UNDERSTANDING OLDER ADULTS'

PERCEPTIONS OF USEFULNESS OF AN ASSISTIVE HOME ROBOT

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UNDERSTANDING OLDER ADULTS'

PERCEPTIONS OF USEFULNESS OF AN ASSISTIVE HOME ROBOT

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SUMMARY

Perceived Usefulness of Assistive Robots

Developing robots that are useful to older adults is more than simply creating robots that complete household tasks. To ensure that older adults find a robot *useful* careful consideration of the user, robot, and task is needed. Perceived usefulness is an important construct to consider within the context of human-robot interaction (HRI) because it has been shown to be a predictor of intentional acceptance. Perceived usefulness may be defined as a person's decision of how well the technology's capability matches their own needs (Venkatesh & Davis, 2000). Thus, it may be assumed that as an individual's capabilities decrease, then the autonomy of an assistive robot will need to increase (i.e., the robot performs tasks on its own) to better meet the user's needs and home environment/task demands (Thrun, 2004). Key factors that influence perceived usefulness emerge as a function of user needs, the match between the user's needs and the robot autonomy, and the task being performed by the robot.

Qualitatively understanding perceived usefulness is a critical first step in determining whether existing technology acceptance models/frameworks are applicable to robotics. As thus, this study informs our understanding of the psychological and system factors that influence perceived usefulness. From a practical standpoint, identifying factors that influence perceived usefulness has the potential to eventually lead to design guidelines for robots that are useful and therefore more likely to be adopted. The development of assistive robots will only be beneficial if the older adult users actually find the robot useful.

Approach

Two groups of older adults participated in this study: (1) mobile older adults, defined as older adults who did not use walkers or wheelchairs, and (2) older adults *with* mobility loss, defined as older adults who used walkers or wheelchairs on a daily basis. The study consisted of two main parts: Part A was an autonomy-selection think aloud task that was designed to assess the match between their own capability and robot autonomy (operationalized as command/control). Part B was a persona-based structured interview that was designed to assess questionnaire constructs believed to be predictive of perceived usefulness (Venkatesh & Davis, 2000), and to assess how older adults determine usefulness via a structured interview. This study addressed the following research questions:

[R1] *What is the relationship between user capability (operationalized in this dissertation as mobility) and perceptions of usefulness for robots of varying autonomy levels (operationalized as command/control methods)?*

-Are perceptions of usefulness of varying autonomy levels task specific?

[R2] *Are constructs shown to be predictive of perceived usefulness of information technology (Venkatesh & Davis, 2000) correlated with perceived usefulness of assistive robots?*

-Are other constructs, such as trust, reliability, and adaptability also correlated with perceived usefulness of assistive robots?

[R3] *What are the facilitators and barriers of acceptance that older adults base their perceptions of usefulness?*

-Do the nature of those barriers and facilitators differ between task or between older adults of varying capability?

Findings

The findings provided insights into our understanding of acceptance in human-robot interaction (HRI). The findings can be organized by research question. The first research question was: *what is the relationship between user capability and perceptions* *of usefulness for robots of varying autonomy levels?* The determination of usefulness was not as simple as a match between user capability and robot capability. Older adults *with* mobility loss preferred the option to command/control a robot themselves, whereas mobile older adults were split between their selection of “I command/control the robot” and “the robot commands/controls itself.” The option of someone else commanding/controlling the robot was not preferred by either group. Furthermore, perceptions of usefulness for the command/control options were task specific. Tasks with a fixed schedule, or that can be preprogrammed into the robot (e.g., medication reminders, monitoring) were considered most useful if the robot commanded/controlled itself.

The second research question was: *are constructs shown to be predictive of perceived usefulness of information technology (Venkatesh & Davis, 2000) correlated with perceived usefulness of assistive robots?* In Part B the persona-based interview, a questionnaire was developed to assess perceived usefulness. This questionnaire was based on the Technology Acceptance Model (TAM; Davis, 1989; Venkatesh & Davis, 2000) as well as additional constructs shown to be important in robot acceptance (Broadbent et al., 2009; Ghazizadeh, Lee, & Boyle, 2012; Heerink et al., 2010; Young et al., 2009). Results suggest that robot assistance was perceived as more useful for the persona with mobility loss, compared to the mobile persona. Participant group differences existed for the task of transfer, where older adults with mobility loss showed a higher perception of usefulness for robot assistance with transfer for the mobile persona. Furthermore, although the constructs were positively correlated with one another, interview data suggest that many of the terms within the questionnaire items were interpreted differently between participants.

Finally, the third research question was: *what are the facilitators and barriers of acceptance that older adults base their perceptions of usefulness?* Participants' reported a variety of barriers and facilitators to acceptance, further supporting the complexity of perceived usefulness. Barriers and facilitators were categorized as human-, robot-, and environment- related. Common themes included need, user (in)capability, importance of task for health, independence, (un)reliability, and robot capability.

The findings advance our theoretical understanding of perceived usefulness. The variability of participant interview responses, and their uncertainty in interpreting TAM questionnaire items suggest that the constructs related to perceptions of assistive robot usefulness are complex. The older adult participants recognized the complexity of technological assistance, and considered the interview questions from a multidimensional perspective. This brings to question the validity of the TAM questionnaire when applied to domains other than information technology; thus, careful consideration is needed when adapting TAM questionnaire wording to other domains. These data suggest that modifications to TAM measurements (i.e., questionnaire wording) may be required to fully understand acceptance in HRI.

These data provide practical guidance to designers for choosing a command/control level that matches the target user group. Preferences for control also varied by task, thus designers should choose a robot that commands/controls itself for tasks with fixed schedules (e.g., medication reminders), whereas, human control was preferred for tasks with specific user preferences (e.g., dressing). Furthermore, some participants held the assumption that the robot would be 100% reliable, which is a dangerous assumption because no machine is completely reliable. Thus these data support the need for training, informative error messages, and proper marketing of assistive robots.

CHAPTER 1: INTRODUCTION

"I don't need a robot right now, but I might need one in the future." This statement has been said by a number of older adults in relation to an assistive home-based robot (Beer et al., in prep). This quote exemplifies the struggle designers will face in developing robots that are *useful* to older adults. As older adults' capabilities and limitations change (i.e., with normal aging), at what point will a home-based assistive robot be of most benefit?

Robot assistance in the home may be especially beneficial to older adults who frequently encounter limitations in performing home activities (Disability & Activity Limitations, 2010; Fausset, Kelly, Rogers, & Fisk, 2011). However, as the quote above suggests, developing robots that are useful to older adults is more than simply creating robots that complete household tasks. A human factors approach to understanding human-technology interaction requires the consideration of factors related to the user, technology, and task. Specifically, research is needed to explore perceived usefulness as it relates to the user needs, how much help the robot provides, and what aspects of the task the robot performs.

Perceived usefulness has a long history of study in relation to the acceptance of information technology (IT; e.g., Davis, 1989). Findings from this literature may inform the field of Human-Robot Interaction (HRI) by providing an initial framework in identifying barriers and facilitators potentially related to robot acceptance. More specifically, using existing technology acceptance models (both in IT and HRI) as a guide, the present research enhances our understanding of perceived usefulness of robots. The overarching purpose of this dissertation was to identify potential factors that are determinants of perceived usefulness, and investigate how those factors might influence older adults' perception of robot usefulness.

Perceived usefulness: An important component in technology acceptance

Technology acceptance can be defined as a favorable attitude towards, intentions to use, and actual use of a system (Chen & Chan, 2011). Historically, this triad approach to acceptance – attitudes, intention, use – has been used to describe acceptance since the 1970s (Theory of Reasoned Action; Fishbein & Ajzen, 1975). More specially, attitudes (e.g., "I like this technology") are based on beliefs. Attitudes form intentions (e.g., "I would like to use this technology"). Intentions results in behaviors or observable actions (e.g., "I'm going to purchase and use this technology") (Fishbein & Ajzen, 1975; Davis, 1989). The widely recognized Technology Acceptance Model (TAM; Figure 1) was proposed by Davis (1989). This model, adapted from the Theory of Reasoned Action, proposed an overarching goal to understand, explain, and model predictive variables that contribute to user acceptance across a broad range of information technologies and user populations.

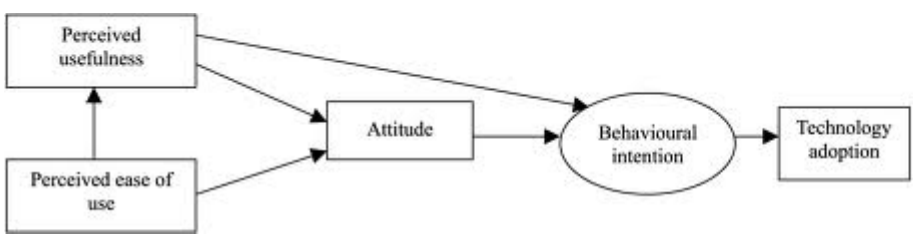


Figure 1. Technology Acceptance Model (TAM) (Davis, 1989).

TAM proposed two main variables that predict acceptance: *perceived usefulness* and *perceived ease of use*. These two variables are modeled to predict behavioral intention, which should then predict future technology use, or "adoption". The primary focus of this dissertation is on the construct perceived usefulness, which can be defined as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p320). In fact, perceived usefulness has been empirically shown to be the strongest predictor of behavioral intention (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003).

There is strong empirical support for the TAM (Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003), in part due to its ease of application to a variety of IT domains. TAM is straightforward, yet explains approximately 40% of a user’s intentional acceptance of information technology in the workplace (King & He, 2006; Schepers & Wetzels, 2007; Venkatesh et al., 2003) and approximately 30% of behavioral acceptance (Schepers & Wetzels, 2007). However, the model has received some criticism for being too simplistic. Thus, later versions of TAM (TAM2 and TAM3) have increased the model’s complexity. In the original TAM model, both perceived usefulness and perceived ease of use were shown to predict attitudes towards use. Subsequently Vankatesh and Davis proposed the TAM2 (Venkatesh & Davis, 2000) and TAM3 (Venkatesh & Bala, 2008), which did not include attitudes toward use, but did expand on the original TAM model by proposing and evaluating variables thought to predict both perceived usefulness and perceived ease of use (see Figure 2). However, the core ideology of the model (shown within the dotted box) remained the same.

