Original research

The design of intelligent in-home assistive technologies: Assessing the needs of older adults with dementia and their caregivers

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S.Czarnuch, A. Mihailidis. The design of intelligent in-home assistive technologies: Assessing the needs of older adults with dementia and their caregivers. Gerontechnology 2011; 10(3):169-182; doi:10.4017/gt.2011.10.3.005.00 **Objective**: To determine the needs of older adults with dementia and their family caregivers during Activities of Daily Living (ADL), and the role of intelligent assistive technology (AT) in supporting these needs. **Methods** An 85 item questionnaire was administered to family caregivers of older adults with dementia exploring: (i) challenging ADL for an older adult with dementia to complete independently, (ii) difficult ADL for a caregiver to assist, (iii) the role of AT supporting ADL completion, and (iv) the features and functions of in-home AT designed to support ADL. **Results** Respondents (n=106) indicated the person they care for has partial ability to complete ADL, that private tasks (e.g., showering) are difficult to assist, and that AT designed to support ADL must be autonomous, familiar, simple and unobtrusive. Respondents also showed little knowledge of existing AT that support ADL. **Conclusions** Designers of AT should focus on supporting caregivers and older adults with dementia in the completion of private and personal ADL.

Keywords: needs assessment, family caregiver needs, Activities of Daily Living

The world's population is aging[1] with the fastest growing segment being those aged 80 or over. Age is one of the leading risk factors associated with Alzheimer's disease – a form of dementia[2]. Thus, as the world's population ages the number of cases of Alzheimer's disease will also increase. It is estimated that 4.3 million people in North America and 35.6 million people worldwide had Alzheimer's disease in 2010[3]. By 2050, researchers estimate 11 million people in North American and over 115 million people worldwide will be living with Alzheimer's Disease[3]. Based on these estimates, the health care costs associated with dementia will soon become unsustainable and the need for informal care will increase considerably. In 2010, the cost of dementia globally was estimated at $604 billion[4]. Based on predicted increases in prevalence rates alone, by 2030 costs are expected to increase by 85%[4]. However, there remains a need to preserve the independence, autonomy and quality of life of older adults with dementia, and to relieve the burden of care experienced by informal caregivers by addressing the functional limitations of older adults with dementia, supporting the current health care system without sacrificing quality of care, and maintain the standard of living of both the person with dementia and the caregiver. One potential solution is to support older adults with dementia and their caregivers with technology, though the actual use of technology tends to shift from the older adult to the informal caregiver over time[5], reducing the utility of

the device. However, a substantial amount of interest has recently been directed toward the development of intelligent technologies that support aging in place – devices that support cognitive deficits while reducing caregiver burden[6] – increasing the likelihood of their use.

SUPPORTING COGNITIVE DEFICITS

Emerging technologies have been designed to support individuals with decreased cognitive abilities resulting from dementia. Such technologies range in function from low technology aids (e.g., medication pill organizers, schedules and notes) to higher technology aids (e.g., intelligent assistive devices that are contextually aware and can provide help when appropriate)[6]. Advances in computer hardware and software, particularly in the domains of computer science and engineering have improved the reliability, affordability and capability of intelligent devices. Accordingly, intelligent devices are increasingly investigated by researchers as potential tools to assist people with dementia who struggle with a range of cognitive disabilities[6].

Intelligent assistive technologies (AT) have been created to compensate for the loss of memory[7-12]; and executive function[9-11,13], and show potential for application to older adults with dementia. Intelligent AT such as the Autominder[7,8] and the Memory Glasses[12] are context-aware memory aids because they provide timed reminders to users as determined necessary by the systems. These systems employ artificial intelligence to detect when a user may have forgotten a required activity and if a reminder should be issued. In addition to time-based reminders, the Memory Glasses also aid in memory recall deficits (e.g. amnesia, Alzheimer's disease, agnosia or prosopagnosia) that cannot always be corrected with simple scheduling. The ISAAC system[9] acts as a problem solving aid during scheduled reminders through the use of a sequential checklist that outlines the steps required to successfully complete an activity. Systems such as the PEAT[10] and Essential Steps[13] go beyond contextually sensitive memory aids by providing planning and organizing support[10,13]. Recently, the PEAT was further extended[11] to include sensor data from global positioning systems (GPS), radio frequency identification (RFID) tags and pressure mats to reduce the amount of explicit, user-initiated feedback required by the original system and to allow the system to infer user activities.

