Technology options to help people with dementia or acquired cognitive impairment perform multistep daily tasks: a scoping review

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Abstract

Purpose – *The purpose of this paper is to review studies that evaluated technology-based prompting systems for supporting participants with dementia or acquired cognitive impairment in their performance of multistep daily tasks.*

Design/methodology/approach – *A scoping review was conducted to identify eligible studies through a search of four electronic databases, that is, PubMed, PsycINFO, Web of Science and Institute of Electrical and Electronics Engineers.*

Findings – *The search, which covered the 2010–2020 period, led to the identification of 1,311 articles, 30 of which were included in the review. These articles evaluated six different types of prompting systems: context-aware, automatic computer prompting, context-aware, mediated computer prompting, teleoperated robot prompting, self-operated augmented reality prompting, self-operated computer or tablet prompting and time-based (preset) computer, tablet or smartphone prompting.*

Originality/value – *Technology-aided prompting to help people with dementia or acquired cognitive impairment perform relevant multistep daily tasks is considered increasingly important. This review provides a picture of the different prompting options available and of their level of readiness for application in daily contexts.*

Keywords *Multistep tasks, Prompting, Technology, Dementia, Cognitive impairment, Daily contexts*

Paper type *Literature review*

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Introduction

People with dementia or acquired cognitive impairment (i.e. forms of the functional decline occurring in the early stages of neurodegenerative diseases or subsequent to neurological damage such as traumatic brain injury) represent a vast and increasing part of the world population and call for medical/pharmacological interventions, as well as behavioral interventions (Gagnon-Roy *et al.*, 2020; Evans *et al.*, 2020). Medical/pharmacological interventions are generally focused on identifying and implementing treatments to halt further deterioration of people's social and cognitive functions and possibly improve those functions (Liu *et al.*, 2020). Behavioral interventions are typically directed at setting up forms of environmental support to help the people remain functionally active, and thus maintain a level of practical integration within their daily context and a positive social image and succeed in slowing down any further decline (Wilson *et al.*, 2019).

One of the main goals of behavioral interventions for people with mild or moderate cognitive impairment and mild or moderate dementia is to support their performance of functional multistep daily tasks (e.g. preparing meals and drinks, washing hands or going through the

morning routine) (Braley *et al.*, 2019). Such support is important because these people are often unable to carry out those tasks independently largely due to memory problems that interfere with their recalling of the task steps and their organization of those steps in an orderly fashion (Lancioni *et al.*, 2017; Pereyda *et al.*, 2019).

Supporting these people's functional task engagement through direct caregiver supervision does not seem a very realistic or desirable option. In a daily context, in fact, caregivers may not necessarily have the time and energy to provide extensive supervision. Moreover, performance under supervision can make people with dementia or cognitive impairment feel dependent and inadequate and develop/consolidate a poor social image of themselves (Burleson *et al.*, 2018; Mahoney *et al.*, 2015).

An alternate to increased caregiver supervision may be the use of technology systems that provide prompts (instructions) for the single steps of those tasks. Such prompts are intended to compensate for the aforementioned memory and executive problems, and thus enable people to manage the tasks in a largely correct and independent manner (Rohrbach *et al.*, 2019; Wolf *et al.*, 2018). Those systems vary widely in terms of technological complexity (e.g. from systems relying on robots to systems relying on tablets or smartphones), prompt conditions (e.g. from automatic prompt delivery to self-prompting) and prompt characteristics (e.g. from simple verbal or pictorial prompts to combinations of verbal and video prompts) (Harris *et al.*, 2020; Pinard *et al.*, 2019; Wang *et al.*, 2017).

This paper is aimed at providing a picture of the different systems and their use with people with dementia or acquired cognitive impairment. Specifically, this paper is directed at reviewing studies carried out between 2010 and 2020 that evaluated those systems so as to determine the level of development (readiness) reached by the systems and the systems' possible/expected contribution in supporting people's performance of multistep tasks in daily contexts. Providing such a general picture to professionals working in the area may be considered useful to orient their choice of technology options in daily practice and stimulate their research initiatives to add essential evidence about those options.

