Understanding the Potential for Robot Assistance for Older Adults in the Home Environment

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Executive Summary

Robots with a wide range of capabilities are being developed that could provide assistance for older adults to perform activities of daily living. Robots have the potential to support the various physical, perceptual, and cognitive aspects of tasks of everyday living. The overall goal of the current literature review was to understand how robots can support older adults' independence by assisting with difficult tasks in the home environment.

Older adults prefer to age in place (AARP, 2005). However, there are many tasks that older adults must perform to maintain their independence and health, including self-maintenance, instrumental, and enhanced activities of daily living (Lawton, 1990; Rogers, Meyer, Walker, & Fisk, 1998). Self-maintenance activities of daily living (ADLs) include the ability to toilet, feed, dress, groom, bathe, and ambulate. Instrumental activities of daily living (IADLs) include the ability to successfully use the telephone, shop, prepare food, do the housekeeping and laundry, manage medications and finances, and use transportation. Enhanced activities of daily living (EADLs) include participation in social and enriching activities, such as learning new skills and engaging in hobbies.

Age-related changes in physical, perceptual, and cognitive abilities may make performing these tasks more difficult or challenging for older adults. The first objective of this report was to identify the range of tasks for which older adults could benefit from robot support. The second objective was to describe illustrative examples of existing robots that have the potential to address some of those needs.

From the literature we identified several activities of daily living with which older adults experience difficulty. Walking, getting in/out of bed/chairs, and bathing/showering were the most frequent ADLs with which community dwelling older adults experienced limitations

(Disability and Activity Limitations, 2009). IADLs with which older adults experienced difficulty included housekeeping, meal preparation, and outdoor home maintenance tasks (Fausset, Kelly, Rogers, & Fisk, in press; Rogers, Walker, Meyer, & Fisk, 1998; Seidel et al., 2009). Older adults indicated that even leisure activities (EADLs) can be difficult or frustrating due to limited physical ability or limited technological knowledge (Rogers et al., 1998).

Our review revealed many robots that could purportedly support the range of activities of daily living for which older adults have difficulties; some robots have the ability to assist with multiple activities. A total of 147 robots were identified that have the potential to support ADLs, IADLs, and EADLS. Seventy robots were identified that may have the capabilities to support ADLs, 42 robots support IADLs, and 61 robots support EADLs. The robots we identified have the potential to support ambulation in two different ways: (1) by reducing the need to move, or (2) by supporting the physical movement. Most of the robots found were developed to support ambulation (an ADL), housekeeping (an IADL), and social communication (an EADL).

In summary, many robots are being developed or are currently available that could potentially support older adults' activities of daily living. By assisting older adults in maintaining their independence in the home environment, robots have the potential to enable older adults to remain in their homes longer, supporting their preference to age in place. Furthermore, by supporting aging in place, robots may be able to delay an undesired move to assisted living or nursing residence (see Mitzner, Chen, Kemp, & Rogers, 2011, for more details about older adults' transition from living independently to assisted living.)

Aging Population and Age-Related Changes

Older adults, people age 65 or older (Erber, 2005), represented 11% of the world population in 2009, and the percentage is expected to double by 2050 (United Nations, 2010). Similar demographic trends exist for the United States; persons 65 and older are expected to represent 19% of the population by 2030 (Administration on Aging, 2010).

A primary goal of older adults is to age in their own homes (AARP, 2005), but age-related changes might threaten this goal of independent living. Certain abilities are maintained or improve with age, such as semantic knowledge (Ackerman, 2008) or everyday problem solving and emotion regulation (Blanchard-Fields, 2007). However, there are other abilities that decline with age. Fine motor skills, balance, and strength diminish (Cavanaugh & Blanchard-Fields, 2006; Newell, Vaillancourt, & Sosnoff, 2006; Vercruyssen, 1997). Vision acuity and hearing decline with age (Schieber, 2006; Schneider & Pichora-Fuller, 2000), and cognitive abilities such as working memory (Hoyer & Verhaeghen, 2006) also decrease. For an overview of age-related changes in capabilities, see Fisk, Rogers, Charness, Czaja, and Sharit (2009). These age-related declines in physical, perceptual, and cognitive abilities may negatively impact older adults' ability to maintain their independence in their home environment.

Activities of Daily Living

To live independently, people must be able to successfully perform a wide range of tasks related to activities of daily living. These activities can be described in three broad classes: (1) Self-Maintenance Activities of Daily Living or ADLs (Lawton, 1990; Lawton & Brody, 1969), (2) Instrumental Activities of Daily Living or IADLs (Lawton; Lawton & Brody), and (3) Enhanced Activities of Daily Living or EADLs (Rogers et al., 1998).

ADLs are physical tasks essential to maintaining one's independence and include the ability to toilet, feed, dress, groom, bathe, and ambulate. IADLs are typically more cognitively demanding than ADLs, and include the ability to successfully use the telephone, shop, prepare food, do the housekeeping and laundry, manage medications and finances, and use transportation outside of the home (e.g., driving a car, using public transit, or riding in a taxi). EADLs include participation in social and enriching activities, such as learning new skills and engaging in hobbies. These categories constitute most of the tasks older adults spend their time performing in the home environment; essentially, older adults want to make their time there as enjoyable and productive as possible (Baltes & Lang, 1997).