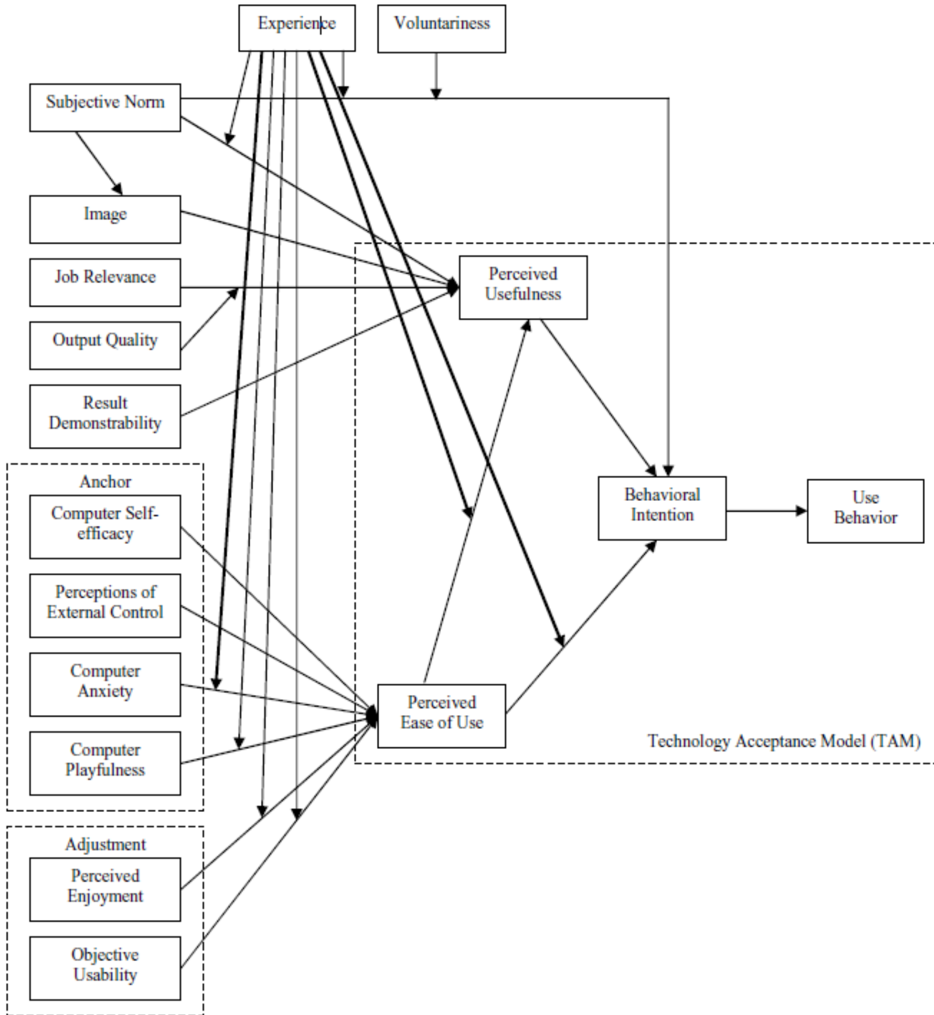


Figure 2. Technology Acceptance Model 3 (TAM3) (Venkatesh & Bala, 2008).

The model shows that a number of variables predict perceived usefulness: subjective norm, image, job relevance, result demonstrability, and perceived ease of use (Table 1 for definitions). Subjective norm and image relate to the impact of social factors on acceptance; referred to as social influence (Venkatesh & Davis, 2000). Output quality, job relevance, result demonstrability, and perceived ease of use are categorized as cognitive instructional processes. Specifically, these predictors relate to the decision making process of acceptance. Venkatesh and Davis explain, "...people form perceived usefulness judgments in part by cognitively comparing what a system is capable of doing with what they need to get done in their job" (2000, p. 190). In other words, perceived usefulness is, in part, dependent on the match between the users' needs and the technology capabilities.

Table 1. Predictors of Perceived Usefulness as Proposed by TAM2 and TAM3.

Predictor	Definition	Measurement Questionnaire Item
Subjective norm	perception that important people think should/not use the system	- People who influence my behavior think that I should use the system. - People who are important to me think that I should use the system. - The senior management of this business has been helpful in the use of the system. - In general, the organization has supported the use of the system.
Image	degree to which the innovation enhances social status	- People in my organization who use the system have more prestige than those who do not. - People in my organization who use the system have a high profile. - Having the system is a status symbol in my organization.
Perceived ease of use	how effortful a system is to use	- My interaction with the system is clear and understandable. - Interacting with the system does not require a lot of my mental effort. - I find the system to be easy to use. - I find it easy to get the system to do what I want it to.
Job Relevance	degree to which system is applicable to job	- In my job, usage of the system is important. - In my job, usage of the system is relevant. - The use of the system is pertinent to my various job-related tasks.
Result demonstr-ability	degree to which gains in job performance can be attributed to system	- I have no difficulty telling others about the results of using the system. - I believe I could communicate to others the consequences of using the system. - The results of using the system are apparent to me. - I would have difficulty explaining why using the system may or may not be beneficial.

The variables within the TAM are typically measured using a short Likert scale questionnaire (see Table 1), with response weights of 1 = "extremely unlikely"; 7 = "extremely likely." When validated for internal consistency, the predictors of perceived usefulness have scored highly across a large number of studies (for meta-analyses, see King & He, 2006; Legris, Ingham, & Collerette, 2003; Turner, Kitchenham, Brereton, Charters, & Budgen, 2010). Interestingly, these meta-analyses have largely suggested that the TAM is an accurate predictor of behavioral intention (King & He, 2006; Legris, Ingham, & Collerette, 2003); however, TAM as a predictor of actual usage has received some criticism (Legris, Ingham, & Collerette, 2003; Turner et al., 2010). This may be due, in part, to inconsistencies in the way actual usage is measured (i.e., self report vs. objective measures of actual usage), and the possibility that other unexplored variables influence actual adoption and continued long-term use (e.g., the notion of time in different stages of the implementation process; Rogers, 2003).

Limitations of Applying the Technology Acceptance Model to Robot Acceptance

TAM is a widely accepted model, particularly considering its reliable measure of behavioral intention. This is of importance when considering new technologies, such as robotics, where perceived usefulness (and subsequently behavioral intention) is an important consideration for future adoption. However, it is an open question regarding to what extent TAM measures can be expanded to include assistive robots. Robotic technology is different from the IT workplace applications that are usually investigated with TAM (Davis et al., 1989; Goodhue & Thompson, 1995; Rogers, 2003; Venkatesh & Bala, 2008; Venkatesh et al., 2003). Therefore, less is known about the application of TAM outside of these applications. There are a number of considerations when applying TAM to assistive robotics.

First, robots are a radical technology; radical technologies are fundamentally different from acceptance of incremental, or common, technologies (Dewar & Dutton 1986). Radical technology use has been shown to have different predictors than incremental technologies. Second, assistive robots are often applied in the home, a very different setting than the workplace where TAM has been traditionally studies. Third, because robots are integrated into the home, they will likely be offered as a commercial product. Therefore, users will have a choice on whether or not to use a robotic system. Mandatory vs. voluntary use of technologies has been shown to impact acceptance

(Venkatesh et al., 2003). For example, subjective norm, the impression that important people such as co-workers or management think the user should adopt the technology, has been shown to be a strong predictor in mandatory settings (Venkatesh et al, 2003), but this predictor may play a less important role in voluntary use.

Nonetheless, TAM may be a good starting point for thinking about robot acceptance. Other variables known to be important in assistive robotics may be good additions to measures and predictors of perceived usefulness (e.g., task type, autonomy, adaptability) and will be discussed next.

Acceptance of Assistive Robots for Older Adults

Matching Human and Robot Capability

Older adults' needs. Maintaining one's independence is a primary goal of older adults and a key component to successful aging and aging-in-place (AARP, 2005; Gitlin, 2003; Lawton, 1990). To do so, there are many tasks that older adults must perform to maintain their independence. For example, self-maintenance activities of daily living (ADLs) include the ability to toilet, feed, dress, groom, bathe, and ambulate (Lawton, 1990). 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 (Lawton, 1990). Enhanced activities of daily living (EADLs) include participation in social and enriching activities (e.g., learning new skills, engaging in hobbies, and communicating for social reasons; Rogers et al., 1998).

If an older adult can no longer perform these activities, consequences could include receiving home-based informal or formal care, moving into an assisted senior living facility, or moving into a nursing home. Robots that can assist with home tasks are rapidly being developed and researched (for a review of the current state of home-based assistive robot development, see Smarr, Fausset, & Rogers, 2011). An open question for many designers is: how do we ensure that older adults will actually use these robots? A number of studies have investigated tasks that older adults might want help with as they age (Beer et al., 2012; Ezer, Fisk, & Rogers, 2009b; Mast et al., 2012; Smarr et al., 2012), which may be a guide for designers to cater robot design to the older adult population.

Although the aforementioned research suggests that older adults may want robot assistance; it is unclear how much assistance is most useful, and if the nature of that assistance varies as a function of task or user capability. Thus, considerations regarding the robot's capability and autonomy need to be investigated in more detail.

Robot capability and autonomy. Consideration of a robot performing useful tasks raises the question, "what makes a robot's capability useful?" The Webster definition of capability is "extent of ability". Robot capability might be thought of as a combination of the task the robot performs (i.e., functionality) and the extent to which the robot can perform those tasks without external control (i.e., robot autonomy).

Robot autonomy, considered to be an important consideration in HRI (Thrun, 2004; Feil-Seifer, Skinner, & Mataric, 2007; Goodrich & Schultz, 2007), can range from teleoperation to fully autonomous, with most robots falling somewhere in the middle of that continuum. Robots are widely defined as systems that sense, plan, and act; it is important to note that autonomy can range along any of these capabilities. For example, a robot could conceivably have high autonomy in decision making (i.e., plan), but low autonomy on action (i.e., only serve as a decision aid; akin to the automation conceptualization of levels of automation, Parasuraman, Sheridan, & Wickens, 2000).

To determine the appropriate level of autonomy for any given task, designers must balance the technology capabilities with the human capabilities, and allocate functions accordingly (Parasuraman, Sheridan, & Wickens, 2000). If proper allocation is achieved, then the human-machine system will be the most useful and effective. In other words, an assistive robot's capabilities should be tailored to match or adapt to the older adult.

Little research has investigated, in-depth, the relationship between perceived usefulness, robot capability, and user needs, within the context of older adults using robots. As an older adult's independent-living needs increase, it might be expected that the robot's capability may also need to increase to meet those needs and be deemed as useful. This balancing act between users' needs and robot adaptability is not new; many factors, related to both the user and the robot, have been identified as important in robot acceptance.

Current Frameworks of Robot Acceptance

With regard to assistive robots, a number of reviews have been conducted with the goal of developing a comprehensive categorization of factors that influence user acceptance of service robots. Broadbent and colleagues (2009) conducted a review of factors found to influence human responses to healthcare robots. They categorized those factors into two categories: robot factors and person factors. Robot factors include the robot's appearance; humanness; facial dimensions and expressions; size; gender; personality; and ability to adapt to users' preferences and needs. Person factors include the user's age; needs; gender; technology/robot experience; cognitive ability; education; culture; role within society (e.g., job); and finally anxiety and attitudes towards robots.

In another literature review, Young and colleagues (2009) posited design guidelines for the development of home-based robots. In contrast to the aforementioned review, Young and colleagues used a social psychology approach to focus on robot acceptance within the context of socialization between home-based robots and humans. With basis in the social psychology literature, seven factors were identified as influential in people's acceptance of home robots: safety; accessibility and usability; practical benefits; fun; social pressures; status gains; and social intelligence. The authors also noted users' previous experiences and perceptions of media, personal social network, and robot design as being also critical.

Some of the variables identified by these two HRI literature reviews (Broadbent et al., 2009; Young et al., 2009) map closely in nature to the predictors of perceived usefulness and perceived ease of use identified in TAM (Davis, 1989; Ventakash & Davis, 2000; Ventakash & Bala, 2008). For example, in Young et al (2009) framework, social pressure and status could map onto TAM predictors image and subjective norm respectively. Furthermore, practical benefits could map onto TAM predictors job relevance or result demonstrability. However, these variables have not empirically tested in detail.

Perceived usefulness and perceived ease of use have specifically been found to be important for predicting intention to use home-based robots in the ALMERE model (Heerink et al., 2010). In this research, functionality related to the robots ability to adapt to the users preference was shown to be a predictor of perceived usefulness. After watching a video of a robot that adapted to an individual's needs, older adults reported a greater intention to use, more positive attitude, and perceived the robot as more enjoyable, useful, and less anxiety provoking than older adults who watched a similar video without the robot adapting to the individual (Heerink et al., 2010). In fact, ALMERE provides evidence that the notion of adaptability is a predictor of perceived usefulness.

Other research suggests that older adults' perceptions of a robot's usefulness may be task-dependent. For instance, older adults rated a healthcare robot's performance on tasks related to physical assistance and monitoring (e.g., detecting falls and calling for help, lifting heavy objects) as most useful, compared to tasks related to judgment-making and care (e.g., providing medical advice, personal care; Broadbent et al., 2011). If a robot is not perceived as performing useful tasks, older adults may not use the robot or may even try to trick it to keep it from performing a task (Klamer & Ben Allouch, 2010). Similarly, a framework extending the technology acceptance model to assess automation has also identified the importance of task-technology fit (but referred to as compatibility); additionally, this framework posits that trust is a likely attitudinal predictor of perceived usefulness (Ghazizadeh, Lee, & Boyle, 2012). Although, much like the HRI literature mentioned above, additional empirical evidence is needed to determine if these factors are, in fact, predictors of perceived usefulness.

