzheimer's disease facts and figures. *Alzheimers & Dementia*, *15*(3), 321–387. https://doi.org/10.1016/j.jalz.2019.01.010

Gibson, G., Dickinson, C., Brittain, K., & Robinson, L. (2015). The everyday use of assistive technology by people with dementia and their family carers: A qualitative study. *BMC Geriatrics*, *15*(1), 89. https://doi.org/10.1186/s12877-015-0091-3

Giovannetti, T., Bettcher, B. M., Brennan, L., Libon, D. J., Wambach, D., & Seter, C. (2010). Target-related distractors disrupt object selection in everyday action: Evidence from participants with dementia. *Journal of the International Neuropsychological Society*, *16*(3), 484–494. https://doi.org/10.1017/S1355617710000081

Giovannetti, T., Bettcher, B. M., Brennan, L., Libron, D. J., Kessler, R. K., & Duey, K. (2008). Coffee with jelly or unbuttered toast: Commissions and omissions are dissociable aspects of everyday action impairment in Alzheimer's disease. *Neuropsychology*, *22*(2), 235–245. https://doi.org/10.1037/0894-4105.22.2.235

Giovannetti, T., Bettcher, B. M., Libon, D. J., Brennan, L., Sestito, N., & Kessler, R. K. (2007). Environmental adaptations improve everyday action performance in Alzheimer's disease: Empirical support from performance-based assessment. *Neuropsychology*, *21*(4), 448–457. https://doi.org/10.1037/0894-4105.21.4.448

Giovannetti, T., Britnell, P., Brennan, L., Siderowf, A., Grossman, M., Libon, D. J., Bettcher, B. M., Rouzard, F., Eppig, J., & Seidel, G. A. (2012). Everyday action impairment in Parkinson's disease dementia. *Journal of the International Neuropsychological Society*, *18*(5), 787–798. https://doi.org/10.1017/S135561771200046X

Giovannetti, T., Buxbaum, L. J., Biran, I., & Chatterjee, A. (2005). Reduced endogenous control in alien hand syndrome: Evidence from naturalistic action. *Neuropsychologia*, *43*(1), 75–88. https://doi.org/10.1016/j.neuropsychologia.2004.06.017

Giovannetti, T., Libon, D. J., Buxbaum, L. J., & Schwartz, M. F. (2002). Naturalistic action impairments in dementia. *Neuropsychologia*, *40*(8), 1220–1232. https://doi.org/10.1016/S0028-3932(01)00229-9

Giovannetti, T., Libon, D. J., & Hart, T. (2002). Awareness of naturalistic action errors in dementia. *Journal of the International Neuropsychological Society*, *8*(5), 633–644. https://doi.org/10.1017/S135561770280131X

Giovannetti, T., Mis, R., Hackett, K., Simone, S., & Ungrady, M. (Under Revision). The goal-control model: An integrated neuropsychological framework to explain impaired performance of everyday activities. *Neuropsychology*.

Giovannetti, T., Schwartz, M. F., & Buxbaum, L. J. (2007). The coffee Challenge: A new method for the study of everyday action errors. *Journal of Clinical and Experimental Neuropsychology*, *29*(7), 690–705. https://doi.org/10.1080/13803390600932286

Giovannetti, T., Seligman, S. C., Britnell, P., Brennan, L., & Libon, D. J. (2015). Differential effects of goal cues on everyday action errors in Alzheimer's disease versus Parkinson's disease dementia. *Neuropsychology*, *29*(4), 592–602. https://doi.org/10.1037/neu0000167

Harris, N., Boyd, H., Evans, N., Cheston, R., Noonan, K., Ingram, T., Jarvis, A., & Ridgers, J. (2020). A preliminary evaluation of a client-centred prompting tool for supporting everyday activities in individuals with mild to moderate levels of cognitive impairment due to dementia. *Dementia*, 1471301220911322. https://doi.org/10.1177/1471301220911322

Hedman, A., Lindqvist, E., & Nygård, L. (2016). How older adults with mild cognitive impairment relate to technology as part of present and future everyday life: A qualitative study. *BMC Geriatrics*, *16*(1), 73. https://doi.org/10.1186/s12877-016-0245-y

Huppert, F. A., Johnson, T., & Nickson, J. (2000). High prevalence of prospective memory impairment in the elderly and in early-stage dementia: Findings from a population-based study. *Applied Cognitive Psychology*, *14*(7), S63–S81. https://doi.org/10.1002/acp.771