Age-related declines in physical, perceptual, and cognitive abilities may make performing activities of daily living tasks difficult for older adults. Figure 1 illustrates the self-maintenance activities of daily living in which non-institutionalized older adults were limited (Disability and Activity Limitations, 2009). Over 25% of adults over the age of 65 had limitations with walking, whereas only 6% of older adults experienced limitations with eating. Note that the rate of limitations in activities among persons 85 and older is much higher than those for persons 65-74 years of age. For example, less than 20% of adults aged 65-74 years are limited in their ability to walk, whereas over 45% of adults over the age of 85 years are limited in their ability to walk. These data highlight potential areas of support that could benefit older adults in achieving their goal of independent living.

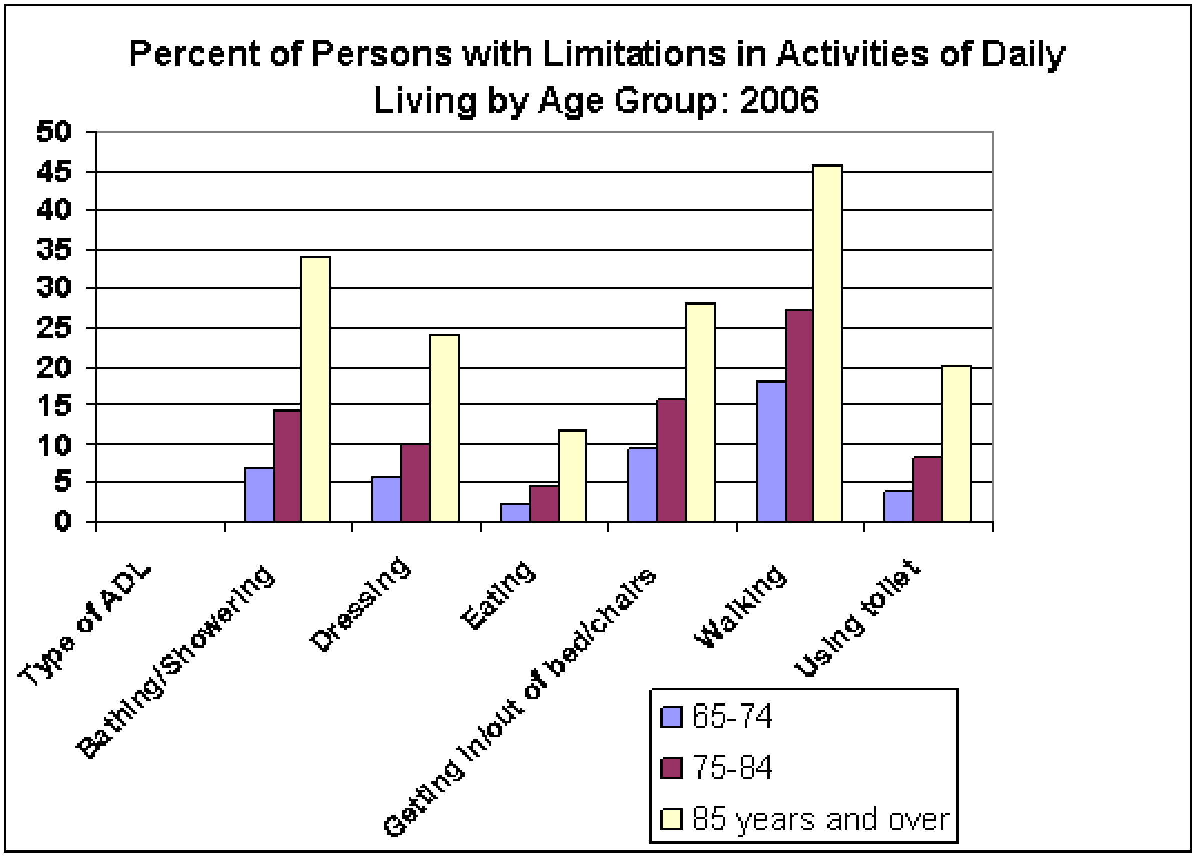

*Figure 1***.** The percentage of non-institutionalized older adults that experience limitations in activities of daily living by age group (Disability and Activity Limitations, 2009, Figure 9).

Living Arrangements of Older Adults

The majority of older adults are not infirm or unable to care for themselves. In 2008, only 4% of older adults lived in institutional settings (nursing home facility or assisted living facility; Living Arrangements, 2010). However, the percentage of older adults residing in institutional settings does increase with age, which is consistent with an age-related increase ADL limitations (see Figure 1): 1.3% for 65-74 year olds to 3.8% for 75-84 year olds to over 15% for persons older than 85 years (Living Arrangements, 2010).

Figure 2 illustrates the percentage of Medicare enrollees age 65 and over with functional limitations by residential setting (Older Americans, 2010). Of the older adults who live in a traditional community residential setting, 40% experience one or more functional limitations. Figure 2 emphasizes the fact that even people who live independently are experiencing one or more ADL or IADL limitations for which they could benefit from support.