Impetus of Research

Insight into the facilitators and barriers of acceptance, in particular in determinants of a user's perceptions of usefulness, will not only aid designers in creating robots that people are willing to adopt, but may also inform theory. By researching robot acceptance, the overall generalizability of technology acceptance models can be critiqued by identifying boundaries for existing factors and extending the existing models to better account for human interactions with robotic systems.

Perceived usefulness has been shown to be a predictor of intentional acceptance. However, little is known about perceived usefulness within the context of older adults and assistive robotics. Key factors that influence perceived usefulness may emerge as a function of (1) robot capability, which may vary by the task the robot performs, and the autonomy at which the robot performs those tasks; and (2) user needs, which may change both physically and cognitively as a person ages.

Perceived usefulness can be described as a person's decision of how well the technology's capability matches their own needs (Venkatesh & Davis, 2000). Thus, it may be hypothesized that as an individual's capabilities decrease, then the capability of an assistive robot will need to increase. Furthermore, not only will the capability likely need to increase, but also the autonomy (i.e., the robot performs tasks on its own) to better meet the user's needs and home environment/task demands (Thrun, 2004). This dissertation was designed to explore the match between user and robot capability, and how this match may change as a function of task. As thus, this dissertation addressed the following research questions:

[R1] *What is the relationship between user capability (operationalized in this dissertation as mobility) and perceptions of usefulness for robots of varying autonomy levels (operationalized as command/control methods).*

-Are perceptions of usefulness of varying autonomy levels task specific?

[R2] *Are constructs shown to be predictive of perceived usefulness of information technology (Venkatesh & Davis, 2000) correlated with perceived usefulness of assistive robots?*

-Are other constructs, such as trust, reliability, and adaptability also correlated with perceived usefulness of assistive robots?

[R3] *What are the facilitators and barriers of acceptance that older adults base their perceptions of usefulness?*

-Do the nature of those barriers and facilitators differ between task or between older adults of varying capability?

These questions were addressed in a mixed methods approach. The study consisted of two main parts: the first being an autonomy-selection think aloud task, that was designed to assess perceived usefulness as a function of user capability and robot autonomy level. The second being a persona-based structured interview that was designed to assess perceived usefulness as a function of persona capability and task type. The findings from this study provide an in-depth systematic assessment of perceived usefulness, and enrich our overall understanding of robot acceptance.

CHAPTER 2: METHOD

Participants

Twenty-four older adults, aged 65-80 (*M* = 71.5, *SD* = 5.1), were recruited to participate in this study. To determine eligibility for the study and screen for cognitive impairment, all older adults had to pass the Wechsler Memory Test WAIS-III (Wechsler, 1997), which was administered over the phone. The eligible older adults were grouped by mobility capability. Half of the older adults were mobile (M = 70.5 years of age, SD = 5.27). The remaining older adults reported having mobility loss (M = 72.4 years of age, SD = 4.98). Older adults who indicated that they used a wheelchair or walker on a daily basis were grouped into the mobility loss group, whereas older adults who reported using no ambulation aids were grouped into the mobile group. Males and females were represented equally within each age group. The older adults were compensated monetarily ($36 total) for their participation in the 3 hour study.

The older adults were recruited from four different senior communities, located in areas of metro Atlanta known to differ in socioeconomic status (SES). Information about the older adults' demographics, health, and technology experience were collected using standardized materials developed by the Center for Research and Education on Aging and Technology Enhancement (CREATE; Czaja et al., 2006).

The older adults' race was diverse, as depicted in Table 2, and they varied in their educational background. Specifically, 25% of mobile older adults reported having less than formal college education, 8.3% had some college education, and 66.7% had a college degree. Of the older adults *with* mobility loss, 33.3% reported having less than formal college education, 58.3% had some college education, and only 8.3% had a college degree.

Table 2. Percent of Participants by Racial Group

	Racial Group					
	White Caucasian	Black/ African American	Asian	Native Hawaiian/ Pacific Islander	Multi-Racial	Total
Mobile Older Adults	7	4	0	0	1	12
Older Adults *with* Mobility Loss	7	5	0	0	0	12

Mobile older adults were widowed (25%), married (33.3%), divorced (25%), or single (16.7%). Mobile older adults lived in a senior community (91.7%), or in a house/apartment/condominium (8.3%). This group reported they were in good health (*M* = 3.75, *SD* = .75; where 1 = poor, 3 = good, 5 = excellent); however, they still indicated some limitations. Limitations were reported most often for walking more than a mile, for climbing several flights of stairs, and for vigorous activities (e.g., running, lifting heavy objects, or participating in strenuous sports). The most prevalent chronic health conditions reported were hypertension, asthma/bronchitis, cancer, diabetes, and heart disease, which is representative of chronic illness trends in the general U.S. older adult population (Federal Interagency Form on Aging Related Statistics, 2010).

Older adults *with* mobility loss were widowed (50%), married (8.3%), divorced (33.3%), or separated (16.7%). They lived in a senior community (75%), in assisted living (8.3%), in a house/apartment/condominium (8.3%), or reported other (8.3%). They reported they were in fair health (M = 2.75, SD = 1.14); reporting some limitation in bathing or dressing, and much limitation in walking more than a mile, climbing several flights of stairs, bending/kneeling, vigorous activities (e.g., running, lifting heavy objects, or participating in strenuous sports), lifting groceries, and walking one or more blocks. The most prevalent chronic health conditions reported were arthritis, hypertension, asthma/bronchitis, diabetes, and heart disease. Older adults in this group generally reported more chronic health conditions compared to the mobile older adults.

All older adults had a visual acuity of 20/40 or better. Table 3 shows the mean performance for each ability test by mobility group; a significant difference between groups is indicated by an asterisk. There was a significant difference between groups for the Digit Symbol Substitution and the Shipley Institute of Living Scale, where mobile older adults scored significantly higher than those with mobility loss on these items. These findings may have been due to differences between groups in prevalence of arthritis (i.e., may impact writing speed, Digit Symbol Substitution) as well as education level (i.e., may impact crystallized intelligence, Shipley).

Table 3. Ability Test Data for Participants

Ability Test		Max Score	Mobile Older Adults (n=12)		Older Adults *with* Mobility Loss (n=12)		t-value
			M	*SD*	*M*	*SD*	
Reverse Digit Span	Memory Span Wechsler (1997)	14	7.33	2.77	7.00	2.82	.291(22)
Digit-Symbol Substitution	Perceptual Speed Wechsler (1997)	93	49.75	10.34	35.58	8.78	3.62(22)*
Digit-Symbol Recall	Implicit Memory Wechsler (1997)	9	4.33	2.19	3.50	2.58	.854(22)
Shipley Institute of Living Scale	Semantic Knowledge (Vocabulary) Shipley (1986)	40	35.25	3.17	26.67	7.50	3.65(22)*

*$p < .05$.

On the Technology Experience Profile, a questionnaire assessing frequency of use for 36 common technologies, mobile older adults reported significantly higher technology experience compared to older adults *with* mobility loss. However, both groups reported low to moderate technology experience overall (mobile older adults M=20.25, SD=8.18; older adult *with* mobility loss M=12.42, SD=7.63; $t(22) = 2.43$, $p < .05$). To assess older adults' experience with robots, we administered a questionnaire measuring familiarity as well as the frequency of using 13 different types of robots (e.g., manufacturing robots, entertainment/toy robots, personal robots, surgical robots). Overall, older adults in both groups were not familiar with robots, and no significant difference was found (mobile older adults $M = 1.34$, $SD = .51$; older adults *with* mobility loss M = 0.98, SD = .62; where 0 = not sure what it is; 1 = never heard about, seen, or used it; 2 = have only heard about or seen this robot; 3 = have used or operated it only occasionally; 4 = have used or operated it frequently; $t(22) = 1.55$, $p = .14$).

Materials

Pre-Interview Questionnaire Materials (Mailed Home to Participants)

Demographics and Health Questionnaire. Participant demographic information was obtained using the Demographics and Health Questionnaire (Czaja et al., 2006). The demographic section of the questionnaire collected information about participants' age, gender, ethnicity, education level, living arrangements, income, and employment status. The health section of the questionnaire collected information about participants' self-reported condition and satisfaction of health, medical conditions, and medication regimen (see Appendix C).

Technology Experience Questionnaire. Participants' technology experience was assessed using the Technology Experience Questionnaire (see Appendix D). The 36-item questionnaire was designed to identify the depth, breadth, and frequency of use for 36 technologies related to communication, everyday use, recreation, computers, health, and transportation. For each technology, participants rated their frequency of use on a 5-point scale (1 = “not sure what it is”, 3 = “Used once”, 5 = “use frequently”).

Robot Familiarity and Use Questionnaire. To assess participants’ experience with robots, a questionnaire was administered measuring different aspects of robot familiarity as well as the frequency of using 13 different types of robots (e.g., manufacturing robots, entertainment/toy robots, personal robots, surgical robots). For each type of robot, participants selected their level of familiarity and usage on a 5-point scale (e.g., 0 = “not sure what this is” to 4 = “have used or operated this robot frequently”). See Appendix E for this questionnaire.

Assistance Preference Checklist (pre). The Assistance Preference Checklist was designed to assess how assistance preferences vary (robot vs. human) as a function of task (see Appendix F). Unlike previous uses of this questionnaire (e.g., Mitzner et al., 2011, Smarr et al., 2012; Smarr et al., in press), participants were asked to consider their *current* capabilities and limitations (i.e., in previous studies, participants were asked to *imagine* they needed assistance) for ADLs and IADLs. Participants then indicated their preferences for human or robot assistance with 40 home-based tasks, with the assumption that the robot could perform the task to the level of a human. The purpose of this questionnaire in this study was to compare assistance preferences (robot vs. human) between those participants with and without mobility loss. We assessed their assistance preferences before and after completing the experiment to capture changes in preferences.

Introduction to the Robot

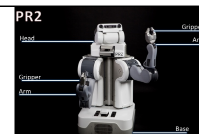
Robot Platform. The mobile manipulator used in this study was Willow Garage's (www.willowgarage.com) Personal Robot 2 (PR2; Fig. 3). The PR2 is a commercially available human-sized robot. The robot has a telescoping spine allowing it to range in height from 130 cm to 160 cm. The PR2 has an omnidirectional wheeled base, with a footprint the size of an average wheelchair. Its pan-tilt head carries two stereo camera pairs and a light emitting diode texture projector. It has two 8-degrees-of-freedom arms/grippers that permit it to manipulate objects in the environment. The PR2 was specifically designed to interact with humans in their environments. It was used in the current study to provide participants with an example of how a mobile manipulator could potentially function in a home setting.

Figure 3. Willow Garage's mobile manipulator, the Personal Robot 2 (PR2); image source www.willowgarage.com.

Video of Mobile Manipulator Robot. Participants were introduced to the PR2 via an 8-minute narrated video consisting of a collage of video clips. The purpose of the video was to introduce the PR2 and depict its capabilities. The video clips were a combination of clips locally developed, as well as adapted, with permission, from the

Willow Garage video blog (http://www.willowgarage.com/blog). The video consisted of three chapters that explained the physical features of the PR2, its capabilities, and a range of tasks the robot could perform (Table 4). The goal was to provide a best-case scenario of the robot's capabilities; therefore, we emphasized to participants that the robot was not limited to what was shown in the video. The video served as a foundation for the older adults' discussion in the interview by ensuring all participants had a similar expectation of mobile manipulators.