Intelligent assistive devices have also been used to support independent navigation[14-16]. Commercially available positioning and navigation systems (e.g., GPS) provide the same type of directions (e.g., small visual display, audio prompts) regardless of the users capabilities, and typically cannot provide the specific assistance required by a person with dementia. Systems such as the navigation tools developed as part of the Assisted Cognition project[14,15] provide GPS functionality to cognitively impaired users. Customized user interfaces and artificially intelligent decision making enable people with cognitive challenges to navigate outdoors without requiring implicit user input. Other devices such as the Robotic Walker[16] and intelligent anti-collision wheelchair[17] provide indoor navigation assistance, automatically determining the user's position and alerting the user about obstacles or hazards.

ACTIVITIES OF DAILY LIVING

Arguably one of the most desirable applications of intelligent assistive technology is as a tool to support an older adult with dementia through activities of daily living (ADL), particularly because support for these tasks is often provided by informal, unpaid care[5]. Logsdon, McCurry & Teri[18] summarized several studies where people with dementia reported the ability to independently complete ADL significantly affected his or her quality of life. Wimo, Winblad & Jonsson[19] found that caregivers provide care by providing supervision and supporting ADL. They separated ADL support further into two categories: personal activities of daily living (PADL) or fundamental tasks, and instrumental activities of daily living (IADL) or more advanced daily tasks. A comprehensive review of 27 studies on caregiver burden revealed that in

high income countries caregivers of people with dementia spent an average of 3.7 hours per day supporting ADL (1.6 hours for PADL and 2.1 hours for IADL)[19]. The effect of this demand on caregivers is increasingly evident in the costs associated with the provision of informal care[5] and through reports of caregiver strain (e.g., physical illness, psychological problems and depression)[3].

Accordingly, the development of AT for recognizing and supporting ADL has become a central research area with the goal of maintaining a person's ability to independently complete ADL as well as reducing the burden experienced by his or her caregiver. An example of such a system is the COACH[20,21], an intelligent AT designed to help a person with dementia progress through the task of handwashing without assistance from a caregiver. An overhead camera unobtrusively tracks the positions of a user's hands as well as environmental objects such as the towel. The system uses artificial intelligence to determine whether an intervention is required based on the user's progress through the task, taking into account uncertainty in the observations provided by the camera as well as estimations of the user's cognitive state. Interventions are provided through a combination of audio and/or video prompts that vary in specificity according to the user's responsiveness to the system. A second intelligent AT, a type of technology assistant[22] was designed to support older adults using a blood glucose meter. This device uses a camera to track the user's hands, blood glucose meter, testing strips and liquid bottle. The camera information is interpreted as progress through the explicitly coded task, and feedback is provided if the user makes any mistakes. A third system, the Ambient Kitchen[23] employs an array of physical inputs (e.g., radio frequency ID tags, accelerometers and pressure sensors) and six integrated cameras to detect kitchen activity and provide assistance as needed. Both audible and visual cues are provided throughout the kitchen using speakers and video projectors. The Ambient Kitchen provides an extensive test bed for developing and testing various intelligent AT.

USER-CENTRED DESIGN

Despite the wide range of AT in development to support people with dementia or their caregivers, few of these intelligent AT have progressed beyond the initial development stage (e.g., a recent review of 58 technologies highlighted only three devices that have undergone clinical trials and none had entered real-world testing)[6]. As such, the appropriateness of many of these devices as tools to support the needs of people with dementia and their caregivers remains in question. To facilitate the process of developing usable AT, we need to understand the needs of cognitively disabled users[24] – fundamental if the end goal is to develop tools that support older adults with dementia[25].

Recently a small number of studies have looked specifically at AT as tools to support ADL. Wherton & Monk[26] conducted two small-sample interview studies investigating which daily activities in the home were most important to caregivers and the person they care for. The first study investigated opinions of professional caregivers with semi-structured interviews (n=9) and a follow-up focus group (n=20); the second study interviewed caregiver–person with dementia pairs (n=9). A grounded qualitative analysis identified the category 'daily activities' within the core theme 'Problems in the Home' which found that the ADL most in need of support were dressing, taking medication, personal hygiene, food and drink tasks, and toileting. In a cross-sectional post-analysis of a Medicare beneficiary survey in the United States, Dudgeon, et al.[27] found that people with dementia needed support with heavy housework, walking, shopping and money management while caregivers desired help assisting with walking, bathing and toileting. The varying results of these studies suggest that more information is required to generalize these needs into a foundation for the development of intelligent AT for older adults with dementia.