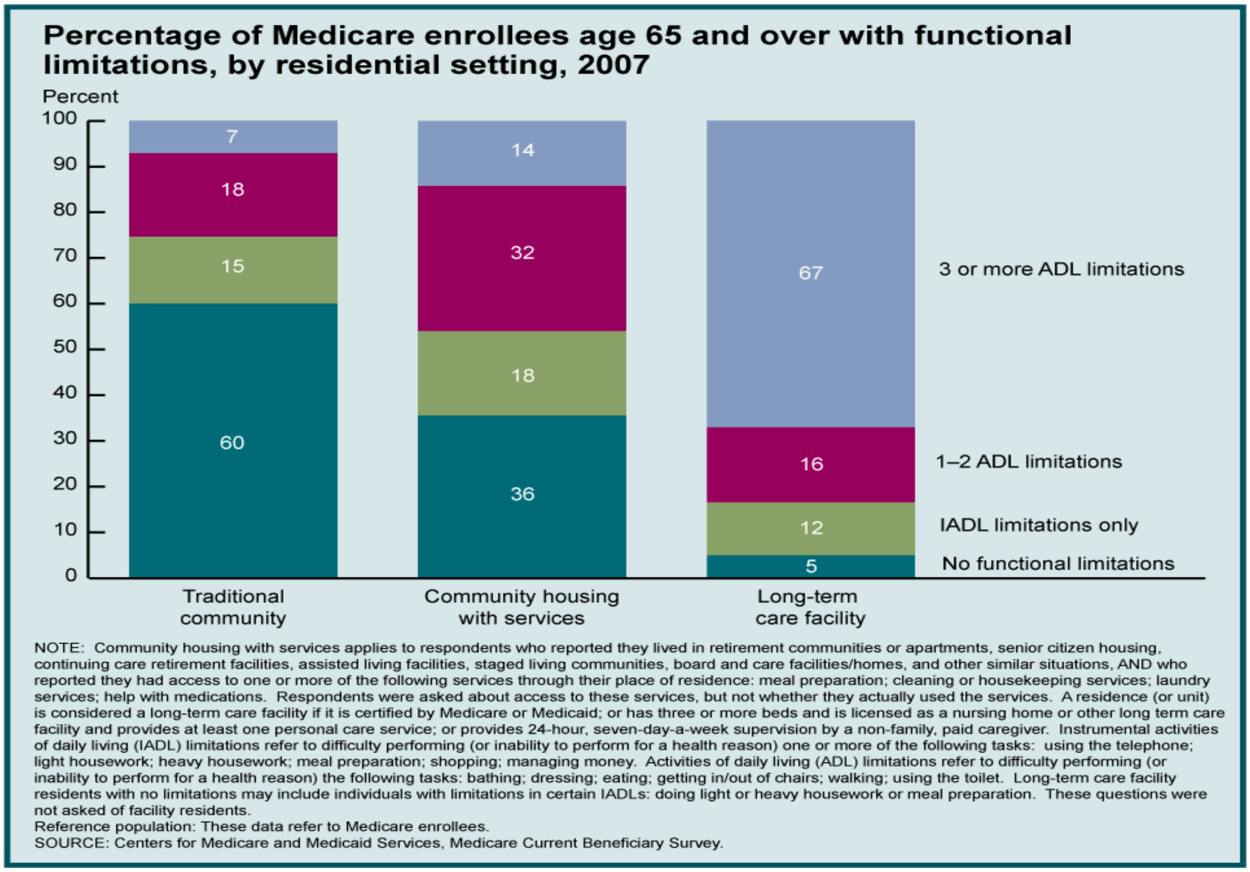

Figure 2. The percentage of older adult Medicare enrollees age 65 and over with functional limitations by residential setting (Older Americans, 2010, Indicator 36, p. 59).

Impact of Age-Related Changes on Activities of Daily Living

Physical, perceptual, and cognitive age-related changes can negatively impact older adults' ability to maintain their independence. Below we provide a review of the literature addressing the impact of age-related changes on activities of daily living. Our review highlights opportunities for robot assistance for older adults.

Physical Limitations

Age-related declines in certain physical abilities can lead to difficulties in activities of daily living for older adults. Motor limitations were identified as the source of nearly 40% of the difficulties in performing tasks of everyday living mentioned by community-dwelling older adults (Rogers et al., 1998). Gross movement issues were the most commonly mentioned difficulty, whereas fine movements were less frequently mentioned. Difficulty balancing was also included in this category of motor limitations. These difficulties contributed to limitations in such activities as housekeeping (IADL), locomotion (ADL), meal preparation (IADL), and personal grooming (ADL), and illustrate potential tasks for which older adults could benefit from support.

In a longitudinal assessment of older adults in Great Britain, Seidel and colleagues (2009) investigated patterns in capability loss and the relationship between limitations of instrumental activities of daily living. Locomotion and reaching were the most prevalent physical limitations identified for 32.5% and 25.5% of the participants, respectively. The onset of limitations in performing IADLs was then related to the older adults' capabilities. Housework and shopping were the first tasks for which older adults encountered difficulties.

In one recent investigation, older adults were asked to describe home maintenance tasks that were or could become difficult to perform (Fausset et al., in press). Nearly 70% of the tasks described were outdoor-related or cleaning-related. All tasks described were physically demanding in nature requiring abilities such as strength, balance, bending, and endurance. Outdoor-related tasks included mowing the lawn, painting the outside of the home, and cleaning the gutters. Cleaning tasks included vacuuming, changing bed linens, washing dishes, doing laundry, cleaning the toilet, and taking out the garbage.

Fausset et al. (in press) also found that age-related declines in physical abilities negatively impact older adults' abilities to perform ADLs and IADLs. Specifically, ambulation and grooming (ADLs) were identified as difficult or frustrating for older adults to perform. Difficult IADLs due to physical limitations included housekeeping, meal preparation, transportation, and shopping. These findings suggest that older adults would benefit greatly from assistance with physically demanding tasks.

Perceptual Limitations

In a large sample of older adults assessed longitudinally, Seidel et al. (2009) found that hearing and vision disabilities occurred with a prevalence of 21.7% and 15.3%, respectively. However, the onset of these perceptual disabilities occurred later in life than the onset of physical limitations. Moreover, these perceptual limitations did not impact older adults' ability to perform instrumental activities of daily living as did physical limitations.