Table 4. Overview of video demonstrating PR2 capabilities.

Overview of PR2 Video		
Video chapter	*Description of what was shown*	*Video Screenshots*
1. Introduction	Layperson overview of robot's physical features (i.e., head, base, arms, grippers)	
2. Capabilities	Navigating forward, backward, side to side; pushing a cart; grasping a variety of objects; and telescoping spine	
3. Tasks	Opening a door; delivering drinks; delivering medication bottles; folding towels; plugging itself in; playing a game of billiards	

Part A: Autonomy-Selection Think Aloud Interview

Autonomy-Selection Think Aloud Script. The interview script was designed following the research methodology outlined by Fisk and colleagues (2009). This methodology includes a systematic development of the interview script and questions, materials, selection of the interview environment, recruitment of participants, and training of interviewers. For the interview portion of Part A, participants were asked to think about their current abilities. They were instructed to consider assistance from a robot, such as the PR2, and to imagine that the robot was a gift or provided by the senior center to remove the consideration of the cost of the robot was not a

Seven home tasks, one of which was a practice task, were discussed (see Table 5). These were selected to represent both physically- and cognitively-oriented tasks. The tasks were also chosen to represent activities of daily living (Lawton, 1990; ADL) and instrumental activities of daily living (Lawton, 1990, IADL), which are both important for maintaining independence. Two tasks were ADLs (dressing, transferring), two IADLs were physical in nature (cleaning, fetching), and two were cognitive in nature (monitoring, reminding). First, the task was described to the participant by stating, "Imagine you are at home with the robot. The robot can assist you with the task of _____". Then, they were asked whether or not they think robot assistance for the task would be useful for them personally.

Table 5. Tasks included in autonomy-selection think aloud.

Task	Nature of task
Grocery shopping	Practice task
Cleaning floors	IADL
Dressing	ADL
Find and fetch objects	IADL
Monitoring health	IADL
Reminding to take medication	IADL
Transfer	ADL

Note: Activity of daily living (ADL); instrumental activity of daily living (IADL); order of tasks was counterbalanced in study

If the participant replied "no" (i.e., they did not think robot assistance for the task would be useful for them personally), then they were asked to elaborate on reasons why they would not like robot assistance. If the participant replied "yes" (i.e., they thought robot assistance for the task would be useful for them personally), then they were presented with a sheet of paper, describing three options for commanding or controlling a robot (see Table 6). These options were designed to broadly represent three command/control options with different loci of control [i.e., local control (self); remote control (someone else); or robot control].

Table 6. Command/control options presented to participants.

Option A	Option B	Option C
I command/control the robot	Someone else (remotely) commands/controls the robot	Robot commands/controls itself

The participants were instructed to think out loud (i.e., to say whatever came to mind) when determining which command/control option would be most useful to them. The think aloud procedure was chosen to provide insight into the decision-making process participants used when determining which command/control option would be most useful. The full interview script is provided in Appendix A.

Part B: Persona-Based Interview

Personas. Personas were used to represent hypothetical older adults. This controlled methodology was chosen to provide context to the discussion regarding how a robot might assist older adults of varying capabilities.

Each persona represented a male or female older adult of 75 years of age (the median age of the recruited participant age range). Male participants were presented with male personas, and female participants with female personas. Each persona indicated that the hypothetical older adult "lives alone in their home" and that their goal was to "live independently for as long as possible." These details were included for the following reasons. First, we were most interested in the hypothetical interaction between the personified older adult and a robot. If the personified older adult lived alone, this mitigated responses on how human caregivers (i.e., spouses or children) might use the robot. Second, by stating that the personified older adult wished to remain independent, the persona's main goal or purpose for using an assistive robot was specified (i.e., the goals of using a home robot for entertainment, for example, are likely to be very different).

Each persona provided a different scenario regarding health status. Two personas were used: one with no physical/mobility loss and one with physical/mobility loss. These personas were partially based on the scenarios used in Caine (2006). The personas underwent several iterations of revisions following pilot testing to ensure older adults perceived the personas as either "healthy" or "limited". Figure 4 depicts the two personas used in this study.

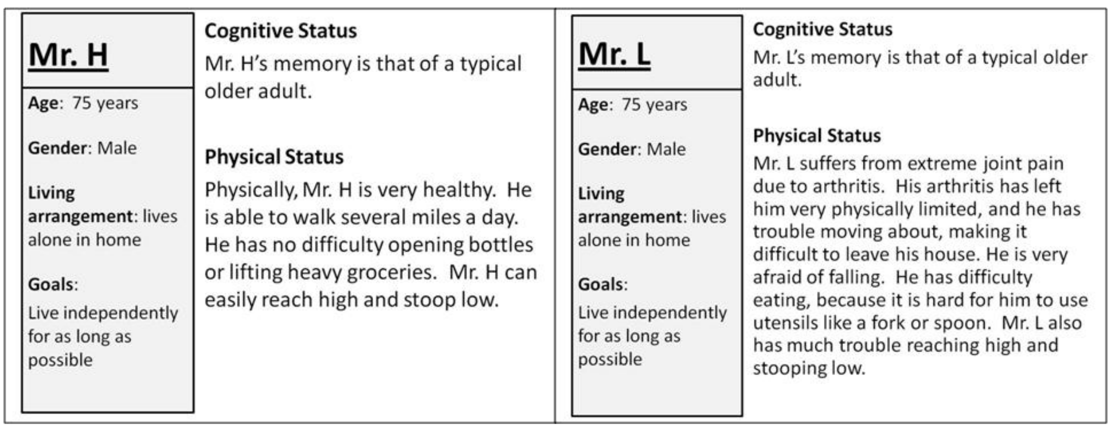


Figure 4. Personas used in interview
Note: Mr. H represents the mobile persona, and Mr. L represents the persona with mobility loss

Perceived Usefulness Task-Specific Questionnaires. Four tasks were discussed for this portion of the study. For each task, the participants completed a Perceived Usefulness Questionnaire. In this questionnaire (Table 7; Appendix B), TAM constructs shown to be predictive of perceived usefulness of robots are included (i.e., image, subjective norm, relevance, result demonstrability, perceived usefulness). The only TAM predictor that was excluded was perceived ease of use, because the video description of the robot and the interview script did not describe how the robot is operated. Therefore, for this portion of the interview, participants did not focus on how the robot was actually commanded (e.g., voice command, joy stick, etc), as was in the first portion (Part A) of the interview. Additional measures of perceived adaptability, trust, and reliability were added to the questionnaire. Based on HRI and automation frameworks of robot acceptance, these measures have been shown to be important in influencing either perceived usefulness or acceptance in general (i.e., Broadbent et al., 2009; Ghazizadeh, Lee, & Boyle, 2012; Heerink et al., 2010; Young et al., 2009).

Table 7. Example of Likert scale questions included in interview script questionnaire

Construct	Likert Question
Image	*Robot assistance with dressing will make Mrs. L seem more independent to others.*
Subjective Norm	*People in Mrs. L's life (i.e., family or friends) think that she should use a robot to assist with dressing.*
Relevance	*Robot assistance with dressing is important to Mrs. L's daily life.*
Result Demonstrability	*The benefits of a robot assisting Mrs. L with dressing are apparent.*
Adaptability	*A robot assisting with dressing will be adaptive to Mrs. L's needs.*
Trust	*A robot assisting Mrs. B with dressing is trustworthy.*
Reliability	*A robot will assist Mrs. L with dressing reliably and without error.*
Perceived Usefulness	*Using a robot to assist with dressing is useful to Mrs. L.*

Note: Persona Mrs. L, and the task of dressing used as example.
Scale: 1=extremely unlikely, 4=neither, 7=extremely likely

Perceived Usefulness Interview Script. The perceived usefulness interview script was designed following the research methodology outlined by Fisk and colleagues (2009). The interview script was written with the following goals in mind: 1) for each of the two personas, to assess perceived usefulness for robot assistance with a set of home-based tasks; 2) to indentify factors that influence perceived usefulness of the robot; and 3) to assess the perceived behavioral intention for each persona to use the robot. The full version of the script is provided in Appendix A.

To meet the first goal, a set of tasks were chosen to be included in the interview. The tasks, described in Table 8, included both ADLs and IADLs. The ability to complete such tasks (in particular, ADLs) is thought to be important for an older adult maintaining their independence. EADLs were not included because EADLs are not generally considered critical for functioning independently, although they contribute to an older adult's quality of life. The tasks included in this interview range in physical and cognitive requirements.

Table 8. Task descriptions.

Task	Description
T1: Organizing (IADL)	A robot that assists with house organization may be capable of the following: • finding lost objects such as remotes, glasses, cell phones, or keys • picking up objects or clutter from the floor • organizing items into containers, such as baskets/bins
T2: Monitoring (IADL)	A robot that assists with monitoring may be capable of the following: • monitoring the house for hazards (i.e., smoke) • signal when the stove has been left on • monitor a person's blood pressure or sugar levels
T3: Dressing (ADL)	A robot that assists with dressing, may be capable of the following: • suggesting clothing that is weather appropriate • assisting with zippers or buttons • provide assistance with balance when getting in/out of clothing
T4: Transfer (ADL)	A robot that assists with transfer may help with the following: • assisting in/out of chairs or beds • assisting in/out of the bathtub • picking up a person who has fallen

These tasks, along with the personas, served as context for the structured interview. For each task in turn, participants were asked to imagine the persona had been offered a robot to assist them. After filling out the Perceived Usefulness Questionnaire for each task, the participants were then asked:

"I see you indicated that it is __(slightly likely__ that the robot would be useful to Mr(s)._(L)_ for this task. How did you determine that?"

In this section of the interview script, participants described how they determined their perceived usefulness judgment. Finally, to close the discussion of each task, participants were asked their opinion on whether each persona should intend to use the robot for each task:

"If Mr(s)._(L)_ was given a robot to assist with the task of _(dressing)_, do you think she should use it?"

Post-Interview Questionnaire Materials

Assistance Preference Checklist (post). The same assistance preference checklist questionnaire administered pre-interview in Part A, was then re-administered after the completion of Part B interview. The purpose of administering this questionnaire both pre- and post-interview was to assess differences in assistance preferences due to exposure to the study.

Procedure

Before the interview, participants were mailed questionnaires about their demographics/health, technology experience, robot experience, and assistance preference. They were instructed to bring these completed materials to the experiment session where they were checked for completeness by the moderator.

On arrival to the structured interview, participants were provided with a written informed consent. Participants were informed that the discussion would be digitally recorded and later transcribed for analysis. The moderator discussed the goals and topic of the structured interview. The interview then followed a specific order, starting with the video depicting the PR2 and its capabilities, and a few icebreaker questions (e.g., "what do you know specifically know about research at Georgia Tech involving robots?" and "when I say *a technology is useful*, what does that mean to you?"). The participants then watched the video of the PR2 robot, and were asked if they had questions about the robot.

Next, the participants completed the Part A interview. The order of the tasks discussed in this portion of the interview was counterbalanced (Appendix A). For each task, the procedure occurred in the following order

- The task was described to the participant
- The participant indicated whether they would find robot assistance useful
- If so, they would determine which method of command/control would be most useful to them, and think aloud as they made this decision

After completion of the Part A interview the participants took a short break; then, they completed the ability tests. Another short break was offered before beginning the Part B interview.

To begin Part B of the interview, the participant was presented with a persona. The persona was printed on a piece of paper, and available for the participant to review throughout the interview. The participant was told that the hypothetical older adult presented in the persona has the option of using a robot to help with a variety of tasks. For each persona, the procedure occurred in the following order:

- Participant completed a Perceived Usefulness Questionnaire for each task.
- Participant discussed how they determined the perceived usefulness of robot assistance for each particular task.

- Participant stated their opinion on whether the persona should use the robot for each task.