Method

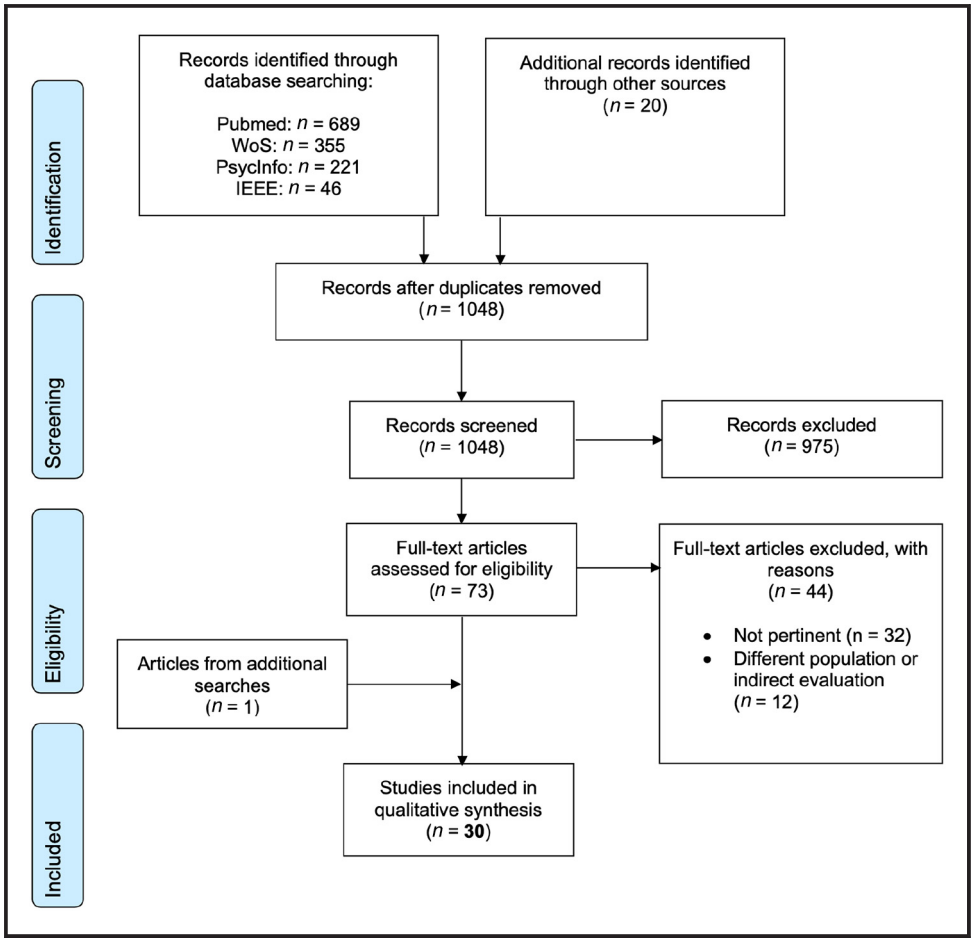
Search strategy

A systematic search was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviewes (PRISMA-ScR) (Tricco *et al.*, 2018) to identify studies that relied on technology arrangements to enable persons with dementia or acquired cognitive impairment to perform multistep tasks. A scoping review approach was used, as our primary aim was to examine the range of technology options available and identifying knowledge gaps (Munn *et al.*, 2018).

Studies were identified through a search of four electronic databases, that is, PubMed, PsycINFO, Web of Science and Institute of Electrical and Electronics Engineers (IEEE). The search process included the following free-text terms for the first three databases: (*dementia* OR *Alzheimer** OR *mild cognitive impairment* OR *acquired cognitive impairment* OR *brain impairment* OR *brain injur**) AND (*assistive technology* OR *technology*) AND (*instruction** OR *prompt* OR *prompting* OR *micro-prompting* OR *step by step* OR *multistep*). For the IEEE database, the terms *technology* and *assistive technology* were omitted, as they were deemed redundant in that the IEEE database includes primarily technical content.

The search, which covered the period between January 2010 and August 2020, resulted in a total of 1,311 papers. The number of papers was reduced to 1,048 after duplicates were removed. Figure 1 illustrates the search process and outcome. Initially, titles and abstracts of the 1,048 papers were screened. When the titles and abstracts were judged to be in line with the inclusion criteria (see below), the corresponding full-text articles were downloaded.

Figure 1 Flowchart of the literature search process



Following this process, 73 full-text articles were downloaded. Those full-text articles were then read by the first and second authors and 29 of them were found eligible for the review. Subsequently, the references of these 29 articles were inspected to possibly identify other relevant articles. In addition, a Google Scholar "cited by" search was conducted using the aforementioned 29 articles. This search led to the finding of one extra article, with the consequence that 30 articles were finally included in the review.