Nevertheless, older adults have identified several ADLs and IADLs that would be difficult with vision or hearing impairments (Kelly, Fausset, Rogers, & Fisk, 2011; Rogers et al., 1998). Related to vision limitations, participants mentioned difficulty cooking (IADL), seeing dust (IADL), dressing (ADL), reading (IADL/EADL), sewing (EADL), and driving (IADL/EADL). Difficulty moving around the house (ADL) was also described. Participants mentioned that it would be difficult to hear the doorbell or the telephone with hearing limitations (IADL).

In summary, age-related changes in perceptual abilities do not impact older adults' ability to perform tasks related to activities of daily living to the extent that age-related physical changes do. However, these data must be interpreted with caution as two of the three studies (Kelly et al., 2011; Rogers et al., 1998) used a focus group approach; these samples did not include older adults with significant hearing and vision limitations. It is likely that assistance for visual and auditory limitations would support older adults' independence in the home for a wide range of older individuals.

Cognitive Limitations

Age-related changes in cognitive ability negatively impact tasks related to both instrumental and enhanced activities of daily living (Baltes & Lang, 1997; Kelly et al., 2011; Rogers et al., 1998; Seidel et al., 2009). Baltes and Lang described the everyday functioning of 485 community-dwelling and institutionalized older adults (age range: 73-103 years) by their level of cognitive resources. Significant differences emerged between thos described as "resource rich" in their cognitive capacity versus "resource poor" in cognitive capacity. Only 2% of older adults in the resource rich group resided in institutions, whereas 23% of the resource poor adults lived in institutions. The resource rich group reported spending more time than the resource poor group performing the following activities: housekeeping (IADL), physical leisure (EADL), intellectual-cultural leisure (EADL), and social engagement activities (EADL).

Additional research has demonstrated that cognitive declines impact IADLs. Seidel and colleagues (2009) identified that the onset of cognitive declines was associated with the onset of difficulties with transportation and cooking (IADLs). Medication management, cooking, and prospective memory tasks, such as remembering appointments and grocery lists, were other IADLs identified as difficult to perform due to cognitive limitations (Kelly et al., 2011). Rogers et al. (1998) found that older adults had difficulty learning something new and experienced memory limitations relevant to ADL performance. Working memory limitations resulted in burning pots while cooking, forgetting where items were placed only moments before, and using telephone menus. Long-term memory limitations made it difficult to remember people's name and where items were stored (Rogers et al.).

These studies illustrate that age-related declines in cognitive abilities limit older adults' ability to perform tasks related to the instrumental and enhanced activities of daily living. IADLs such as housekeeping, cooking, medication management, using the telephone, using transportation were difficult for older adults with cognitive limitations. Memory limitations were the source of frustration or difficulty for remembering grocery lists and appointments. Activities of leisure were negatively impacted by limitations in cognitive ability as well. Older adults would benefit from assistance with memory for many tasks related to IADLs and EADLs.

Summary

Age-related declines in physical, perceptual, and cognitive abilities contribute to limitations in performing activities of daily living. Table 1 provides a summary of age-related changes in physical, perceptual, and cognitive abilities and the activity of daily living impacted by the limitation. Assisting older adults in their goal of maintaining their independence in the home environment means that support for physical limitations followed by cognitive and perceptual limitations is necessary. Robots can provide that assistance.

Table 1

Impact of Age-Related Changes on Activities of Daily Living

Age-Related Change	Specific Difficulty	Activity of Daily Living Limited: ADL	IADL	EADL
Physical	Gross movement Balance Locomotion Reaching Strength Balance Bending Endurance	Locomotion Personal grooming	Transportation Housekeeping Meal preparation Housework Shopping Cleaning tasks Vacuuming Changing bed linens Washing dishes Doing laundry Cleaning toilet Taking out garbage Outdoor tasks Mowing lawn Painting Cleaning gutters	Leisure activities
Perceptual	Vision	Dressing Ambulation	Cooking Dusting Reading Driving	Sewing Reading Driving
	Hearing		Telephone Doorbell	
Cognitive	Limitations		Transportation Cooking	Difficulty learning something new
	Resource poor		Housekeeping	Physical leisure Intellectual-cultural leisure Social engagement
	Memory		Medication management Cooking Remembering appointments Remembering grocery lists Using telephone menus	

Robot Assistance for Older Adults

To help maintain older adults' independence in the home, tools and technology that can support older adults with difficult home tasks should be considered. Robots with a wide range of capabilities are being developed that could provide assistance to older adults for activities of daily living. Robots have the potential to support the various physical, perceptual, and cognitive aspects of tasks of everyday living.

A robot can be defined as an embodied "reprogrammable multi-functional manipulator" containing "sensors, effectors, memory, and some real-time computational apparatus" (Sheridan, 1992, pp. 3-4). Traditionally, robots were designed to perform tasks that are menial, repetitive, or too hazardous for a human. For example, robots in an automotive factory assemble the same part on a car repetitively for long periods of time whereas robots in the military defuse bombs or monitor dangerous territory. However, with advancing technology and increasing research, robots are intentionally being developed to expand beyond the factory or battlefield and into the home. Such robots are created with the goals of interacting with and assisting people in their everyday lives. They are designed with a range of capabilities such as helping a person out of bed, reminding them of appointments, and facilitating communications with friends and family.