Determining the needs of technology users for developing technological products has a well-established history in industry. Industrial

tools such as Quality Function Deployment (QFD)[28], the stage-gate model[29] and Design for Six Sigma[30] are developed principles promoting solutions driven by end users of a product or process. In the development of AT an analogous approach (though much less developed or systematic) called User Centred Design (UCD), has recently emerged[31-33]. The UCD approach involves actively identifying the needs of users, which are then synthesized into technical design criteria using tools such as QFD and used to develop a functional, testable prototype. The efficacy of the prototype is later tested in a real-world environment, with the results iteratively cycled back into the design criteria and development stages. The main difference between the UCD process and more typical design philosophies used by AT developers is that the end users are involved in all stages of the process, not just during the needs assessment stage.

Recent work has seen the first iterations of a UCD approach toward the successful development and deployment of AT to support people with dementia. The Keep In Touch Everyday project conducted a needs assessment of people with dementia and their caregivers, developed two prototype devices to help increase independence for people with dementia, and conducted two simple trials with participants of the UCD[33]. Kinney, et al.[34] also examined how AT can assist caregivers of people with dementia, finding safety was their primary concern followed by the person with dementia maintaining their pre-illness lifestyle. Based on these two needs a commercially available internet-based monitoring system was installed in a trial home and tested by the participants with generally positive evaluations. The Bath Institute of Medical Engineering recently completed an entire iteration of the UCD project to design and evaluate entire smart-home systems for people with dementia[35]. The study identified safety, task guidance (through prompting) for cooking, toileting and bathing, and social connectivity for family and friends as most desired. Familiarity, caregiver emulation and user control were also identified as critical for successful adaptation. Several de-

vice prototypes were developed and tested, revealing that device usability and robustness, as well as careful user-interface considerations were critical to device acceptance. Perhaps the most substantial project to employ a UCD approach is the COGKNOW project[31] which, through focus groups and workshops, found that caregivers and people with dementia desired AT that reinforced memory, socialization, ADL support and safety. Emphasizing the development of a commercial product, the study followed a UCD approach to produce a complete system to support these needs. The system was installed and tested in the homes of 16 people with dementia, highlighting several successes and failures that will be integrated into additional UCD cycles. However, these projects are few in number and provide data from a small number of participants making it difficult to generalize the needs into something useable by intelligent AT developers.

THE CURRENT STUDY

The market for technology to support older adults with dementia is rapidly growing, largely because the prevalence of dementia is rising dramatically while the ratio of caregivers to older adults with dementia is becoming less favorable. Yet technology developers have little data beyond preliminary user needs assessments to identify the technology needs of older adults with dementia, let alone to determine the efficacy of developed devices. This research presents the results of a user needs assessment – the first stage of a user-centered design process looking to extend the COACH beyond clinical trials into an intelligent AT that works in the homes of older adults with dementia. Toward this end, the study contributes to the extension of the COACH and to the development of other intelligent AT by identifying the needs of older adults with dementia and their caregivers during ADL completion and determining valued features and functions of in-home AT. In doing so, this paper addresses four key research questions:
(i) What ADL do people with dementia struggle with while trying to complete independently?

(ii) What ADL do informal caregivers of people with dementia struggle with to support?
(iii) Can intelligent assistive technology play a role in supporting ADL completion?
(iv) What features and functions are required for an in-home intelligent assistive technology in order to facilitate its acceptance?

METHODS

Purpose

A pilot questionnaire was designed to explore which ADL are challenging for an older adult with dementia to complete independently, which ADL are difficult for a caregiver to assist, the role of intelligent AT as a tool to support ADL completion, and the features and functions of an in-home AT designed to support the completion of ADL. The study sought to elicit views of family caregivers, defined as any person providing care without financial compensation, as well as to identify the needs of older adults with dementia from the perspective of the caregiver.

Participants

Participants were recruited in five ways. First, information about the study and online questionnaire was posted on internet message and discussion boards serving caregivers of older adults with dementia (e.g., American and Canadian Alzheimer Associations). Second, emails were sent out through caregiver email lists. Third, caregivers were contacted through formal advocacy and care organizations located in the Greater Toronto Area (Ontario, Canada). Fourth, ads were posted in caregiver resources such as newspapers and newsletters for caregivers. Lastly, respondents were informed of the study via word-of-mouth from respondents contacted through the previous methods. Respondents were included in the study only if they were currently a primary, informal caregiver of a person with dementia.