Inclusion and exclusion criteria

Two basic inclusion criteria were used in selecting the studies for the review. First, the studies involved the participation of adults (i.e. aged > 18 years) with dementia or acquired cognitive impairment (i.e. forms of the functional decline occurring in the early stages of neurodegenerative diseases or subsequent to neurological damage such as traumatic brain injury). Second, the studies used technology systems aimed at helping the participants to perform one or more multistep daily tasks. Studies aimed at developing technology systems to support multistep tasks were excluded if the evaluation of the systems occurred via focus groups or the involvement of participants other than those on whom this review was concentrated (studies such as those reported by Bouchard *et al.*, 2020; Gagnon-Roy *et al.*, 2020; Pereyda *et al.*, 2019; Wilson *et al.*, 2019; Yaddaden *et al.*, 2020).

Interrater agreement

Interrater agreement was checked between the first two authors on scoring the eligibility of the 73 full-text articles, which were downloaded after screening titles and abstracts and on reporting the data extracted from the articles reviewed (see Results and Table 1). Interrater agreement on this latter measure was checked over 10 articles. The percentage of agreement on the 73 full-text articles was 97%. That is, the authors provided the same label (i.e. "included" or "excluded") for 71 of the 73 articles. Consensus between authors on the two articles with initial disagreement was then achieved after a brief discussion. Interrater agreement on reporting the data extracted from 10 of the articles included in the review was 100%.

Data extraction and coding

Data were extracted in terms of country in which the study was conducted, number and functioning characteristics (i.e. dementia or cognitive impairment) of the participants included, tasks targeted, setting where the study was implemented (i.e. with the use of the technology), the method used to assess the impact of the prompting system and data reported on task performance (Table 1). Moreover, following a consensus-based approach between the first two authors, codes were created to group the studies included in the review (results) according to the forms of technology support they used to foster multistep task performance.

Results

As indicated above, 30 studies were identified that relied on technology arrangements to enable persons with dementia or acquired cognitive impairment to perform multistep tasks (see Table 1 for an overview). Those studies were conducted in Canada (n = 8), UK (n = 8), Italy (n = 7), the USA (n = 3), Taiwan (n = 2) and Germany (n = 2). In total, 302 participants were involved.

The studies were grouped into six categories:

1. context-aware, automatic computer prompting;
2. context-aware, mediated computer prompting;
3. teleoperated robot prompting;
4. self-operated augmented reality prompting;
5. self-operated computer or tablet prompting; and
6. time-based (preset) computer, tablet or smartphone prompting.

The various forms of technology reported by the studies show clear differences in terms of the level of support afforded to the participants to enable their successful task performance. Forms of technology providing context-aware, automatic prompting, for example, are designed to ensure extensive support (i.e. require minimal human input/oversight). Conversely, forms of technology entailing self-operated prompting ensure relatively moderate support. Accordingly, the complexity of the former types of technology is much higher than the complexity of the latter types.

The studies show large variability in terms of the methodology used to assess the effects of prompting. A concise description of the methodological approach adopted in each study is provided in Table 1 (see "Assessment methods" column). In total, 14 studies used a clearly recognizable experimental approach (i.e. ABAB, multiple baselines, multi-element, multiple probes, alternating treatments and cross-over designs or a randomized controlled trial; Table 1). The remaining studies reported simple AB (baseline-prompting) sequences,

Table 1 List of the studies included in the review, which are divided according to the six types of technology-based prompting used