Currently Available Robot Assistance for Older Adults in the Home

We have described the importance of considering different categories of activities that older adults must engage in to maintain their independence. Older adults often experience difficulties performing activities in everyday life because of age-related declines in physical, perceptual, or cognitive abilities. Robots have the potential to assist older adults with their activities of daily living. We conducted a thorough search of the currently available robots for the home to determine how they support ADLs, IADLs, and EADLs. The goal of the search was to provide an overview of the availability of robot assistance, whether in development or for sale on the market. Note that we describe the purported capabilities of robots to support the needs of older adults – we did not test or verify the robots' capabilities with users. Our review is meant to highlight the *potential* for robots, which has not necessarily been realized yet in these examples.

Robots can provide targeted and adaptable support for different aspects or for the whole process of daily activities. For example, a person with a motor impairment may have difficulty with picking up food and bringing it to his or her mouth. A robot such as Secom's *My Spoon* could assist by waiting for the person to indicate what food he or she would like to eat and then picking up the designated bite-sized morsel and bringing it gently to the mouth. Alternatively, if a person has cognitive and motor impairments, the robot could assist with the whole process of eating: selecting the food, picking it up, and bringing it to the mouth.

Search Method

The search was conducted from September 2010 to January 2011 using internet search engines (e.g., Google Scholar) and literature databases (i.e., EBSCO, INSPEC, IEEE). We searched for robots using words related to ADLs, IADLs, and EADLs. Key phrases included "robot[ic]" combined with the whole process of an activity (e.g., feeding robot, robotic housekeeper) or with an aspect of the activity (e.g., robot cuts food, robotic vacuum). Additionally, search terms were used that combined "robot", assistance terms (e.g., aid, intelligence, smart) and aging (e.g., older adults, eldercare). A complete list of robots can be found in the Appendix.

Search Results

Robots were classified based on which ADLs, IADLs, and EADLs they had the potential to support older adults with in the home (see the Appendix). Most robots had the ability to perform multiple tasks within the ADL, IADL, and EADL categories (i.e., robots are not mutually exclusive within a category or between categories). For instance, *RIBA* (2011) assists people in transferring from their bed to their wheelchair or to the toilet by lifting them. Thus, *RIBA* would be classified as assisting two different ADLs: ambulation and toileting. There were many assistive devices that supported activity performance yet they did not possess the characteristics of a robot, as defined by Sheridan (1992). For example, the *Aquatec Bath Lift* is an in-tub bath lift controlled by a hand-operated joystick, yet it does not use memory or a real-time computational apparatus to operate (Aquatec Bath Lift, 2011).

Robot assistance for ADLs. Seventy different robots were identified to support some aspect of an activity of daily living in the home. See Table 2 for the number of robots that support each ADL. Sixty-three of these 70 robots assisted ambulation in two different ways: (1) reducing the need to move, or (2) supporting the physical movement. Robots such as *Hawk* (2011) and *TOPIO Dio* (2011) reduce the need to move by bringing desired objects to the older adult, or by performing tasks for them (e.g., fetching and delivering a drink, answering the phone). Robotic walkers and wheelchairs, such as Carnegie Mellon University's *robotic walker* (Glover et al., 2003) and *NavChair* (2011), actually support the physical movement and can assist older adults in avoiding obstacles and navigating.

Compared to the 63 robots identified that assist ambulation, a fewer number of robots supported the other five ADLs (Table 2). Few robots were identified that assisted people with feeding (7 robots), grooming (6 robots), bathing (4 robots), toileting (3 robots), and dressing (2 robots).

Table 2

The number of robots that support each ADL

ADL	# of Robots that Support
Ambulation	63
Support movement	35
Reducing need	34
Feeding	7
Grooming	6
Bathing	4
Toileting	3
Dressing	2

Table 2. Robots assisted ambulation in two ways: reducing the need to move (e.g., the robot fetches and delivers a drink) or supporting the physical movement (e.g., robotic walker). Robots are not mutually exclusive within or among the ADLs, IADLs, EADLs, or other activities.

Robot assistance for IADLs. Forty-two different robots were identified that support some aspect of an IADL in the home. See Table 3 for the number of robots that support each IADL. Over half of the robots (i.e., 53 robots) identified as providing support for IADLs assisted with some aspect of housekeeping. In decreasing number of robot supports, 14 robots supported meal preparation, followed by 13 robots supporting medication management. Few robots were identified that assisted people with laundry (7 robots), shopping (5 robots), and telephone use (4 robots). No robots were identified that assist with money management and transportation. Note that transportation involves not only physically going to a location outside the home but also some cognitive components, such as figuring out what bus to take when.

Robot assistance for IADLs tended to be in one of two categories: multipurpose or specialized. Multipurpose robots were created to do many things, such as fetching and delivering objects, searching for information online, preparing a meal, and reminding of appointments (e.g., *PerMMA*, 2011*; uBOT-5*, 2011). In contrast, other robots are more specialized and only support one IADL, such as cleaning the floor (e.g., *Roomba*, 2011; *Scooba*, 2011).

Table 3

The number of robots that support each IADL

IADL	# of Robots that Support
Housekeeping	53
Meal preparation	14
Medication management	13
Laundry	7
Shopping	5
Telephone use	4
Money management	0
Transportation	0

Note. Robots are not mutually exclusive within or among the ADLs, IADLs, EADLs, or other activities.

Robot assistance for EADLs. Sixty-one different robots were identified that support some aspect of an EADL such as hobbies (e.g., dancing, exercising), social communication (e.g., phoning a friend, emailing a family member), and new learning (e.g., acquiring a skill in cooking). Table 4 shows the number of robots that support each EADL. A greater number of robots are designed to support social communication than hobbies and new learning.