This procedure repeated for each of the four tasks. After all of the tasks were covered, a short break was offered. Then, the above procedure repeated for the next persona. The order of the tasks, as well as the order of the personas, was counterbalanced using a partial Latin Square (Appendix A). After completing all personas, the participant completed the Assistance Preference Checklist (post). Finally, upon completion of the study (parts A and B), the participants were debriefed and paid for their time.

CHAPTER 3: RESULTS

Segmentation and Coding Scheme Development

The interview transcripts were analyzed according to a coding scheme to identify patterns and themes from the discussions. To do this, first the audio recordings were transcribed verbatim with the participant's personal information omitted. Next, transcripts were segmented into units of analysis. A segment was defined as a statement or description that included the following dimensions: any utterance in which a (1) thought, (2) feeling, or (3) opinion was related to perceived usefulness. Each segment was also task-specific. For example, a statement such as "*I think I would find assistance with dressing not useful because I want to remain in control - the robot won't know what I like to wear*" was coded as one segment. However, a statement such as the following would be split into two segments to represent two different tasks: "*I would love a robot to clean my floors; that would save me so much time. Now, I'm not so sure I would find help with medications as helpful. I do that on my own just fine.*"

Next, a coding scheme was developed to categorize each segment. A coding scheme is an organized categorization of the information in the interviews. For Part A of the study, the coding scheme was organized as facilitators (i.e., pros) and barriers (i.e., cons) for each command/control option. The coding scheme was based on both the literature and the nature of the participant comments. In other words, it included themes already known to be related to perceived usefulness (i.e., other's opinions, relevance, reliability, etc.). Also an iterative category generation strategy was used. In this approach, the first segment was coded either on a category already included in the coding scheme, or assigned a *new* category label determined by the researcher that describes the general idea of that segment (i.e., a bottom-up approach). Therefore, each segment was grouped naturally by its label(s).

For Part B of the study, the coding scheme was organized as facilitators (i.e., pros) and barriers (i.e., cons) for robot assistance, but the facilitators and barriers were further categorized as related to the robot, person, or environment. The coding scheme was based on both the literature and the nature of the participant comments, following the same scheme development process as described in Part A.

Coders were calibrated by conducting 2 rounds of independent coding on the same 4 randomly selected transcripts. Each round was followed by discussion of discrepancies and revision to the coding definitions. The final round of reliability resulted in an average of 86.4% agreement between the two coders. Percent agreement was calculated as the percentage at which different coders agreed and remained consistent with their assignment of particular codes to particular data. There is no standard or base percentage of agreement among qualitative researchers, but 85% seems to be a minimal acceptable benchmark (Saldana, 2012). After inter-coder agreement was met, the remaining transcripts were divided among the two coders to code independently.

Part A: Autonomy-Selection Think Aloud Results

Autonomy Selection: Trends Across Tasks

Autonomy selection. In this section of the study, participants indicated whether they would like robot assistance for a particular task, and what level of command/control they would perceive to be the most useful. Collapsed across task, the overall results are shown in Table 9.

Table 9. Command and control selection frequency across all tasks.

	Command and Control Across All Six Tasks				
	No robot assistance	I command /control the robot	Someone else (remotely) commands/ controls the robot	The robot commands / controls itself	Mixed Answer
Mobile Older Adults (n=12)	27	23	0	21	1
Older Adults *with* Mobility Loss (n=12)	14	32	10	13	3
TOTAL	**41**	**55**	**10**	**34**	**4**

Note: 24 older adults responded to 6 tasks, yielding 144 total responses

As shown in Table 9, participants' responses varied between group, as well as command/control level. First, older adults with mobility loss indicated a greater need for robot assistance, with only 14 instances of "No robot assistance". However, both the mobile $\chi^2(1, N = 12) = 4.50$, $p < .05$ and the older adults *with* mobility loss $\chi^2(1, N = 12) = 26.89$, $p < .001$ reported wanting robot assistance (i.e., any command/control option) significantly more often than no robot assistance. This suggests that no matter the mobile capability, older adults in this sample reported they would benefit from robot assistance.

Comparing the command/control options, "someone else commands/controls the robot" was the least preferred option for both groups. In fact, not a single mobile older adult indicated that they perceived this option to be useful for any task.

The older adults *with* mobility loss were almost three times more likely to select "I command/control the robot" compared to "the robot command/controls itself". Comparatively, the mobile older adults were relatively equally split between the selection of these two options.

In a small number of instances, some older adults selected a mixed answer. In all 4 of these instances, the selection was a mix of "I command/control the robot" and "the robot command/controls itself," where the older adults suggested that it would be most useful to provide the initial command to the robot, and then the robot would complete the rest of the task autonomously.

Reasons for command/control selections. To understand the older adults' reasoning behind their command/control selections, they were asked to think out loud as they determined which option they perceived as most useful. For the selection of "no robot assistance", the exclusive reasoning was that the participant did not need robot assistance for that task. However, the reasons that drove the selection of the other command/control options varied.

What led to preferences to control the robot (facilitators) and what led participants to not prefer to control the robot (barriers) across all tasks identified for "I Command/Control the Robot" are depicted in Figure 5. The assessment of usefulness for this command/control option was relatively straightforward, with older adults mentioning a small variety of determinants.

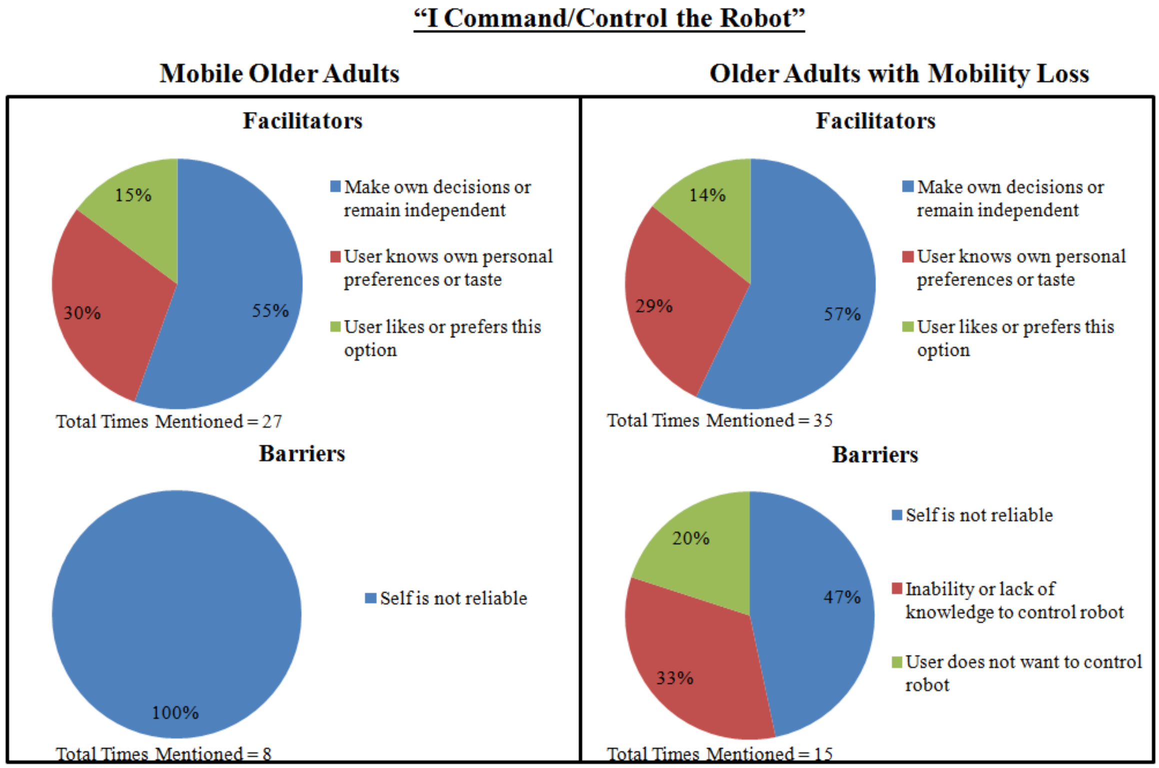


Figure 5. Facilitators and barriers mentioned for "I command/control the robot"

For both mobile older adults and older adults *with* mobility loss, the most commonly mentioned facilitator for selecting this command/control option was related to remaining in control to make own decisions. Participants identified that the ability to remain in control, make decisions, and control their own independence was a useful aspect. Furthermore, a secondary useful aspect of this command/control option was that participants wanted to remain in control of the robot because they know their own preferences, and want to determine how/when a task should be completed. For example, one older adult explained, "*I'd like to tell it to do it myself. [Researcher: And why is that?] I just feel more comfortable, even though it is state of the art technology..I may not be ready to do it [clean floors] when it [the robot] was ready to do it... so I would like to do it when I was ready.*" Older adults *with* mobility loss also mentioned barriers related to lack of knowledge on how, or a lack of desire to, control a robot.

When identifying barriers to "I command/control the robot," both groups of older adults suggested that this option may not be ideal if they cannot rely on themselves to know when a task should be done or how a task should be completed (code: "self is not reliable"). For example, they may forget to tell the robot to deliver their medications, or they may not know when the floor needs to be cleaned, "*because if I really need a reminder [for medication management], I might forget to command it [the robot] myself.*"

Although "Someone Else Commands/Controls the Robot" was overall not a preferred option (see Table 9), a few affirmative reasons were identified nonetheless primarily by the older adults *with* mobility loss (Figure 6). In particular, participants identified that they would not want someone else involved with robot assistant. Also, the expertise of someone else, or someone else's ability to control the robot, was considered as reasons for selecting this option. For example, some participants indicated that a medical professional, because of their expertise, might be useful to control the robot. For the task of monitoring, one older adult stated, "*That would be great... by someone else like a doctor or something because he knows what the normal is.*" A few mobile older adults indicated this option might be useful if they are incapable, for example if they are not feeling well.

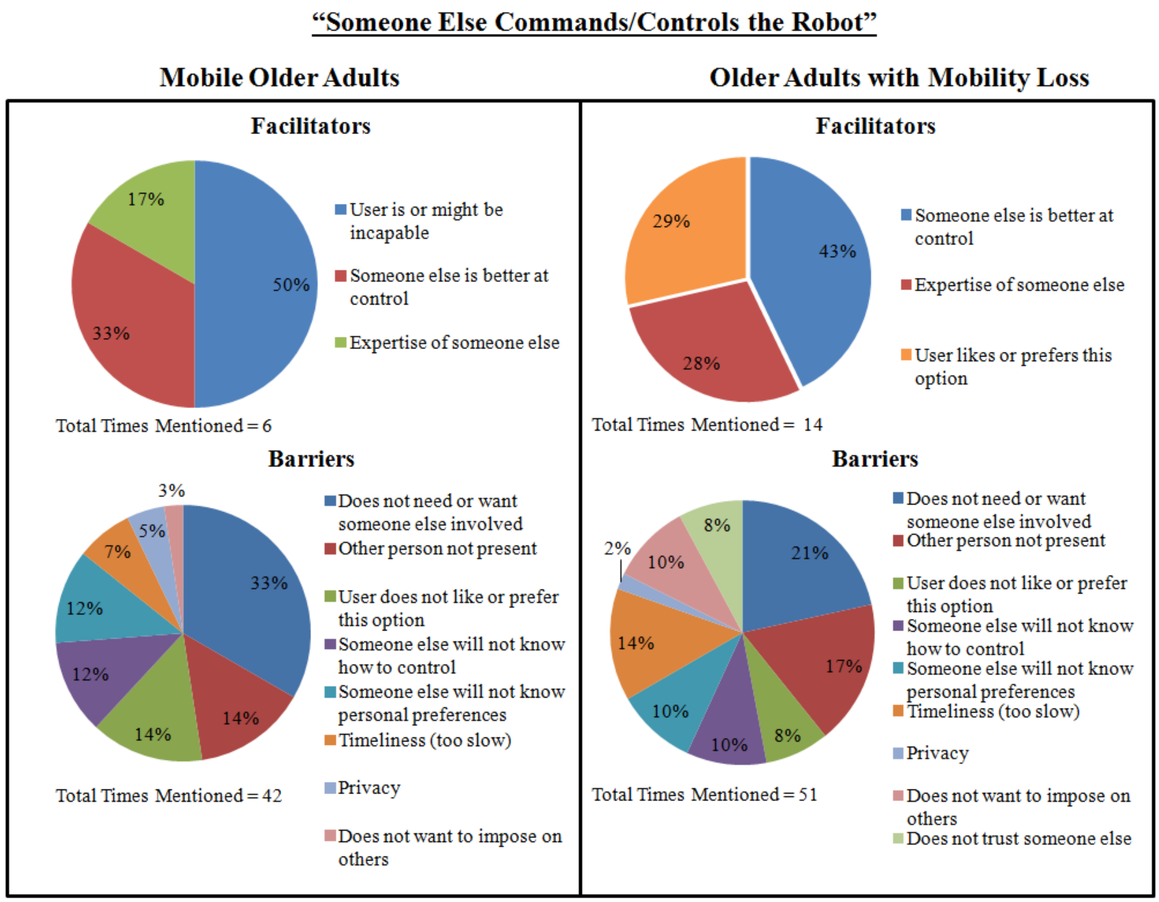


Figure 6. Facilitators and barriers mentioned for "Someone else commands/controls the robot"