Studies and countries of origin	*Participants with dementia or cognitive impairment*	*Tasks targeted*	*Setting*	*Assessment methods*	*Data reported on task performance*
Context-aware, automatic computer prompting					
Hoey *et al.* (2010) Canada	6 participants with moderate or severe dementia	Washing hands	Care facility's washroom	Baseline (non-prompting) and prompting conditions were alternated according to an ABAB design	No data reported on task performance
O'Neill *et al.* (2010) UK	8 participants with mild or moderate cognitive impairment	Putting on prosthetic limbs	Mobility and rehabilitation center	Baseline and prompting task trials were randomly presented in line with a multi-element design	6 participants showed significant task improvement with prompting
Chang *et al.* (2011) Taiwan	2 participants with mild dementia or cognitive impairment	Making pizza	Laboratory setting	Baseline and prompting conditions were alternated (ABAB)	Prompting promoted percentages of correct task performance reaching 100%
Chang *et al.* (2012) Taiwan	3 participants with mild/ moderate cognitive impairment	Serving dessert and beverages	Kitchen setting	Prompting conditions were compared with other intervention strategies	All 3 participants reached 100% correct task performance with prompting. Two of them were equally successfully using written notes
Czarnuch *et al.* (2013) Canada	20 participants with mild to severe dementia	Washing hands	Medical facility's washroom	Prompting accuracy and participants' performance were recorded during the task trials	206 of the 246 task steps involved in the trials of all participants were completed
O'Neill *et al.* (2013) UK	1 participant with severe cognitive impairment	Mourning routine	Neurorehabilitation center and home	Baseline and prompting conditions were implemented in two settings as two successive AB sequences	Prompting promoted performance improvement in both settings
O'Neill *et al.* (2018) UK	10 participants with mild or moderate cognitive impairment	Mourning routine	Neurorehabilitation center	A group receiving prompting and a group without prompting were compared in a randomized controlled trial	The group with prompting performed significantly better than the control group
Pinard *et al.* (2019) Canada	3 participants with mild to moderate cognitive impairment	Cooking tasks	Smart apartments	Recording of prompting effects during the technology development's stages	Participants resumed safe and independent meal preparation with prompting
Context-aware, mediated computer prompting					
Seelye *et al.* (2013) USA	47 participants with mild cognitive impairment	Cooking and other daily tasks	Smart home testbed	Recording of the participants' task performance with prompting	Prompting was effective in helping participants perform the tasks
Jean-Baptiste *et al.* (2017) UK	12 participants with mild or moderate cognitive impairment	Making tea	Laboratory setting	Comparing task trials with prompting with task trials without prompting	10 participants reduced the number of errors made when assisted with prompts
Braley *et al.* (2019) USA	13 participants with very mild to moderate dementia	Cooking, household chore and other daily tasks	Smart home testbed	Video-recordings and observers' descriptions of participants' performance with prompting	Tasks that participants could not perform were often completed with the help of prompts
Wang *et al.* (2019) USA	16 participants with mild or moderate cognitive impairment	Two cooking tasks	Cueing kitchen testbed	Comparing task performance with prompting and with a self-operated tablet via a randomized cross-over design	Computer prompting was more effective than self-operated tablet prompting for 12 participants

(*continued*)

Table 1

Studies and countries of origin	*Participants with dementia or cognitive impairment*	*Tasks targeted*	*Setting*	*Assessment methods*	*Data reported on task performance*
Tele-operated robot prompting					
Begum *et al.* (2013) Canada	5 participants with mild to severe dementia	Washing hands and making tea	Simulated home context	Video-recordings of participants' performance with prompting and participants' interviews	Data on making tea showed that 2 participants succeeded in completing the task with prompting
Begum *et al.* (2015) Canada	10 participants with mild to severe dementia	Making tea	Simulated home context	Video-recordings of task performance with the prompting system and post-intervention interviews	No data reported on task performance
Rudzicz *et al.* (2015) Canada	10 participants with mild to severe dementia	Making tea	Simulated home context	Video-recordings of the participants' interactions with the prompting system and interviews about it	No data reported on task performance
Wang *et al.* (2017) Canada	10 participants with mild to severe dementia	Washing hands and making tea	Simulated home context	Interviews of participants about the prompting system	No data reported on task performance
Self-operated augmented reality prompting					
Rohrbach *et al.* (2019) Germany	10 participants with mild or moderate dementia	Making tea	University-affiliated center	Comparing task performance with prompting and with a natural condition via a cross-over design plus participants' interviews	No significant performance differences were reported between the two conditions
Wolf *et al.* (2019) Germany	6 participants with mild cognitive impairment	Cooking pancakes	Therapy center's kitchen	Comparing task performance with prompting and with paper cues plus questionnaire and self-reports	5 participants required lower levels of caregiver's help in the prompting condition
Self-operated computer or tablet prompting					
Boyd *et al.* (2017a) UK	12 participants with mild or moderate dementia	Food and drink preparation and other daily tasks	Home	Interviews of participants to get their opinion about the prompting system and to evaluate goal achievement	Participants fully or partially managed 16 of the 24 goals/tasks targeted
Boyd *et al.* (2017b) UK	9 participants with mild or moderate dementia	Card-and-envelope, CD player, plus a chosen task	Home	Comparing the impact of different prompting strategies on task performance	Participants' task performance could require some caregiver's support across all strategies
Evans *et al.* (2020) UK	23 participants with mild or moderate dementia	Food preparation, telephone use and other daily tasks	Home	Interviews of participants about the prompting system and goals	22 participants were reported to benefit from tablet prompting
Harris *et al.* (2020) UK	11 participants with mild or moderate dementia	Food preparation, telephone use and other daily tasks	Home	Participants' ratings of their success in using the prompting system and reaching goals	8 participants were reported to benefit from tablet prompting
Time-based computer, tablet or smartphone prompting					