The robots supporting EADLs can be categorized into two categories: service-type and companion-type (Broekens, Heerink, & Rosendal, 2009). Service-type robots have functions supporting activities of daily living in addition to having social functions (e.g., *Care-o-bot 3*, 2011). These social functions were designed to facilitate a person's interaction with the robot (Broekens et al.). Companion-type robots (e.g., *Paro*, 2011) were created to enhance cognitive well-being and health (Broekens et al.). Both types of socially assistive robots were shown to be beneficial to older adults by increasing positive mood, decreasing feelings of loneliness, alleviating stress, and increasing social ties (Broekens et al.).

Table 4

The number of robots that support each EADL

EADL	# of Robots that Support
Social Communication	46
Hobbies	29
New Learning	16

Note. Robots are not mutually exclusive within or among the ADLs, IADLs, EADLs, or other activities.

Robot assistance for other activities. Many robots that provide assistance for ADLs, IADLs, and EADLs also perform other activities. Three patterns noted amongst the 147 robots reviewed were monitoring, interfacing with technology, and using telepresence (see Table 5).

First, monitoring was implemented in nearly a quarter of the robots (37 out of 147) that support ADLs, IADLs, and EADLs (Table 5). Monitoring involved the robot checking on a person's health or safety. Older adults have reported being concerned about their safety (e.g., burglars) and their health (e.g., falling, toxic gases; Harmo et al., 2005).

Second, 13 of the 147 robots interfaced with non-telephone technologies in the home. A robot that supported interfacing with telephones would be categorized under that IADL (Table 3). For example, *Chapit* (2011) can turn off the lights or other electronic devices (e.g., appliances, television). Some of these robots allowed distal control of home electronics from an internet or network connect (e.g., *Chapit*, 2011; *Enon*, 2011).

Third, 11 robots that supported ADLs, IADLs, and EADLs also used telepresence, which allows a person to experience another location without physically being there. It has been useful for many activities of daily living such as social communication (e.g., *Carebot*, 2011) or shopping (e.g., *TMSUK-4*, 2011).

Table 5

The number of robots that monitor, interface with other technologies, and use telepresence while assisting with ADLs, IADLs, and EADLs

Other activities	# of Robots that Support
Monitoring	37
Interface with technologies	13
Telepresence	11

Note. These activities are not directly related to the activities of daily living but were identified as trends in the capabilities of these robots. Robots are not mutually exclusive within or among the ADLs, IADLs, EADLs, or other activities.

Patterns in Robot Assistance

From our search of currently available robots that can potentially support tasks related to activities of daily living, we found that there was support for all the activities of daily living except one. Aside from money management and transportation, aspects related to every ADL, IADL, and EADL had at least one robot being designed to support that activity. Housekeeping, ambulation, hobbies, and social communication were supported by the most robots, whereas transportation, money management, grooming and laundry were supported by the fewest robots. ADLs were supported by the greatest number of robots (70 robots), followed by EADLS (61 robots), and IADLs (42 robots). Other activities (i.e., monitoring, interfacing with technology, and using telepresence) were supported by 46 robots.

Much of the current robot assistance is aimed at the more physical aspects of ADLs and IADLs. However, there are many robots that supported cognition by reminding older adults of previous actions (e.g., *Mamoru*, 2011), where objects are located (e.g., *Mamoru*, 2011), to take medication (e.g., *Pearl*, 2011; *Wakamuru*, 2011), or of appointments (e.g., *Basil*, 2011; *Pearl*, 2011; *WLMA*, 2011). Support for perceptual capabilities was not a primary focus of the robots reviewed.

There are several possible explanations as to the reason that most robots have been developed to assist with physical aspects of the activities of daily living. For one, developers may not see as large a market for perceptual or cognitive robot assistance as they do for physical assistance, and as such, choose not to create robots in this area. Also, the technology may not be available to create a robot to safely and reliably perform such tasks.

We have described the areas of activities that have support as well as identify areas with fewer supports. For example, few robots were identified that supported bathing, telephone use, toileting, dressing, money management, and transportation (Table 6). If robots were developed to support those activities, older adults would likely benefit in that they might be able to maintain their independence longer. This review has identified areas of need that are not being met by current robot support (Tables 2-6). However, more research is needed to determine what robot assistance older adults want or need. In addition, it is critical that the robots be tested in user studies with older adults in the contexts in which the robots will be used.

Table 6

ADLs and IADLs that have the fewest robot supports

Activity	Category	# of Robots that Support
Bathing	ADL	4
Telephone use	IADL	4
Toileting	ADL	3
Dressing	ADL	2
Money management	IADL	0
Transportation	IADL	0

Note: Robots are not mutually exclusive within or among the ADLs, IADLs, EADLs, or other activities.

Conclusions

Older adults prefer to maintain their independence and age in place (AARP, 2005). This might be challenging for some older adults because of age-related declines in physical, cognitive, or perceptual abilities that make activities of daily living difficult to perform. With advancing technology, robots may have the capabilities to support older adults in these activities. The purpose of this report was to (1) present a high level review of difficulties that older adults experience with activities of daily living, and (2) identify robots that are currently available or being developed to assist with activities in the home environment. Other trends in robot development (i.e., monitoring, interfacing with other technologies, and telepresence capabilities) were also discussed.