Ienca, M., Fabrice, J., Elger, B., Caon, M., Scoccia Pappagallo, A., Kressig, R. W., & Wangmo, T. (2017). Intelligent assistive technology for Alzheimer's disease and other dementias: A systematic review. *Journal of Alzheimer's Disease*, *56*(4), 1301–1340. https://doi.org/10.3233/JAD-161037

Imbeault, H., Bier, N., Pigot, H., Gagnon, L., Marcotte, N., Fulop, T., & Giroux, S. (2014). Electronic organiser and Alzheimer's disease: Fact or fiction? *Neuropsychological Rehabilitation*, *24*(1), 71–100. https://doi.org/10.1080/09602011.2013.858641

Jay, G. M., & Willis, S. L. (1992). Influence of direct computer experience on older adults' attitudes toward computers. *Journal of Gerontology*, *47*(4), P250–P257. https://doi.org/10.1093/geronj/47.4.P250

Kelley, A. S., McGarry, K., Gorges, R., & Skinner, J. S. (2015). The burden of health care costs for patients with dementia in the last 5 years of life. *Annals of Internal Medicine*, *163*(10), 729–736. https://doi.org/10.7326/M15-0381

Kenigsberg, P.-A., Aquino, J.-P., Bérard, A., Brémond, F., Charras, K., Dening, T., Droës, R.-M., Gzil, F., Hicks, B., Innes, A., Nguyen, S.-M., Nygård, L., Pino, M., Sacco, G., Salmon, E., van der Roest, H., Villet, H., Villez, M., Robert, P., & Manera, V. (2019). Assistive technologies to address capabilities of people with dementia: From research to practice. *Dementia*, *18*(4), 1568–1595. https://doi.org/10.1177/1471301217714093

Knapp, M. (2015). The cost-effectiveness challenge: Is it worth it? *Alzheimer's Research & Therapy*, *7*(1), 10. https://doi.org/10.1186/s13195-015-0095-4

Le Dorze, G., Villeneuve, J., Zumbansen, A., Masson-Trottier, M., & Bottari, C. (2014). Verbal assistance within the context of an IADL evaluation. *Open Journal of Therapy and Rehabilitation*, *02*(04), 182–198. https://doi.org/10.4236/ojtr.2014.24024

Lewis, J. R., & Sauro, J. (2009). The factor structure of the System Usability Scale. In M. Kurosu (Ed.), *Human centered design* (pp. 94–103). Springer. https://doi.org/10.1007/978-3-642-02806-9_12

Marchetti, S., & Schellens, J. H. M. (2007). The impact of FDA and EMEA guidelines on drug development in relation to phase 0 trials. *British Journal of Cancer*, *97*(5), 577–581. https://doi.org/10.1038/sj.bjc.6603925

McCallum, S., & Boletsis, C. (2013). Dementia games: A literature review of dementia-related serious games. In M. Ma, M. F. Oliveira, S. Petersen, & J. B. Hauge (Eds.), *Serious games development and applications* (pp. 15–27). Springer. https://doi.org/10.1007/978-3-642-40790-1_2

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, *14*(7), S127–S144. https://doi.org/10.1002/acp.775

McKhann, G. M., Knopman, D. S., Chertkow, H., Hyman, B. T., Jack, C. R., Kawas, C. H., Klunk, W. E., Koroshetz, W. J., Manly, J. J., Mayeux, R., Mohs, R. C., Morris, J. C., Rossor, M. N., Scheltens, P., Carrillo, M. C., Thies, B., Weintraub, S., & Phelps, C. H. (2011). The diagnosis of dementia due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's & Dementia*, *7*(3), 263–269. https://doi.org/10.1016/j.jalz.2011.03.005

Mentes, J. (2006). Oral hydration in older adults: Greater awareness is needed in preventing, recognizing, and treating dehydration. *AJN The American Journal of Nursing*, *106*(6), 40–49. https://doi.org/10.1097/00000446-200606000-00023

Mobile Fact Sheet. (2019). Pew Research Center. https://www.pewresearch.org/internet/fact-sheet/mobile/

Nauha, L., Keränen, N. S., Kangas, M., Jämsä, T., & Reponen, J. (2018). Assistive technologies at home for people with a memory disorder. *Dementia*, *17*(7), 909–923. https://doi.org/10.1177/1471301216674816

Olivari, B. S. (2018). CDC grand rounds: Promoting well-being and independence in older adults. *MMWR. Morbidity and Mortality Weekly Report*, *67*(37). https://doi.org/10.15585/mmwr.mm6737a4

Olivari, B. S., French, M. E., & McGuire, L. C. (2020). The public health road map to respond to the growing dementia crisis. *Innovation in Aging*, *4*(1). https://doi.org/10.1093/geroni/igz043