Negative statements regarding this "Someone Else Commands/Controls the Robot" were widely varied, as shown in Figure 6. The most commonly mentioned barrier was that the participants did not want someone else involved in a task, "*I don't need someone else coming in on that situation.*" Likewise, there was some concern that if the operator was remote, they may not be as useful because they are not present with the older adult and robot, thus less aware of their wants and needs.

Finally, the option "The Robot Commands/Controls Itself" yielded a variety of both facilitators and barriers (Figure 7). Mobile older adults suggested a greater variety of facilitators compared to older adults *with* mobility loss; but, the top 3 reasons were the same. First, both groups suggested that the robot could be preprogrammed. Older adults indicated this would be useful because the robot would already know the schedule (e.g., clean floor daily) or how to complete the task. Another facilitator for this option was related to robot capability. For this command/control option, sometimes participants indicated that based on what they saw in the robot video, some tasks seem likely to be performed by a robot (e.g., "*finding and fetching is something the robot could do*"). Finally, both groups mentioned that the robot would be highly reliable, and some participants even suggested that the robot would be more reliable than a human.

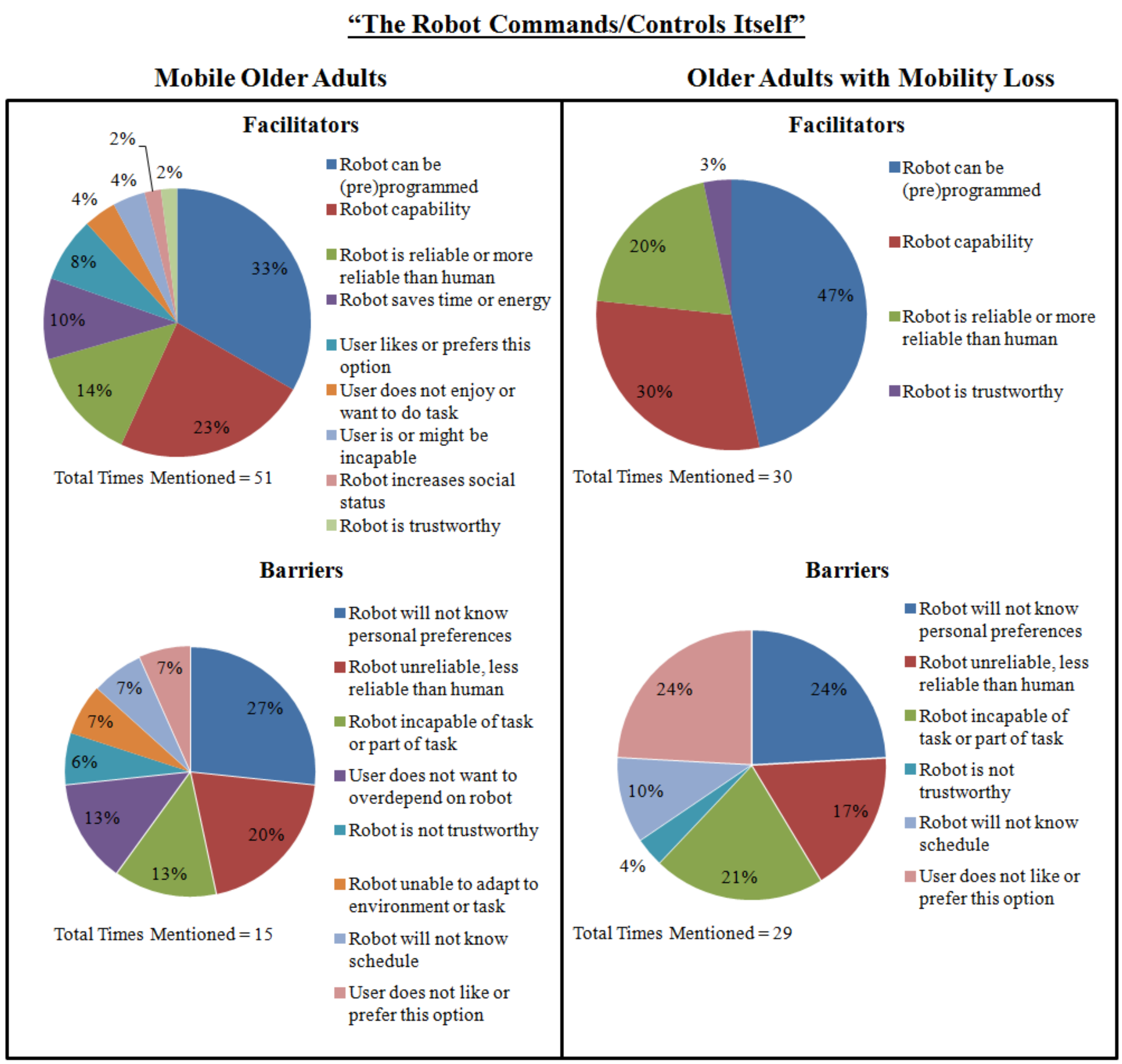


Figure 7. Facilitators and barriers mentioned for "The robot commands/controls itself"

Barriers for the robot commanding/controlling itself included the assumption that the robot would not know the users' personal preferences. For example, how would the robot know what clothing to select for dressing, or know what object to find/fetch? Similarly, some participants doubted the robots' capability of actually performing autonomously or reliably. Although, some participants suggested reliability as a facilitator, others were more doubtful, with one participant stating they would use the robot "*If they [designers] could prove to me how accurate this robot would be.*"

Although it is useful to consider the command/control options overall, it is important to note that the facilitators and barriers often differed by task. That is, participants' usefulness judgments were based on task-specific considerations, as well as their own capabilities and limitations. The next section discusses task-specific and mobility-specific trends in the data.

Autonomy Selection: Task-Specific Trends

Clean Floors. Nearly all participants, in both groups, indicated that assistance with cleaning floors would be useful. Two participants with mobility loss stated that they did not want robot assistance. Their preference might have been because, in part, these two individuals suggested they had maids clean their homes. All of the remaining participants indicated interest in robot support for this task.

Table 10. Command and control selection frequency for clean floors.

	Command and Control for CLEAN FLOORS				
	No robot assistance	I command /control the robot	Someone else (remotely) commands/ controls the robot	The robot commands / controls itself	Mixed Answer
Mobile older adults (n=12)	0	6	0	6	0
Older adults *with* mobility loss (n=12)	2	5	1	3	1
TOTAL	**2**	**11**	**1**	**9**	**1**

Participants' preferences were split between "I command/control the robot" and "the robot commands/controls itself." For the first, both groups suggested that a useful aspect of this option was that they could remain in control and could make their own decisions regarding how/when the floor should be cleaned. The mobile older adults suggested that they preferred to control/command the robot because only they could determine their own preferences. For example, "*… if I needed my floors cleaned and I would have the robot do it… Well, I still think initially I would have to be there and give it commands because I'm thinking about each room is different. The way the furniture is and laid out, it might be some things that I would need to be moved out of the way.*" Few barriers for this command/control option were mentioned, with no obvious patterns.

For "The Robot Commands/Controls Itself", majority of the facilitators were mentioned by the mobile older adults. In particular, useful aspects of this option were that the robot could be preprogrammed to clean on a regular schedule. The robot could also save them time or energy by relieving them of doing the task themselves.

"Someone Else Commands/Controls the Robot" received nearly exclusively negative remarks for this task by both groups. The most mentioned barrier, by both older adults with and without mobility loss, was that they did not want someone else involved in this home cleaning task.

Dressing. Although nearly half of the participants suggested that they would *not* find assistance with dressing useful, those that did almost exclusively wanted to command/control the robot themselves. The older adults with mobility loss were more likely to want assistance with this task. The female participants who wanted assistance with this task suggested that it would be useful for a robot to assist with fastening bras, jewelry, and other tasks requiring fine motor movement. For example, one female (mobile) stated, "*Yes, it would be useful. How would be um, zipping all the way to the top, sometimes fastening necklaces, sometimes buttoning the back of a garter at the neck, and I also have a dress that has a bow that needs snapping and it doesn't stay snapped so it'd be helpful if it could put the safety pin in.*" Male participants suggested help with socks, shoes, and balance when putting on/off pants.

Table 11. Command and control selection frequency for dressing.

	Command and Control for DRESSING				
	No robot assistance	I command /control the robot	Someone else (remotely) commands/ controls the robot	The robot commands / controls itself	Mixed Answer
Mobile older adults (n=12)	8	4	0	0	0
Older adults *with* mobility loss (n=12)	4	7	1	0	0
TOTAL	**12**	**11**	**1**	**0**	**0**

Regarding "I Command/Control the Robot," both groups mentioned that this option was useful because only they know their own personal preferences/taste. For example, one older adult *with* mobility loss stated, "*I don't think he had that much sense to know what color or what… I can't really explain it. I'd rather put my own apparel and clothes on. I don't want that. No. And I would just feel funny with something electrical, something following me around and doing things like that for me. No.*" This barrier was mentioned primarily with regard to choosing colors, styles, and putting on clothing the way they want it put on.

Barriers related to "Someone Else Commands/Controls the Robot" were mentioned by each group, but with no obvious trend. Barriers ranged in nature, and included not wanting someone else involved, limitations because the other person may not be present (i.e., if operated remotely), and simply not preferring or liking this option.

Likewise, for the robot commanding/controlling itself, few facilitators were identified by either group. Barriers included speculation that the robot would not actually be capable of the task or would not be able to determine the older adults' preferences in dress or style; one older adult explained "*because the robot wouldn't necessarily know because not everybody dresses the same way.*" A few older adults simply expressed that they did not like this option for this task, without effectively elaborating more on why they held this preference/dislike.

Find and Fetch. All participants, from both groups, indicated that they would find robot assistance with finding and fetching objects to be useful. They indicated assistance with this task would be useful for both physical (e.g., stooping low) and cognitive (e.g., remembering where items were placed) aspects of the task.

Table 12. Command and control selection frequency for find and fetch

	Command and Control for FIND AND FETCH				
	No robot assistance	I command /control the robot	Someone else (remotely) commands/ controls the robot	The robot commands / controls itself	Mixed Answer
Mobile older adults (n=12)	0	10	0	1	1
Older adults *with* mobility loss (n=12)	0	11	0	0	1
TOTAL	**0**	**21**	**0**	**1**	**2**

Nearly all of the participants indicated that the option "I Command/Control the Robot" to find and fetch objects would be the most useful. There were a large number of facilitators mentioned from both user groups. The most common facilitator was the desire to remain in control. Participants suggested that they would not want the robot delivering objects to them unless they indicated to the robot an explicit need for such object.