From our search, we identified 147 robots that assisted with some aspect of ADLs, IADLs, and EADLs. The Appendix provides a complete list of all the robots identified that can potentially assist older adults with ADLs, IADLs, and EADLs in the home. The greatest number of robots were designed to assist with ambulation, housekeeping, and social communication, whereas the fewest number of robots were found to support money management, transportation, dressing, and toileting. Most of the robots assisted with physical aspects of these activities of daily living (e.g., ambulation, housekeeping). Some assisted with cognitive aspects such as reminding older adults to take medication (e.g., *Pearl*, 2011; *Wakamuru*, 2011) but none directly assisted perception

Future Directions and Challenges

There are many potential opportunities for robots to support older adults in performing activities of daily living. This search showed that there are many robots currently available or being developed to assist with some activities of daily living (e.g., housekeeping, ambulation, social communication) whereas other activities have few robot supports (e.g., money management, grooming, laundry). However, research is required to determine and prioritize what robot assistance older adults *actually* need to maintain their independence and what support they are willing to accept from robots. Research exploring older adults' needs and preferences for robot assistance can provide direction for developers to create robots that are more likely to be adopted by older adults.

Developing robot assistance for older adults in the home environment is not without challenges. First, what robot assistance are older adults willing to accept? Many factors influence a person's acceptance and use of a robot including the robot's function, appearance, and social capability. For a review, see Beer, Prakash, Mitzner, and Rogers (2011).

Second, how should older adults interface with robots? Older adults reported wanting to interface with a robot by giving it voice commands or having it preprogrammed (Ezer, 2008). However, older adults may not realize all their options for interfacing with robots (e.g., RFID tags, laser pointers). It will be challenging for developers and researchers to incorporate aspects of age-related changes in abilities (e.g., physical, perceptual, cognitive), desires of the older adult users, and the state of technology to produce a successful and efficient interface between humans and robots.

Third, should robots adapt to the abilities of an individual user? Older adults experience not only long-term age-related declines in physical, cognitive, or perceptual abilities, but also temporary challenges. For example, an older adult who has broken a hip might need more targeted robot assistance with certain activities of daily living (e.g., ambulating, housekeeping) during the recovery period than before. After recovery, robot assistance can resume its usual amount or type of assistance. A robot should be able to provide support based on the capabilities of the user, whether temporary or long-term.

Further challenges in designing robots for older adults include addressing how older adults can teach robots new objects and tasks, standards of safety for robots, privacy concerns, cost versus benefit of owning a robot, methods of training older adults to use a robot, and the feasibility for a robot to operate within the person's home environment (e.g., maneuvering, perceiving objects in a cluttered environment).

The present report provides the first step in understanding the needs of older adults in conjunction with the current research and development in robotics that might assist them. Older adults' capabilities, limitations, and preferences must be considered throughout the design process if personal robots are going to reach their full potential to support older adults in their home environments.

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Appendix: Robot Assistance for ADLs, IADLS, and EADLs

Table A1

Robots identified that supported older adults performing ADLs, IADLS, and EADLs at home

Robot	Creator
914 PC-Bot	Whitebox Robotics
Active Home	Quality of Life Center
Aibo	Sony
AIC-AI Cookingrobot	Fanxing Science & Technology Co. Ltd
AIMEC:4 (Artificially Intelligent Mechanical Electronic Companion 4)	Applied Machine Intelligence
ApriAlpha™ version 3	Toshiba
ApriAttenda™ version 2	Toshiba
Apripoko	Toshiba
Aquabot	Aquaproducts
ARMAR III	Collaborative Research Center on Humanoid Robots, Karlsruhe, Germany
ASIMO	Honda
Assistant Robot (AR)	Tokyo University’s IRT (Information & Robotic Technology Research Institute)
AutoMower®	Husqvarna (part of Electrolux?)
AVA	iRobot
Bandit-II	USC's Viterbi School of Engineering
Basil (Basic Service Level robot)	Gamma Two Robotics
Belvedere	made by a robot enthusiast for his family
BigMow®	Belrobotics
CareBot	GeckoSystems International
Care-O-bot® 3	Fraunhofer IPA
Cat Genie 120	Petnovations
Chapit	Raytron
Charlie the Robot	University of Auckland, Health Bots project/Yujin Robots
CiCi	iRobot
CMU robotic walker	Carnegie Mellon University
Cody	Georgia Institute of Technology, Healthcare Robotics Lab
ConnectR	iRobot
COOL Aide (Co-operative Locomotion Aide)	University of Virginia
Dirt Dog	iRobot

Dishwashing Robot	Panasonic Corporation
Dolphin Supreme M4	Maytronics LTD
Domo	MIT
EL-E	Georgia Institute of Technology, Healthcare Robotics Lab
EMIEW 2 (Excellent Mobility and Interactive Existence as Workmate)	Hitachi
EngKey	Korea Institute of Science and Technology's Center for Intelligent Robotics
Enon (Exciting nova on network)	Fujitsu Frontech
Family Nanny	Siasun
Fatronik robotic assistant	Fatronik
Femisapien	WowWee
FlatThru	Sanyo
FRIEND (Functional Robot arm with user-frIENdly interface for Disabled people)	Institute of Automation (IAT) at the University of Bremen
FUSIONBOT	ASORO
Gardening robot	Nikolaus Correll, MIT
GENIBO Robot Dog	dASA ROBOT
Giraffe	Headthere
GuideCane	University of Michigan
Guido	Haptica Ltd., Dublin, Ireland
Handy1	Forschungsinstitut Technologie und Behinderung der Evangelischen Stiftung Volmarstein, Germany
HAR (Home Assistance Robot)	Toyota and the University of Tokyo
Hawk	Dr Robot
HERB	Intel Labs in Pittsburgh and Carnegie Mellon University
Hermes	Institute of Measurement Science, Bundeswehr University Munich
Hitachi walker	Hitachi
HITOMI	Renesas
HLPR (Home Lift, Position and Rehabilitation) Chair	National Institute of Standards and Technology
HOAP-3	Fujitsu
HRP-2	Kawada and US-American SARCOS
Huggable	MIT Media Lab
Hybrid Assistive Limb (HAL)	Cyberdyne
iARM (intelligent Assistive Robotic Manipulator) / Manus ARM	Exact Dynamics BV, Netherlands
iCat	Philips Electronics