Materials

The exploratory 94 item online questionnaire was constructed, including demographic questions, based on our research questions[36]. ADL were explored through 54 items constructed based on the results obtained in other similar studies[26, 27, 31] in three categories (18 items in each): Independent ADL completion by a person with dementia; Caregivers assisting with completion of ADL; and Supporting ADL with intelligent Assistive Technology. In addition, features and functions of AT as tools in the home were explored through 24 items constructed using face validity as other studies or scales to measure this don't exist. In this category multiple items were constructed to facilitate post-analysis validity and reliability tests[37]. Four additional items (e.g., "What is your relationship to the person you are caring for?") identified the respondent's relationship to the older adult with dementia. The questionnaire was initially reviewed by an expert in the field of intelligent AT designed to support ADL completion, validated by members of the research team, piloted by students in an academic research lab and then piloted by three caregivers of older adults with dementia.

Caregiver's opinions about their own role in daily tasks as well as the abilities of the person they were caring for were considered in three separate sections: Independent ADL completion by a person with dementia; Caregivers assisting with completion of ADL; and Supporting ADL with intelligent Assistive Technology. Within each section 18 close-ended items presented daily tasks within common PADL and IADL categories[38,39]. For the first section respondents were asked: "Typically, how easily can the person you're caring for complete the following tasks". For each of the 18 items respondents were asked to choose the response that best reflected their belief on a 5 point Likert-like scale ranging from "Cannot complete at all on his/her own" to "Can easily complete on his/her own".

For the second section respondents were asked: "Typically, how hard is it to assist the person you're caring for to complete the following tasks". For each of the 18 items respondents were asked to choose the response that best reflected their belief on a 5 point Likert-like scale ranging from "Very

hard to help" to "Very easy to help". For the final section respondents were presented with the statement: "Assuming technology exists that can help you care for a person with dementia, for the following list of common tasks please circle the answer that best describes your opinion about the technology supporting your care efforts". For each of the 18 items respondents were asked to choose the response that best reflected their belief on a 5 point scale ranging from "Technology can't help me support this" to "Technology can help me support this".

Caregiver's opinions about the features and functions of an in-home AT were assessed through 24 close ended items. Items were constructed within three conceptual categories: physical attributes, functionality, and device cost. For each item respondents were asked to select the response that best represented their belief from the possible responses of 'Strongly disagree', 'Disagree', 'Neutral', 'Agree' and 'Strongly agree'.

Procedure
Ethics approval was granted for the questionnaire by University of Toronto (REB #24637). The questionnaire was posted online on December 14, 2009, and paper copies were distributed on April 30, 2010. Informed consent was required for online respondents in order to continue to the survey, or collected in person before completion of the questionnaire.

Data analysis
The questionnaire data were analyzed using an exploratory factor analysis. Factor analysis is a statistical process that reduces a large number of observed independent variables (survey items) into a smaller number of inferred hypothetical variables called factors[40]. Exploratory factor analysis first determines underlying factors represented in the questionnaire items by assuming that each item may be related to each factor. Each factor is reported as explaining a percentage of the total variance in the data. In other words, each factor represents an underlying quality or belief that may not be intuitively obvious in the original items. Factors were extracted

using Principal Axis Factoring, a technique recommended for exploratory analyses[41]. Following factor extraction rotation was used to simplify the data structure revealing a more clear relationship between each item and the factors. For each factor analysis oblique (Promax) and orthogonal (Varimax) rotation methods were compared. Factors were described by the rotated factor matrix, which shows the factor loadings of each item on each factor. Factors were retained if they satisfied Kaiser's criterion (eignenvalue > 1); were above the elbow of the scree plot; and had at least three items[42].

Items were associated with a factor if the factor loading was greater than the critical value (CV) of 0.505, calculated using the formula $CV = 5.152/Sqrt(n-2)$ and a sample size of n=106[43]. Items were deleted from analysis if they loaded below the critical value or loaded above the critical value on more than one factor after rotation. The reliability of the resulting factors was measured for internal consistency using Cronbach's α[44]. Internal consistency in this context measures whether different scale items assigned to a factor provide the same results.

RESULTS
One hundred and six (106) respondents including professionals, executives, educators, caregivers, members of the military, artists, administrators, self-employed, service workers and retirees participated in the study. The age of respondents ranged from 21 to 77 with an average age of 56, and years of caregiving ranged from six months to sixteen years, with an average of 4.5 years. The majority of the sample reported their relationship to the person they care for as either their child (n=37), family member (n=36) or partner (n=30). Two respondents reported their relationship as friend (n=1) and other (n=1). One respondent did not state a relationship. The sample reported that the person with dementia either shared a residence with them (n=63), lived alone (n=28) or lived in a long-term care facility (n=8). Seven respondents did not state where the person they care for lived relative to themselves.