For "Someone Else Commands/Controls the Robot," few facilitators were mentioned by participants. However, a variety of barriers were mentioned, and patterns were similar between groups. Barriers included not wanting someone else involved, lack of timeliness (i.e., someone else controlling the robot would be too slow), and someone else would not know personal preferences (e.g., when an item was needed). For example, on older adult stated, "*When I lose something, it's usually something I need right that minute because I wouldn't know it lost otherwise...so I wouldn't like B [someone else command/controls the robot]".*

Although the robot commanding/controlling itself was not identified as a useful option, there were some facilitators identified, mostly by the mobile older adults. For example, some older adults mentioned that this task seemed like something the robot should be able to perform based on the video they watched.

Medication Reminders. Nearly all participants indicated that they would like assistance with medication reminders. Of those who indicated that they do not want robot assistance, they said they did not need it because either 1.) they did not take medication, or 2.) they had a reminder system in place (e.g., a pill box) that worked for them. The mobile older adults primarily indicated that they would like the robot to command/control itself; whereas, older adults *with* mobility loss suggested a split between the three command/control options.

Table 13. Command and control selection frequency for medication reminders

	Command and Control for MEDICATION REMINDERS				
	No robot assistance	I command /control the robot	Someone else (remotely) commands/ controls the robot	The robot commands / controls itself	Mixed Answer
Mobile older adults (n=12)	2	1	0	9	0
Older adults *with* mobility loss (n=12)	2	4	3	3	0
TOTAL	**4**	**5**	**3**	**12**	**0**

A few facilitators (e.g., remain in control) were mentioned for the option "I Command/Control the Robot," but the primary barrier of this option was that the older adults in both groups suggested that they cannot rely on themselves. They are sometimes forgetful, thus it would not be useful for them to control the robot because it would increase the likelihood of missing an important medication.

Facilitators for someone else controlling the robot were mentioned by a few participants *with* mobility loss. They suggested it would be useful for a healthcare professional to control the robot due to their expertise and likelihood of better controlling the robot. One older adult *with* mobility loss stated, "*Well I think B [someone else commands/controls the robot] would probably be better and that answers this because I may not remember and if someone is already have it, like my doctor could tell the robot* *at such and such a time she is to take this medication and the robot would remind me of taking it*."

The robot commanding/controlling itself was perceived as the most useful option by mobile older adults. They suggested that the robot, because it can be preprogrammed with their medication schedule ahead of time, particularly if their medication schedule is fixed, as indicated by this mobile older adult, "*well I think it'd be programmed into the robot. I take medication morning upon waking up in the bathroom and second again a bed time medication before I go to bed.*" Some participants also stated that a robot would be more reliable then themselves or another human.

Monitor Health. Nearly all older adults *with* mobility loss indicated they would like a robot to monitor health. In particular, they mentioned their fear of falling. For mobile older adults, five participants recognized the utility of this task; however, the rest of the group simply stated they would not find a robot for this task useful because they do not have health issues that would require monitoring.

Table 14. Command and control selection frequency for monitor health.

	Command and Control for MONITOR HEALTH				
	No robot assistance	I command /control the robot	Someone else (remotely) commands/ controls the robot	The robot commands / controls itself	Mixed Answer
Mobile older adults (n=12)	5	2	0	5	0
Older adults *with* mobility loss (n=12)	1	2	4	4	1
TOTAL	**6**	**4**	**4**	**9**	**1**

The option "I Command/Control the Robot" yielded a mix of facilitators and barriers, with similar trends between groups. Mentioned facilitators included the desire to remain in control and determine when the robot should monitor. The most commonly mentioned barrier was that the participants could not rely on themselves to tell the robot when/how to monitor. For examples, a few participants mentioned that they were supposed to monitor their blood pressure but neglect to do so, or they recognize that they should have a healthy diet but lack the willpower to do so. Thus, they felt they would be less likely or reliable to command the robot for these monitoring tasks.

A few older adult *with* mobility loss suggested that "Someone else Commands/Controls the Robot" would be a useful option for the task of monitoring. Their primary reasoning was that if a medical professional controlled the robot, then their expertise is useful for this task. Also, some older adult with mobility loss simply preferred or felt more comfortable with this option, "*Because I have somebody besides myself who is monitoring. I can't be, I couldn't feel secure without some human factor involved.*" Barriers for this command/control option were mentioned by both groups. There were a variety of barriers mentioned, with no clear patterns. Examples included not wanting someone else involved, or simply not liking this option.

For the task of monitoring health, "The Robot Commands/Controls itself" was the most preferred option overall. One mobile older adult explained, "*If there's a robot that can do that kind of stuff, that's good because it takes some of the pressure off of me to remember all of that and still have the tools to see what I'm actually doing good and not so good.*" Mostly facilitators were mentioned for this option, and there were similar trends between groups. The two most commonly mentioned facilitators were that the participants perceived the robot to be capable for this task, and that it would be useful for the robot to be preprogrammed. Several participants mentioned that a robot commanding/controlling itself would be particularly useful if they could be monitored with the robot being minimally invasive.

Transfer. For the task of transfer, none of the mobile older adults indicated that they would find robot assistance useful, stating they do not need help with this task. However, for older adults *with* mobility loss, just over half indicated they would like robot assistance with transfer.

Table 15. Command and control selection frequency for transfer.

	Command and Control for TRANSFER				
	No robot assistance	I command /control the robot	Someone else (remotely) commands/ controls the robot	The robot commands / controls itself	Mixed Answer
Mobile older adults (n=12)	12	0	0	0	0
Older adults *with* mobility loss (n=12)	5	3	1	3	0
TOTAL	**17**	**3**	**1**	**3**	**0**

No robot assistance was primarily chosen because the participants indicated that they do not need assistance with transfer. Discussion of facilitators and barriers for the various command/control options was sparse, but were related to risk of fall or convenience of robot availability. One older adult *with* mobility loss explained, "…'*cause I could tell it to help me back to bed, but that would be a good thing to have because y'all wouldn't have to worry about, you know, nobody else coming to help. You know, it's hard to get help these days, I would rather have a robot than a human, I would. If it was as good as a human, you know.*" Barriers identified included someone else controlling the robot would be too slow, "*If I control it [opposed to someone else controlling it], I could hurry it up and tell him to get me out that bath tub,*" or the robot would not know the users' personal preferences regarding how they would like to be moved.

Summary of Key Findings: Part A

Overall both groups, the mobile older adults and the older adults *with* mobility loss, selected robot assistance as being useful more often than 'no robot assistance'. This suggests that older adults, of varying capabilities, perceive they could benefit from robot assistance. However, the older adults' preferences and reasons for determining usefulness varied as a function of both task and user capability. A summary of key findings and their relation to the dissertation research questions are outlined below:

***[R1]** What is the relationship between user capability (operationalized in this dissertation as mobility) and perceptions of usefulness for robots of varying autonomy levels (operationalized as command/control methods).*

-Are perceptions of usefulness of varying autonomy levels task specific?

- Key findings about usefulness for varying autonomy levels:
    - Overall, "I Command/Control the Robot" and "The Robot Commands/Controls Itself" were the most preferred options, if robot assistance was deemed useful.
    - Overall, "Someone Else Commands/Controls the Robot" was perceived as the least useful option.

- Key findings about relationship between user and robot capability:
    - Older adults *with* mobility loss tended to prefer "I Command/Control the Robot" compared to the other command/control options.
    - Mobile older adults were split between preferences for "I Command/Control the Robot" and "The Robot Commands/Controls Itself."

- Key findings for task specific preferences (both groups combined):
    - Preferences for command/control were task specific, largely due to the nature of the task
    - Tasks related to personal preferences trended toward "I Command/Control the Robot", whereas tasks that are on a fixed schedule trended toward "The Robot Commands/Controls Itself"

- <u>Cleaning</u>: "I Command/Control the Robot" and "The Robot Commands/Controls Itself"
- <u>Dressing</u>: "I Command/Control the Robot"
- <u>Finding and fetching</u>: "I Command/Control the Robot"
- <u>Medication reminding</u>: "The Robot Commands/Controls Itself"
- <u>Monitoring</u>: "The Robot Commands/Controls Itself"
- <u>Transferring</u>: "No Robot Assistance"

[R3] *What are the facilitators and barriers of acceptance that older adults base their perceptions of usefulness?*

-Do the nature of those barriers and facilitators differ between task or between older adults of varying capability?

- Key findings about facilitators and barriers to assistive robots
    - Facilitators and barriers differed across command/control options, but were relatively similar between mobile older adults and older adults *with* mobility loss.
        - "I Command/Control the Robot":
            - Facilitators included making own decisions and determining own personal preferences.
            - Barriers included inability to command/control robot if the self is unreliable. For example, an older adult might not want to command/control robot for medication reminders if they forget their medication schedule.
        - "Someone Else Commands/Controls the Robot
            - Facilitators included having someone else who is better at controlling the robot, and someone else might have more expertise (e.g., medical professional)
            - Barriers included not wanting someone else involved, someone else might not be present in home, and a general dislike toward this command/control option.

- "The Robot Commands/Controls Itself"

    - Facilitators included the convenience of having a robot (pre)programmed to do task, and the reliability of the robot.

    - Barriers included the robot not knowing the users' personal preferences (e.g., what color clothing to wear), and the possibility of the robot being unreliable or making a mistake.

Part B: Persona-Based Interview Results

In Part B of the interview, participants were asked to consider the usefulness of robot assistance for two personas: 1.) mobile persona and 2.) persona with mobility loss. For each of the four tasks discussed, a Likert questionnaire (Scale: 1=extremely unlikely, 4=neither, 7=extremely likely) was administered to measure the participants' perceptions of usefulness of an assistive robot, as well as variables known to predict usefulness (for questionnaire items for each variable, see Table 7). To explore relationships between questionnaire items, each participant's questionnaire responses across all tasks were aggregated; correlations of those aggregate scores are shown in Table 16. Both groups were combined to ensure a large enough sample size appropriate for correlation (Bonnet & Wright, 2000).

Table 16. Correlations between items in Perceived Usefulness Questionnaire.

	Image	Subjective Norm	Relevance	Result Demonstr-ability	Adapt-ability	Trust	Reliability	Perceived Usefulness
Image	1	.65**	.81**	.68**	.81**	.73**	.62**	.76**
Subjective Norm	.65**	1	.88**	.94**	.80**	.73**	.66**	.83**
Relevance	.81**	.88**	1	.92**	.93**	.79**	.71**	.96**
Result Demonstr-ability	.68**	.94**	.92**	1	.87**	.71**	.67**	.90**
Adapt-ability	.81**	.80**	.93**	.89**	1	.82**	.80**	.97**
Trust	.73**	.73**	.79**	.71**	.82**	1	.86**	.80**
Reliability	.62**	.66**	.71**	.67**	.80**	.86**	1	.72**
Perceived Usefulness	.76**	.83**	.96**	.90**	.97**	.80**	.72**	1

** Correlation is significant at the 0.01 level (2-tailed), N=24

As shown in Table 16, medium to strong positive correlations were found between each variable. Specifically, the TAM variables (i.e., image, subjective norm, relevance, and result demonstrability) were positively correlated with the perceived usefulness questionnaire item, as depicted in the last row/column of Table 16. Also, the added variables (i.e., adaptability, trust, and reliability) were also positively correlated with perceived usefulness. The positive correlations imply that as each predictor variable increased, so did perceptions of usefulness. Regarding construct validity, the fact that all variables correlated positively with one another suggest that items are observed to be related to each other.