iMow	Toro Co.
Intelligent Wheelchair (AIST)	Japan's National Institute of Advanced Industrial Science and Technology (AIST)
Intelligent Wheelchair (Toyota)	Toyota
iRobiQ	Yujin Robots
Jazz	GOSTAI
Justin Robot	Institute of Robotics and Mechatronics at the Deutsches Zentrum for Luft-und Raumfahrt
Koala	K-team mobile robotics
Kompai	Robosoft
Kompott Robotic Agent	Zurich University of the Art’s Interaction Design lab in Switzerland
Kreepy Krauly® Prowler® 720	Pentair Water
Kreepy Krauly® Prowler® 730	Pentair Water
LawnBott	Kyodo America
Litter Robot LR-II	Paradise Robotics
Looj	iRobot
LUCAS	ASORO
Mahru-Z	KIST, Korea
MAid (Mobility Aid for Elderly and Disabled People)	Prassler, E., Scholz, J., & Fiorini, P. (2001). A robotic wheelchair for crowded public environments. *IEEE Robot Automation Magazine, 8*(1), 38–45.
Mamoru	University of Tokyo
MATS robot	European Union MATS project
MIKA	ASORO
Mint cleaner	Evolution Robotics
MOBIL Walking & Lifting Aide	FernUniversität Hagen - Lehrstuhl Prozeßsteuerung und Regelungstechnik PRT, Hagen, Germany (general project leader)
Motoman SDA10	Yaskawa
MOVAID	Scuola Superiore Sant' Anna, Italy
MS800	MSI
My Spoon	Secom
Nao	Aldebaran Robotics in France
Nao	ALDEBARAN Robotics
NavChair	University of Michigan
Neato XV-11	neato robotics
Nitro®	SmartPool
OLIVIA	ASORO
OMNI	Forschungsinstitut Technologie und Behinderung der Evangelischen Stiftung

	Volmarstein, Germany
PAMM	MIT
Panasonic hair washing robot	Panasonic Corporation
Panasonic's Robotic Bed	Panasonic Corporation
ParcMow®	Belrobotics
Paro	AIST
Pearl	University of Pittsburgh Nursing and Rehabilitation, in cooperation with Carnegie Mellon Computer Science and Robotics
Personal Mobility & Manipulation Appliance (PerMMA)	CMU Quality of Life Center
PLEO	innvo labs lifeforms
Pool Rover	Aquaproducts
PR2 (Personal Robot 2)	Willow Garage
R-1300	MSI
Rampage	Dirt Devil
RIBA	Riken Research Center
RI-MAN	RIKEN Bio-mimetic Control Research Center
RobChair	Institute of Systems and Robotics, University of Coimbra, Portugal
Roboking	LG
Robomower®	Friendly Robotics
ROBOTIC BUTLER	ASORO
Robovie-II	Advanced Telecommunications Research Institute International (ATR)
ROLA	National Chiao Tung University of Taiwan
Rolland III - Bremen Autonomous Wheelchair	DFKI-Labor, Bremen, Germany
Roomba	iRobot
RP2W (Remote Presence 2-Way)	SuperDriod (http://superdroidrobots.com/site/shop/)
Scooba	iRobot
Scrubber60™	SmartPool
Sharioto	Katholieke Universiteit Leuven
Silbo	Intelligent Healthcare Laboratory, Korea
Sincere Kourien	Matsushita Electric Industrial Co.
SmartChair	Parikh, S. P., Grassi, V., Kumar, V., & Okamoto, J. (2004). Incorporating user inputs in motion planning for a smart wheelchair. *Proceedings of the IEEE International Conference on Robotic Automation*.
SmartPal V	Yaskawa

Snackbot	Carnegie Mellon University
SPC-101C	Speecys
Taizo	General Robotix National Institute of Advanced Industrial Science and Technology, Japan
Tamer	Karon MacLean of University of British Columbia
Teddy Bear	Fujitsu
Telenoid R1	Osaka University and the Advanced Telecommunications Research Institute (ATR)
TMSK WL-16R3	Waseda University and TMSK
TMSUK-4	TMSUK
Topio Dio	Tosy
Trilobite 2.0	Electrolux
Twendy-One	Japan's Waseda University
uBOT-5	University of Massachusetts Amherst
VAHM	University of Technology of Troyes, Laboratory ISTIT/M2s, Troyes, France
VC-PL62W	Samsung
Verro	iRobot
Wakamaru	Mitsubishi
Weston	Hillman et al. at Bath Institute of Medical Engineering, Bath, UK.
Wheelsely	MIT
WheeMe	DreamBots
Wilma (Wheelchair Level Mobility Assistant)	Gamma Two Robotics
Yurina	Japan logic machine
ZJ0405	EcoVacs
ZJ0713	EcoVacs