An initial factor solution was obtained for each of the four survey sections: (i) independent ADL completion by a person with dementia; (ii) caregivers assisting with completion of ADL; (iii) supporting ADL with intelligent Assistive Technology; and (iv) features and functions of an in-home AT. Large Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy (greater than 0.7)[42] and significant Bartlett's Test of Sphericitys (p < 0.05)[42] in all four sections substantiate the use of factor analysis on the items. The factors that satisfied the eigenvalue and Scree plot conditions were identified. The rotation method that produced the least complex items and the most items loaded on factors was selected as the optimal technique[41] and items that were complex (loaded on multiple items) or below the critical value (CV) were removed from the data (*Table 1*). For each section a final factor solution was forced on the items satisfying the inclusion criteria with the number of factors satisfying the three conditions.

Independent ADL completion
In trying to identify which ADL were difficult for a person with dementia to complete using exploratory factor analysis two factors clearly emerged as well-documented ADL categories: PADL (fundamental tasks)[37]

and IADL (advanced daily tasks)[38] (*Table 2*). Looking at the factor means suggest that caregivers believe the person they care for still has some ability to independently complete PADL (M=3.52, SD=1.22) but almost no ability to complete IADL (M=1.58, SD=0.94). The individual item means give some insight into the specific tasks people with dementia struggle with. For example the mean for the PADL 'Getting dressed' (M=2.7) shows that respondents believe the person they care for has some difficulty completing this task. Similarly, low item means for all ADL within the IADL factor indicate that people with dementia struggle with 'Preparing simple meals', 'Cleaning the house' and 'Preparing complex meals'. Conversely, based on higher item means within the PADL factor respondents' believe the person they care for has the ability to partially complete the tasks 'Eating finger foods', 'Drinking', 'Eating with cutlery', and 'Using the bathroom'. For intelligent AT designers this shows that a user's abilities need to be considered when targeting ADL with technologies. For example, devices supporting PADL completion should leverage a user's remaining abilities while devices targeting IADL completion likely need to be more autonomous and provide additional functionality to compensate for the user's lost abilities.

Table 1. Factorability statistics, factors satisfying each of the three inclusion criteria and optimal rotation techniques for each of the four survey sections; ADL=Activities of Daily Living; AT=Assistive Technology

	Independent ADL completion	Caregivers assisting with completion of ADL	Supporting ADL with AT	Features & Functions of an in-home AT
KMO measure of sampling adequacy	0.857	0.848	0.858	0.720
Bartlett's test of sphericity	$\chi^2(153)=1257.681$ p<0.001	$\chi^2(153)=1349.028$ p<0.001	$\chi^2(153)=1412.754$ p<0.001	$\chi^2(136)=894.647$ p<0.001
Eigenvalues >1	5	4	4	5
Factors above the 'elbow' in screen plot	2	4	3	4
Factors with >3 significant items	2	2	3	3
Factors satisfying all three criteria	2	2	3	3
Rotation technique with best results	Varimax	Varimax	Varimax	Promax

Table 2. Rotated matrix factor loadings of 0.505 or higher (Varimax rotation) of independent ADL (Activities of Daily Living) completion;=on a scale of 1(Cannot complete at all on his/her own)-5(Can easily complete on his/her own)*

Item	Mean*	Factor loadings	
		1	2
Eating finger foods	4.2	0.847	
Drinking	4.1	0.900	
Eating with cutlery	3.5	0.770	
Using the bathroom	3.1	0.744	
Getting dressed	2.7	0.645	
Preparing simple meals (e.g., Sandwich, salad)	2.0		0.813
Cleaning the house	1.4		0.667
Preparing complex meals (e.g., Using a stove)	1.3		0.721
Eigenvalue		4.84	1.31
% of variance		43.0	7.47
% of rotated variance		52.9	11.4
Factor mean		3.52	1.58
Standard deviation		1.22	0.94
Reliability (Cronbach's α)		0.92	0.78