Oriani, M., Moniz-Cook, E., Binetti, G., Zanieri, G., Frisoni, G. B., Geroldi, C., Vreese, L. P. D., & Zanetti, O. (2003). An electronic memory aid to support prospective memory in patients in the early stages of Alzheimer's disease: A pilot study. *Aging & Mental Health*, *7*(1), 22–27. https://doi.org/10.1080/1360786021000045863

Pachana, N. A., Byrne, G. J., Siddle, H., Koloski, N., Harley, E., & Arnold, E. (2007). Development and validation of the Geriatric Anxiety Inventory. *International Psychogeriatrics*, *19*(1), 103–114. https://doi.org/10.1017/S1041610206003504

Pfeffer, R. I., Kurosaki, T. T., Harrah, C. H., Chance, J. M., & Filos, S. (1982). Measurement of functional activities in older adults in the community. *Journal of Gerontology*, *37*(3), 323–329. https://doi.org/10.1093/geronj/37.3.323

Raskin, S., & Buckheit, C. (2004). Memory for intentions screening test. *Journal of the International Neuropsychological Society*, *10*(Suppl. 1), 110.

Reitan, R. M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills*, *8*(3), 271–276. https://doi.org/10.2466/pms.1958.8.3.271

Rog, L. A., Park, L. Q., Harvey, D. J., Huang, C.-J., Mackin, S., & Farias, S. T. (2014). The independent contributions of cognitive impairment and neuropsychiatric symptoms to everyday function in older adults. *The Clinical Neuropsychologist*, *28*(2), 215–236. https://doi.org/10.1080/13854046.2013.876101

Roll, E. E., Giovannetti, T., Libon, D. J., & Eppig, J. (2019). Everyday task knowledge and everyday function in dementia. *Journal of Neuropsychology*, *13*(1), 96–120. https://doi.org/10.1111/jnp.12135

Roque, N. A., & Boot, W. R. (2018). A new tool for assessing mobile device proficiency in older adults: The Mobile Device Proficiency Questionnaire. *Journal of Applied Gerontology*, *37*(2), 131–156. https://doi.org/10.1177/0733464816642582

Schretlen, D., Testa, S., & Pearlson, G. (2010). *Calibrated neuropsychological normative system professional manual*. Psychological Assessment Resources.

Schretlen, D. J., Winicki, J. M., Meyer, S. M., Testa, S. M., Pearlson, G. D., & Gordon, B. (2009). Development, psychometric properties, and validity of the Hopkins Adult Reading Test (HART). *The Clinical Neuropsychologist*, *23*(6), 926–943. https://doi.org/10.1080/13854040802603684

Schulz, R., Wahl, H.-W., Matthews, J. T., De Vito Dabbs, A., Beach, S. R., & Czaja, S. J. (2015). Advancing the aging and technology agenda in gerontology. *The Gerontologist*, *55*(5), 724–734. https://doi.org/10.1093/geront/gnu071

Seelye, A. M., Schmitter-Edgecombe, M., Das, B., & Cook, D. J. (2012). Application of cognitive rehabilitation theory to the development of smart prompting technologies. *IEEE Reviews in Biomedical Engineering*, *5*, 29–44. https://doi.org/10.1109/RBME.2012.2196691

Siek, K. A., Rogers, Y., & Connelly, K. H. (2005). Fat finger worries: How older and younger users physically interact with PDAs. In M. F. Costabile, & F. Paternò (Eds.), *Human-computer interaction—INTERACT 2005* (pp. 267–280). Springer. https://doi.org/10.1007/11555261_24

Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(4), 756–777. https://doi.org/10.1037/0278-7393.30.4.756

Sposaro, F., Danielson, J., & Tyson, G. (2010). iWander: An Android application for dementia patients. 2010 *Annual International Conference of the IEEE Engineering in Medicine and Biology*, pp. 3875–3878. https://doi.org/10.1109/IEMBS.2010.5627669

Szymkowiak, A., Morrison, K., Shah, P., Gregor, P., Evans, J., Newell, A., & Wilson, B. (2004). *Memojog øe an interactive memory aid with remote communication*.

Wagner, N., Hassanein, K., & Head, M. (2010). Computer use by older adults: A multi-disciplinary review. *Computers in Human Behavior*, *26*(5), 870–882. https://doi.org/10.1016/j.chb.2010.03.029

World Health Organization. (2019). *Dementia key facts*. https://www.who.int/news-room/fact-sheets/detail/dementia

Yesavage, J. A. (1988). Geriatric depression scale. *Psychopharmacology Bulletin*, *24*(4), 709–711.