(*continued*)

Table 1

Studies and countries of origin	*Participants with dementia or cognitive impairment*	*Tasks targeted*	*Setting*	*Assessment methods*	*Data reported on task performance*
Lancioni *et al.* (2010) Italy	11 participants with mild or moderate dementia	Food, coffee and table preparation tasks	Day center	Baseline followed by the prompting condition according to multiple baseline designs across participants or tasks	Prompting promoted percentages of correct task performance exceeding 85%
Lancioni *et al.* (2012) Italy	3 participants with moderate dementia	Food and drink preparation and other daily tasks	Day center	Comparing the effects of various prompting conditions through alternating treatments designs	All prompting conditions promoted percentages of correct task performance exceeding 90%
Perilli *et al.* (2013) Italy	8 participants with mild or moderate dementia	Food, coffee and table preparation tasks	Nursing home	Comparing the effects of various prompting conditions through alternating treatments designs	All prompting conditions promoted percentages of correct task performance exceeding 85%
Lancioni *et al.* (2013) Italy	3 participants with mild or moderate dementia	Food and coffee preparation tasks	Day center	Baseline followed by the prompting condition according to a multiple probe design across tasks	Prompting promoted percentages of correct task performance of about 90%
Lancioni *et al.* (2014) Italy	4 participants with moderate dementia	Food, coffee or tea preparation tasks	Day center	Baseline followed by the prompting condition according to a multiple probe design across tasks	Prompting promoted percentages of correct task performance nearing or exceeding 85%
Lancioni *et al.* (2017) Italy	8 participants with mild or moderate dementia	Food and drink preparation and several other daily tasks	Day center	Baseline followed by the prompting condition according to a multiple baseline design across participants	Prompting promoted percentages of correct task performance nearing or exceeding 90%
Lancioni *et al.* (2018) Italy	8 participants with mild or moderate dementia	Food and drink preparation and several other daily tasks	Day center	Baseline followed by the prompting condition according to a multiple baseline design across participants	Prompting promoted percentages of correct task performance nearing or exceeding 90%
Hackett *et al.* (2020) Canada	10 patients with mild cognitive impairment or dementia	Drink task	Research laboratory	Comparing the prompting condition with a non-prompting condition according to an AB sequence	Prompting led the participants to complete the task more than 90% of the times

comparisons of various prompting strategies or of a prompting strategy with other conditions without specifying the design used and video recordings of prompting trials, interviews or self-rating. The following paragraphs summarize studies that clearly illustrate the different types of technology systems available and some of their applications.

Context-aware, automatic computer prompting

The eight studies using this type of technology have set up systems capable of monitoring the participants' responses and determining the kind of prompting to provide to help the participants' successful task performance. For example, Hoey *et al.* (2010) and Czarnuch *et al.* (2013) used a system known as Cognitive Orthosis for Assisting aCtivities in the Home (COACH; see Mihailidis *et al.*, 2008) to help participants with mild to severe dementia to wash their hands successfully. The system involves a video camera mounted above a sink, which feeds a tracking device (following the position of hands and towel), an evaluation unit that estimates the progress of the participant in the task and an intervention unit that translates the information on progress difficulties into action. Action may involve an audio or video prompt or a call for human assistance. Hoey *et al.* (2010) adopted an ABAB (in which baseline and system use were alternated) but did not report specific data as to the level of improvement in handwashing the six participants of their study achieved with the help of the system. Czarnuch *et al.* (2013) reported that the 20 participants included in their study completed 206 of the 246 steps available in the trials recorded (83.7%). The system correctly identified 96 of those steps (39.0%) as completed, while it failed to correctly identify the other 110 steps completed (44.7%).

O'Neill *et al.* (2018) used a system called Guide to support the morning routine of 10 people with mild to moderate cognitive impairment due to brain damage. The Guide system relies on a computer with a voice tracker, speech recognition software, activity protocols and activity protocol player. Specifically, the computer entails audio-verbal interactive forms of prompting emulating the verbal prompts and questions that are characteristically used by staff. During the morning routine, the system was set up to present the participants with a variety of step-related checks (questions) and instructions/prompts. Staff intervention was used when the participants failed to make progress in their performance. Data indicate that the system had a beneficial impact. In fact, the 10 participants using the system were able to complete the routine with a significantly smaller number of staff interventions than counterparts randomly assigned to a control group not using the system.