Caregivers assisting with ADL

When looking at the challenges faced by caregivers while assisting with ADL, the same two factors emerged from the data: PADL and IADL (*Table 3*). In contrast to the previous section which looked at independent task completion the factor means here indicated that, in general, caregivers do not find it difficult to provide support for PADL (M=3.23, SD=1.19) and IADL (M=3.42, SD=1.42) completion. Looking at the individual item means shows that supporting a person with dementia with 'Remembering to take medication', 'Preparing simple meals', 'Eating finger foods', 'Drinking' and 'Eating with cutlery' was rather easy. Additionally, the item means for tasks such as 'Cleaning the house', 'Having a conversation' and 'Preparing complex meals' showed a somewhat neutral response. However, the item means for more private tasks like 'Getting dressed', 'Washing hands', 'Brushing teeth' and 'Using the bathroom' show they were more difficult to support. This is not surprising as tasks that involve an invasion of privacy (e.g., getting dressed or using the bathroom) or tasks that are typically performed independently throughout one's lifetime (e.g., washing hands or brushing teeth) can be difficult to help a person complete. As such, from a caregiver's perspective tasks that are private and personal are perhaps most desirable for intelligent AT to support.

Table 3. Rotated matrix factor loadings of 0.505 or higher (Varimax rotation) of caregivers assisting completion of ADL;=on a scale of 1(Very hard to help)-5(Very easy to help)*

Item	Mean*	Factor loadings	
		1	2
Remembering to take medication	3.8	0.741	
Preparing simple meals (e.g., Sandwich, salad)	3.5	0.887	
Paying bills	3.4	0.730	
Cleaning the house	3.3	0.800	
Having a conversation with someone	3.3	0.560	
Preparing complex meals (e.g., Using a stove)	3.2	0.848	
Eating finger foods	3.9		0.767
Drinking	3.8		0.822
Eating with cutlery	3.7		0.708
Getting dressed	3.0		0.735
Washing hands	2.9		0.694
Brushing teeth	2.8		0.591
Using the bathroom	2.5		0.643
Eigenvalue		6.0	2.5
% of variance		38.5	14.0
% of rotated variance		43.4	16.0
Factor mean		3.42	3.23
Standard deviation		1.42	1.19
Reliability (Cronbach's α)		0.91	0.89

Supporting with intelligent devices

When considering the role of assistive technology as a tool to support the completion of ADL, three factors were revealed: Hygiene & Personal Care; Food

& Nourishment; and Medication & House-keeping (*Table 4*). The Hygiene & Personal Care factor represented activities typically performed independently and/or in private (e.g., washing hands, bathing, getting dressed). The Food & Nourishment factor was comprised of daily tasks related to food preparation and consumption – tasks that are often performed in more public places and/or with others present. The Medication & Housekeeping factor was comprised of tasks that span a relatively long period of time, requiring longer-term memory and focus. The factor means were all notably low, particularly Hygiene & Personal Care (M=2.54, SD=1.19) and Food & Nourishment (M=2.26, SD=1.25) though Medication & Housekeeping (M=2.92, SD=2.92) was also relatively low. The individual item means for the factor Hygiene & Personal Care were all consistent with the factor mean showing that caregivers think it is unlikely that intelligent AT can support a person with dementia through the ADL 'Brushing teeth', 'Using the

bathroom', 'Washing hands', 'Bathing', 'Getting dressed' and 'Showering'. Within the factor Food & Nourishment the individual item means suggest that caregivers also think it is unlikely that intelligent AT can support 'Drinking' and 'Eating with cutlery', and that 'Eating finger foods' and 'Preparing complex meals' cannot be supported with intelligent AT. Notably, the factor mean for Medication & Housekeeping (M=2.92, SD=2.92) did not represent the item means well. Specifically, the item mean for 'Remembering to take medication' (M=3.4) was higher than the factor mean (M=2.92) and was the only item on in the survey section with a response above average – the only activity caregivers believed intelligent AT could assist.

In-home AT

Investigating the features and functions required for an in-home AT identified three factors: Appearance & Usability; Familiarity & Autonomy; and Technical Expertise (*Table 5*). The Appearance & Usability factor

Table 4. Rotated matrix factor loadings of 0.505 or higher (Varimax rotation) of caregivers assisting completion of ADL;*=on a scale of 1(Technology can't help me support this)-5(Technology can help me support this)

Item	Mean*	Factor loadings		
		1	2	3
Brushing teeth	2.7	0.721		
Using the bathroom	2.7	0.665		
Washing hands	2.6	0.665		
Bathing	2.5	0.827		
Getting dressed	2.5	0.561		
Showering	2.4	0.838		
Drinking	2.5		0.773	
Eating with cutlery	2.5		0.854	
Eating finger foods	2.1		0.822	
Preparing complex meals (e.g., Using a stove)	1.9		0.526	
Remembering to take medication	3.4			0.818
Cleaning the house	2.8			0.812
Paying bills	2.5			0.625
Eigenvalue		6.87	1.77	1.23
% of variance		43.9	9.54	5.92
% of rotated variance		5.60	11.4	7.09
Factor mean		2.54	2.26	2.92
Standard deviation		1.19	1.25	1.35
Reliability (Cronbach's α)		0.92	0.88	0.83