Context-aware, mediated computer prompting

The four studies using this technology model, like those of the previous group, seek to monitor the participants during task performance and to provide them with the type of prompts that are matching their performance needs. In contrast to the studies of the previous group, however, these studies do not deliver the prompts automatically. Essentially, they rely on sensors technology to monitor the participants' task behavior and need of prompts and human supervisors to approve or activate the prompts to be delivered. For example, Wang *et al.* (2019) carried out a study aimed at supporting 16 participants with mild to moderate cognitive impairment (secondary to traumatic brain injury) in performing two cooking tasks. The experimental kitchen included an integrated sensor network and prompting elements, which allowed monitoring the participants' behavior and to deliver verbal and visual prompts subject to confirmation/approval from a human supervisor. The authors compared the effectiveness of this prompting model with the effectiveness of an iPad Mini, which required the participants to activate prompts on their own, according to a randomized cross-over design. Task performance data indicate that the participants required a significantly lower amount of assistance from the investigator with the context-aware system than with the self-operated iPad. The system proved relatively accurate, thus requiring mere supervisor's approval, regarding prompt

decisions based on contact switch sensors (e.g. decisions based on the participants' opening/closing cabinets and drawers). Decisions based on power consumption and Kinect sensors were less accurate (i.e. only about 60% of them were correct) asking for the supervisor's specific/corrective input.

Tele-operated robot prompting

The four studies carried out to ensure this form of prompting rely on human supervisors to operate the robot's prompts in relation to the participants' needs as determined by the monitoring process. For example, Begum *et al.* (2015) carried out a study involving 10 participants with mild to severe dementia who were informed that the robot's movements, speech and orientation/pointing were controlled by a researcher (teleoperator). The participants were asked to interact with the robot (and use its help) while making a cup of tea in the kitchen of a simulated home. The teleoperator continuously monitored the participants' task progress and their overall mood conditions in a video stream sent by the robot and made the robot initiate social conversation, ask task-related questions, provide confirmations and deliver prompts to guide the participants toward successful completion of the tea-making task. The robot enabled the participants to start the task steps but delivered the appropriate prompts if the participants looked around or asked for directions. The prompts could vary from a suggestion to a direct verbal instruction plus a video display. If a participant asked a question about the location of an item needed for a specific step, the robot indicated the place by orienting to it. Data on task performance are not specifically reported. The authors' analysis of task video recordings and post-intervention interviews focused on a number of participants' behaviors such as interaction, natural dialogue and emotion. Such an analysis was extended by Rudzicz *et al.* (2015), who concentrated particularly on the communication between participants and robots to identify difficulties that need to be addressed.

Self-operated augmented reality prompting

The two studies using this type of technology follow the view that augmented reality instructions/prompts might be advantageous over paper-based and screen-based instructions (Lin *et al.*, 2016). They used a head-mounted display (i.e. Microsoft HoloLens) to visually present the instructions/prompts and guide the participants through the task steps (Rohrbach *et al.*, 2019; Wolf *et al.*, 2019). For example, Rohrbach *et al.* (2019) developed a prompting application installed on a HoloLens to enable participants with mild and moderate dementia to prepare a cup of tea. A prompt consisted of a holographic simulation of the corresponding step projected on the head-mounted display that the participants wore during the tasks. The holographic simulation was supplemented by a young female voice instructing the participant about the step illustrated by the hologram (i.e. to be performed) and the appearance of the corresponding written instruction. The participant could proceed to the next step by uttering the word "Next." In total, 10 participants were involved in carrying out the task via the augmented reality application and a standard condition (i.e. without such application) according to a cross-over design. Data show that seven participants managed to carry out the task with the augmented reality application. This performance was not statistically different (not more satisfactory) than that observed in the standard/control condition.

Self-operated computer or tablet prompting

The four studies carried out to set up and evaluate this form of prompting stress the importance of simple technology that can be used in daily (home) contexts. Early work by Boyd *et al.* (2017b) was essentially directed at developing a simple prompting product that could be adjusted by a caregiver to fit the functioning level of participants with mild or

moderate dementia so as to help them carry out multistep tasks independently at home. Their study compared four types of prompting, that is, written text, verbal prompts, picture prompts and video prompts. The prompts were displayed on the touchscreen of a tablet. The nine participants were to try each of the prompts on different tasks. Together with the evaluation of the various types of prompting, the authors also assessed the possibility of using a touch/push area on the screen to enable the participants to move to the next prompt for the next task step. With regard to the prompts, the authors reported that written text and verbal instructions were more effective with one of the two tasks directly evaluated while no differences among prompts were found with the second task. The touch/push area on the screen was a viable means to allow access to prompts. Task performance data suggest that participants could still require some caregiver support to complete the tasks. Harris *et al.* (2020) extended the work just described by assessing whether caregivers and people with dementia could manage to use a prompting package (i.e. a tablet and a manual) without any previous training on it. Their preliminary data seem quite encouraging in that eight of 11 participants with dementia had some improvement in their task performance (Harris *et al.*, 2020).

Time-based computer, tablet or smartphone prompting

The eight studies using this approach are based on the view that providing participants with task step prompts occurring at preset intervals (i.e. at intervals deemed appropriate to enable the participants to complete the steps being prompted) may be advantageous as compared to asking the participants to operate their own prompting (Lancioni *et al.*, 2011). Indeed, a system-based prompt delivery spares the participants from the need of operating their prompts (i.e. from an extra demand on their weakening memory function). Programming the intervals between prompts based on the participants' performance pace is critically important to secure a timely occurrence of the prompts and enhance the prompts' efficacy. For example, Lancioni *et al.* (2017) evaluated such an approach with eight participants with mild to moderate dementia using a non-concurrent multiple baseline design across participants. For each participant, 12 or 14 daily tasks of practical relevance were selected (e.g. preparing coffee, setting the table and watering plants). The technology included a tablet device with a Talking Alarm Clock application and a wireless Bluetooth earpiece through which the participants received the tablet's verbal outputs. Specifically, the tablet was programmed to remind the participants of any specific task at the time when the task was due, provide prompts for the task steps and deliver encouragement and praise in between prompts to foster their motivation to remain active and accurate. The task performance data indicate that the participants started (virtually) all tasks independently in relation to the tablet's reminders and carried out nearly or more than 90% of the task steps correctly following the tablet's prompts.

Discussion

Supporting the independence of people with dementia or acquired cognitive impairment in performing functional tasks is one of the main goals of behavioral interventions. The aim of this paper was to provide an overview of technology-based prompting systems to promote independence in daily tasks that require the execution of a sequence of steps (i.e. multi-step tasks). In light of the findings of this scoping review, it is relevant to discuss the prompting systems reported in terms of complexity and readiness for use within applied contexts. Regarding the complexity aspect, one could divide the systems into at least two groups. The first group would involve the more sophisticated systems, that is, context-aware, automatic computer prompting, context-aware, mediated computer prompting, teleoperated robot prompting and self-operated augmented reality prompting. The second group would include the remaining two systems, which are much simpler.

Complex systems

If one examines the COACH system, for example, the first consideration is that it is aimed at providing appropriate prompting to the participants in an automatic and independent manner. Such an objective is based on the use of monitoring devices that inform the prompting system as to the participant's progress or difficulties and cause such system to provide the prompting the participant requires at any particular point of the task sequence. While this approach has been proven promising in earlier studies (Mihailidis *et al.*, 2008), the accuracy of the monitoring process (i.e. the dependability of the intelligent judgment of the system) may not yet be viewed as satisfactory. The data provided by Czarnuch *et al.* (2013) with regard to the COACH's accuracy in identifying task steps completed are an indication of the problem and pose questions as to the system's readiness for general use. Whether the problem noticed with COACH (i.e. a system based on visual monitoring) might be less serious in a system such as Guide (i.e. based on verbal monitoring) is not known. It should also be pointed out that the data reported on task performance need to be taken with caution due to methodological issues such as the involvement of small numbers of participants or the use of observational data.

Context-aware, mediated computer or robot prompting systems might be viewed as technology packages, which have achieved different levels of development. For example, the computer prompting system described by Wang *et al.* (2019) appears to be at an advanced stage of development compared to other systems. In fact, the authors' evaluation goal was to determine how much human supervision the system still required and what obstacles needed to be overcome to make it function independently. The robot prompting system described by Begum *et al.* (2015) and Rudzicz *et al.* (2015) appears to be at a lower stage of development. The experimental work was focused on determining how functional the robot might be in guiding the participants through the tasks, but the robot was still operated by a human supervisor. That means no evidence exists as to whether the robot can move and provide accurate prompting based on environmental information (i.e. ambient sensors and participants' verbal and physical behavior). Data on task performance (reported by all studies using mediated computer prompting and one of the robot-based studies) may need to be viewed with caution, as only Wang *et al.* (2019) used a clear experimental design.