(M=3.04, SD=1.00) represents appearance items (e.g., visibility of computers and wires) as well as usability items (e.g., simple, intuitive technologies). The Familiarity & Autonomy factor (M=3.60, SD=0.91) reflects caregiver's opinions on how the device should blend in with other household items (e.g., be familiar), and how it should adapt to the different members of the home without taking away the user's sense of control. The Technical Expertise factor (M=2.57, SD=0.91) represents the knowledge and experience our caregivers have with technology.

Looking at the individual item means within the Appearance & Usability factor demonstrates that our caregivers want AT that are simple to use and intuitive because they are busy and do not have time to dedicate to learning how to use complicated devices ("I'm busy so I like things to be simple", "I don't have time to play with it"), even though they believe they have the capability to learn ("I'm past the point where I want to learn new things"). Furthermore responses to items such as "It's important I don't see any wires" and "It's important I don't see any computers" suggests that caregivers prefer less physically obtrusive AT – an important feature to consider when designing AT. Within the Familiarity & Autonomy factor high item means for the items "The visual display needs to be large enough to see clearly" and "I want things to look as familiar/normal as possible" highlight a need for in-home AT – especially their user interfaces – to look similar to other devices commonly found in the homes of older adults. High means within the factor for the three items "It needs to recognize different users on its own", "I want to know that I'm in control" and "I envision something revolutionary" emphasize that an in-home AT must be able to autonomously adapt to multiple users without infringing on the users' sense of control. The Technical Expertise factor suggests that caregivers are not overly technical people and have little time to spend learning new technology based on low item means for "I'm a very technical person", "I love to

Table 5. Rotated matrix factor loadings of 0.505 or higher (Promax rotation) of features and functions of an in-home assistive technologies;*=on a scale of 1-5

Item	Mean*	Factor loadings		
		1	2	3
I'm busy so I like things to be simple	3.4	0.721		
It's important that I don't see any wires	3.3	0.790		
I don't have time to play with it	3.1	0.608		
It's important that I don't see computers	3.0	0.884		
I'm past the point where I want to learn new things	2.4	0.646		
The visual display needs to be large enough to see clearly	4.0		0.689	
It needs to recognize different users on its own	3.8		0.526	
I want things to look as familiar/normal as possible	3.7		0.638	
I want to know that I'm in control	3.4		0.725	
I envision something revolutionary	3.2		0.563	
I'm a very technical person	2.9			0.794
I love to play with cutting-edge gadgets	2.7			0.973
I'm always buying new toys and gizmos	2.1			0.522
Eigenvalue		4.13	2.83	1.17
% of variance		24.7	15.1	9.0
% of rotated variance		28.3	19.1	5.5
Factor mean		3.04	3.60	2.57
Standard deviation		1.00	0.91	0.91
Reliability (Cronbach's α)		0.85	0.76	0.80

play with cutting-edge gadgets" and "I'm always buying new toys and gizmos". This is likely an expression of the burden and time demands experienced by caregivers of older adults with dementia.

Reliability

The internal consistency, or degree to which the different items within each factor represent their common factor, was measured for each factor in each section (*Table 6*). High values indicate good reliability, suggesting the items are measuring the common factor.

DISCUSSION

Given these results it appears that caregivers of people with dementia believe the person they care for has at least partial ability to complete many personal activities of daily living (PADL or fundamental tasks) but not instrumental activities of daily living (IADL or advanced daily tasks). They also indicate that assisting with the completion of most PADL and IADL is not overly difficult but that PADL typically performed privately (e.g., getting dressed, using the bathroom, washing hands, brushing teeth) are most challenging to assist. Accordingly our findings imply that intelligent assistive technologies that determine when assistance with a PADL is required, particularly more private PADL, are likely to both reduce the burden on the caregiver and increase the independence and quality of life of the person with dementia. This findings are of fundamental importance for intelligent AT developers as many interventions – both technical and non-technical – tend to shift the burden of care from one individual to another (e.g., from the person with dementia to the caregiver) or reduce

the quality of life or independence of the user (e.g., complete a task rather than allow the user to attempt the task).