The self-operated augmented reality prompting systems appear less complex than the previous systems. Yet, their readiness for use is difficult to judge due to the exploratory nature of the studies conducted and the uncertainty as to the willingness and ability of people with dementia or cognitive impairments to adapt to the unnatural interaction with the holographic system (Rohrbach *et al.*, 2019; Wolf *et al.*, 2019).

In light of the comments made above, one might argue that the complex systems have significant potential but need to undergo further developments and/or assessments before they can be considered suitable and ready for use in daily contexts. Those developments would need to make the systems function independent of human inputs, have a level of accuracy sufficient to improve the participants' task performance significantly, have an application cost that is affordable for daily contexts and be acceptable to the participants and their caregivers (Wang *et al.*, 2017).

Simple systems

Self-operated computer or tablet prompting appears the simplest system of all. Indeed, such a system is particularly straightforward for caregivers to set up and seemingly helpful for supporting the participants' task performance. One more advantage of this system is that it is highly affordable in terms of cost and suitable for home environments (Evans *et al.*, 2020). A question one might raise about this system is that the need to operate the prompting may be a progressively significant burden on the participants' memory function.

This function, which grows weaker in people with more severe forms of cognitive impairment and dementia, may become insufficient to guarantee that the participants operate the prompts reliably, and thus maintain reasonably high levels of correct task performance (Chang *et al.*, 2013; Lancioni *et al.*, 2017).

Time-based computer, tablet or smartphone prompting may be viewed as a system complementary to the self-operated prompting mentioned above. Time-based prompt delivery provides the participants with a regular stream of prompts related to the different steps of the tasks to be performed. This programmed prompt availability spares the participants from the need of operating the prompts and allows them to fully concentrate on the task-step performance those prompts are meant to support. A difficulty inherent to this system concerns the identification of adequate intervals between prompts. To tackle this difficulty, one would need to ensure that the intervals are set up for each participant following preliminary observations of the time the participant requires for the single task steps and the intervals are re-adjusted over time if the participant's performance speed changes. Although these measures cannot be a guarantee of errorless performance, they can increase the likelihood of success and heighten the participant's level of satisfaction (Lancioni *et al.*, 2018).

In light of the aforementioned comments and the performance data reported, one could argue that those systems represent a viable option for daily contexts. Indeed, they may constitute the only realistic option at this point in time given the fact that the more complex/sophisticated systems may not be ready or accessible for daily use. It may also be noted that the simple systems would be largely affordable and easy to transport, while the more sophisticated systems would reasonably be rather expensive, as well as difficult to move across settings.

Limitations

Two limitations of this paper may be underlined. First, the focus on articles written in English may have prevented the inclusion of pertinent studies reported in other languages. Second, although the search strategy we used has been refined over a series of pilot searches to ensure comprehensiveness, the exclusion of relevant databases such as the Association for Computing Machinery (ACM) Digital Library might have reduced the number of articles eventually identified. Notwithstanding this latter limitation, the combination of academic databases used for this review is generally considered adequate to ensure an acceptable outcome (Bramer *et al.*, 2017).

It might also be stressed here that the studies reviewed do not allow to formulate any definite statements about the effectiveness of prompting technology to support independent task performance in adults with dementia or acquired cognitive impairment. This is due mainly to the absence of clear experimental designs in many of the studies and to the rather small sample sizes involved.

Conclusion

Six technology systems to support multistep task performance in people with dementia or cognitive impairment were analyzed:

1. context-aware, automatic computer prompting;
2. context-aware, mediated computer prompting;
3. teleoperated robot prompting;
4. self-operated augmented reality prompting;

5. self-operated computer or tablet prompting; and
6. time-based computer, tablet or smartphone prompting.

The first four systems involve sophisticated technology arrangements while the last two are based on rather simple technology solutions. Application of the complex systems in daily contexts would require new developments of such systems capable of increasing their accuracy, ensuring their functioning independent of staff and making them affordable, as well as acceptable to participants and caregivers. The relatively positive task performance data reported for the simple systems suggest that they may represent the only realistic option for daily use at this point in time. In fact, notwithstanding their limits, they may provide a meaningful level of support at a very modest cost and with minor operational difficulty. New research will need to advance the development of the complex systems (with the aim of making them suitable for use in non-experimental settings) and extend the evaluation of the simple systems and possibly upgrade them to increase their applicability in daily contexts and their impact on the lives of people with cognitive impairment or dementia, as well as on the lives of their caregivers.

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