When asked to assume "technology exists that can help you care for a person with dementia" our participants overwhelmingly indicated they did not feel technology could help with any of the ADL presented except "Remembering to take medication". As such, caregivers appear to know very little about existing or emergent intelligent AT that have been shown to help with various ADL[20, 31, 33, 35]. However, intelligent AT developers need to consider the role of users in the entire process of device development; not simply in terms of determining user needs to ensure the product is developed appropriately but also to increase the chance of device adoption by users. Central to this objective is adopting a User-Centred Design (UCD) approach [31-33], where users are included in all stages of device development including: needs assessment; idea generation; device prototyping; and efficacy testing. Considering the lack of knowledge caregivers showed about available or emerging intelligent AT, our findings suggest that developers of intelligent AT interested in using a UCD approach must revise existing strategies of recruitment and dissemination of information (which are arguably not working) if caregiver participation and device acceptance is desired, For example, the use of caregiving resources (e.g., caregiver newsletters, websites) or more public magazines (e.g., Popular Science, AARP The Magazine) may spread the word more effectively. Indeed, the lack of penetration of intelligent AT into the general knowledge of the public warrants a more comprehensive study to understand the barriers preventing this knowledge translation.

Table 6. Reliability statistics (Cronbach's α) of each factor for each of the four survey sections; ADL=Activity of Daily Living; AT=Assistive Technology

Survey section	Factor loadings		
	1	2	3
Independent ADL completion	0.921	0.779	-
Caregivers assisting completion of ADL	0.905	0.887	-
Supporting ADL with AT	0.920	0.884	0.830
Features and functions of an in-home AT	0.845	0.762	0.798

We also investigated needed features and functions for intelligent assistive technologies designed to operate in the homes of people with dementia. Our caregiv-

ers emphasized that in-home intelligent AT must be able to autonomously adapt to the changing capabilities of a person with dementia and to the different users of the technology. This was substantiated by the fact that caregivers indicated having little time to interact with any sort of AT and were not interested in learning new technologies (even though they thought they were still capable) – again, a reflection of the burden associated with being a caregiver. The caregivers also wanted any in-home AT to be familiar and unobtrusive, presenting an interesting challenge for intelligent AT designers; acquire adequate sensor information and provide useful and intuitive user interfaces without compromising the user's home atmosphere.

This study provides insight into the general needs of older adults with dementia and their caregivers as they participate in ADL together and investigates the role of AT in this relationship, but is important to remember that caregivers in the study acted as proxies for the person they care for. Studies directly involving older adults with dementia as well as studies with a larger sample would increase the generalizability of the findings. Additionally, the exploratory nature of this research compels caution when interpreting these results to rank individual ADL and design features. The exploratory approach was necessitated by a lack of existing scales to measure: the challenges faced by older adults with dementia during ADL completion; the corresponding support challenges faced by their caregivers; and features and functions required by in-home AT. Future studies that adapt existing ADL scales to older adults with dementia [37,38], or the development of new scales specifically designed to measure the burden experienced by caregivers supporting ADL can provide more specific information about individual tasks. The effect of other factors on these results need to be considered, such as the level of dementia of the user, where the user lives relative to the caregiver (e.g., in the same home or alone), the relation (e.g., partner, family, friend) and the genders of both the person with dementia and the caregiver. Dementia level was not a factor included in this study because our respondents acted as proxies for the person they cared for; obtaining this information would either compromise ethical approval (e.g., if MMSE scores existed for the older adult with dementia) or be subjective (i.e., the opinion of the caregiver). The other factors were obtained in this study but could only be included in the analyses with a larger sample size. Larger studies investigating user needs as shaped by these factors, as well as other social factors (e.g., culture) could provide more context and understanding of user needs.

CONCLUSIONS

The ability to independently complete ADL is a critical component of our sense of self and quality of life. However, the loss of cognition associated with dementia compromises one's ability to perform ADL necessitating support from a caregiver; a role typically filled by a family member or friend. Accordingly, interest in the development of intelligent AT designed to support people with dementia and their caregivers has increased, but the specific needs of these users are not well known. This study investigated the needs older adults with dementia and their caregivers have for intelligent assistive technologies. Findings suggest that older adults with dementia still have at least partial ability to participate and complete ADL, that caregivers find private tasks (e.g., showering) are difficult to assist, and that in-home intelligent assistive technology must be autonomous, familiar, simple and unobtrusive. Based on these results, intelligent assistive technology developers should focus on devices that can support caregivers and older adults with dementia in the completion of private and personal tasks – where the most help is necessary.

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