Comparison of Personas

Tables 17-20 display Wilcoxon Signed Rank Nonparametric comparisons to test if questionnaire responses differed between the two personas. For these tests, the participant groups were combined, and an overall comparison between personas was conducted. Findings suggest that the participants perceived a difference between personas for almost every questionnaire item and for every task, with a significantly higher median for the persona with mobility loss (Mr. L) compared to the mobile persona (Mr. H).

Table 17. Differences in questionnaire responses between persona types for the task of dressing.

	Dressing			
	Mobile Persona	*Mobility Loss Persona*	*Wilcoxon Signed Rank Test*	*p*
Image	Median = 5.00 Range = 1-7	Median = 7.00 Range = 1-7	$Z = 3.64$	<.001
Subjective Norm	Median = 4.50 Range = 1-7	Median = 7.00 Range = 4-7	$Z = 3.94$	<.001
Relevance	Median = 4.00 Range = 1-7	Median = 7.00 Range = 6-7	$Z = 4.04$	<.001
Result Demonstrability	Median = 4.50 Range = 1-7	Median = 7.00 Range = 6-7	$Z = 4.04$	<.001
Adaptability	Median = 5.00 Range = 1-7	Median = 7.00 Range = 6-7	$Z = 4.05$	<.001
Trust	Median = 5.00 Range = 1-7	Median = 7.00 Range = 4-7	$Z = 3.14$	<.001
Reliability	Median = 5.00 Range = 1-7	Median = 6.00 Range = 4-7	$Z = 2.75$	<.001
Perceived Usefulness	Median = 5.00 Range = 1-7	Median = 7.00 Range = 6-7	$Z = 3.98$	<.001

Scale: 1=extremely unlikely, 4=neither, 7=extremely likely

Table 18. Differences in questionnaire responses between persona types for the task of transfer.

	Transfer			
	Mobile Persona	*Mobility Loss Persona*	*Wilcoxon Signed Rank Test*	*p*
Image	Median = 4.50 Range = 1-7	Median = 7.00 Range = 1-7	$Z = 3.09$	<.01
Subjective Norm	Median = 5.00 Range = 1-7	Median = 7.00 Range = 3-7	$Z = 3.69$	<.001
Relevance	Median = 4.50 Range = 1-7	Median = 7.00 Range = 6-7	$Z = 3.84$	<.001
Result Demonstrability	Median = 4.50 Range = 1-7	Median = 7.00 Range = 5-7	$Z = 3.64$	<.001
Adaptability	Median = 5.50 Range = 1-7	Median = 7.00 Range = 6-7	$Z = 3.65$	<.001
Trust	Median = 6.00 Range = 1-7	Median = 7.00 Range = 4-7	$Z = 2.97$	<.01
Reliability	Median = 6.00 Range = 1-7	Median = 7.00 Range = 5-7	$Z = 2.81$	<.01
Perceived Usefulness	Median = 5.00 Range = 1-7	Median = 7.00 Range = 6-7	$Z = 3.74$	<.001

Scale: 1=extremely unlikely, 4=neither, 7=extremely likely

Table 19. Differences in questionnaire responses between persona types for the task of organizing.

	Organizing			
	Mobile Persona	*Mobility Loss Persona*	*Wilcoxon Signed Rank Test*	*p*
Image	Median = 5.50 Range = 1-7	Median = 6.00 Range = 1-7	*Z* = 2.96	<.01
Subjective Norm	Median = 6.00 Range = 1-7	Median = 7.00 Range = 4-7	*Z* = 3.33	<.01
Relevance	Median = 6.00 Range = 1-7	Median = 7.00 Range = 5-7	*Z* = 3.56	<.001
Result Demonstrability	Median = 6.00 Range = 1-7	Median = 7.00 Range = 5-7	*Z* =3.47	<.01
Adaptability	Median = 6.00 Range = 1-7	Median = 6.50 Range = 6-7	*Z* = 2.98	<.01
Trust	Median = 6.00 Range = 1-7	Median = 6.00 Range = 4-7	*Z* = 2.22	<.05
Reliability	Median = 6.00 Range = 1-7	Median = 6.00 Range = 1-7	*Z* = 1.77	.08
Perceived Usefulness	Median = 6.00 Range = 1-7	Median = 7.00 Range = 5-7	*Z* = 3.06	<.01

Scale: 1=extremely unlikely, 4=neither, 7=extremely likely

Table 20. Differences in questionnaire responses between persona types for the task of monitoring.

	Monitoring			
	Mobile Persona	*Mobility Loss Persona*	*Wilcoxon Signed Rank Test*	*p*
Image	Median = 6.00 Range = 1-7	Median = 7.00 Range = 1-7	*Z* = 1.96	.05
Subjective Norm	Median = 6.00 Range = 2-7	Median = 7.00 Range = 4-7	*Z* = 2.83	<.01
Relevance	Median = 6.00 Range = 1-7	Median = 7.00 Range = 6-7	*Z* = 3.21	<.01
Result Demonstrability	Median = 6.00 Range = 1-7	Median = 7.00 Range = 5-7	*Z* = 3.08	<.01
Adaptability	Median = 6.00 Range = 1-7	Median = 7.00 Range = 6-7	*Z* = 3.33	<.01
Trust	Median = 6.00 Range = 1-7	Median = 7.00 Range = 4-7	*Z* = 2.41	<.05
Reliability	Median = 6.00 Range = 1-7	Median = 6.50 Range = 5-7	*Z* = 2.80	<.01
Perceived Usefulness	Median = 6.00 Range = 1-7	Median = 7.00 Range = 6-7	*Z* = 3.48	<.001

Scale: 1=extremely unlikely, 4=neither, 7=extremely likely

As shown in Tables 17-20, the Wilcoxon Signed Rank Test measures the statistical difference between medians (scale: 1=extremely unlikely, 4 = neither, 7 = extremely likely"). For a single example consider the last row in Table 20, robot assistance was perceived as "more likely" to be useful for the task of monitoring for the persona *with* mobility loss (Median = 7.0, Range = 6.0-7.0), compared to the mobile persona (Median = 6.0, Range = 1.0-7.0). Because this trend was found across all questionnaire items and tasks, these findings suggest that the participants (both groups combined) perceived the robot as overall more useful for the persona *with* mobility loss, compared to the mobile persona.

Differences between Participant Groups

To test whether perceptions of usefulness for personas differed between participant groups (i.e., mobile older adults vs. participants *with* mobility loss), Mann-Whitney U tests were conducted. Overall, a significant difference between the mobile older adults and the older adults *with* mobility loss for their perceptions of usefulness ($U(1) = 109.00$, $p < .05$). The older adults *with* mobility loss (Median = 6.40) viewed the robot as more useful, across personas and tasks, than the mobility group (Median = 5.50).

This statistical significance was primarily driven by differences between participant groups specifically for a robot assisting the mobile persona with the task of transfer; results are shown in Table 21.

Table 21. Differences in questionnaire responses between older adult groups.

Transfer for Mobile Persona (Mr. H)				
	Mobile Older Adult Group	*Older Adults with Mobility Loss Group*	*Mann-Whitney U Test*	*P*
Relevance	Median = 2.50 Range = 1-6	Median = 6.00 Range = 1-7	*U* = 110.00	<.05
Adaptability	Median = 3.50 Range = 1-6	Median = 6.00 Range = 1-7	*U* = 112.50	<.05
Usefulness	Median = 2.50 Range = 1-6	Median = 6.00 Range = 1-7	*U* = 114.50	<.05

First, for the construct of relevance, the questionnaire item was "robot assistance with transfer is important to Mr. H's daily life." When asked to discuss this questionnaire item, the older adults *with* mobility loss suggested that the robot would be important (for help with potential falls), whereas the mobile older adult group clearly held the distinction that the robot would not be as likely to be *as* important *on a daily basis.* Differences between groups are depicted in Figure 8.

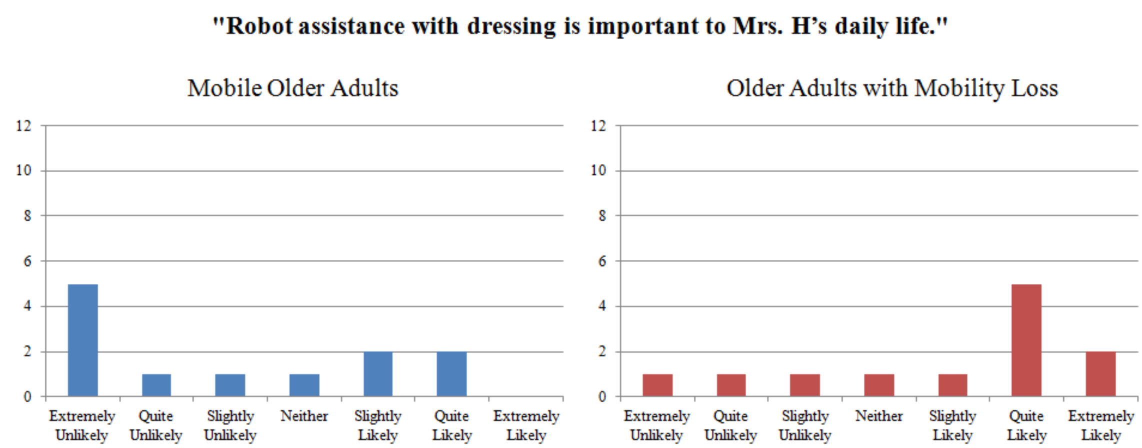


Figure 8. Difference between groups for mobile persona transfer relevance.

Second, the differences between groups for the construct of adaptability are depicted in Figure 9. The questionnaire item was "a robot assisting with transfer will be adaptive to Mr. H's needs." When asked to elaborate on their opinions on adaptability, they were not verbose or explanatory in their discussion on the construct. The mobile older adult group did not interpret the robot to be as adaptive for the mobile persona, possibly because they did not interpret transfer as a task in need of assistance.

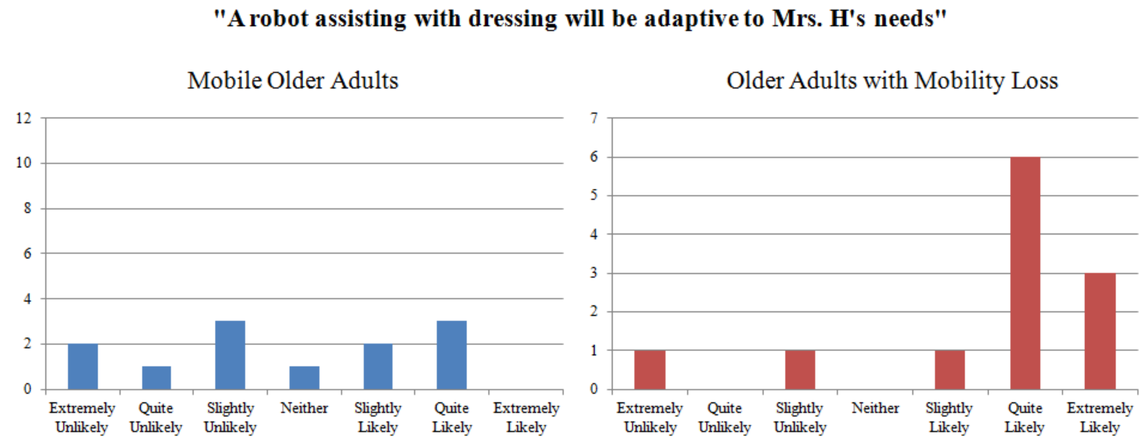


Figure 9. Difference between groups for mobile persona transfer adaptability.

Finally, there were group differences in perceptions of usefulness for the task of transfer for the mobile persona. There were a number of participants *with* mobility loss who indicated it would be useful to have the robot for the purposes of transfer because "*you never know when a fall could happen.*" Their pronounced fear of falling could reflect their own experience with falls, imbalance, and mobility limitation. Therefore, they focused on the use of robot transfer assistance "just in case". The mobile older adults, on the other hand, perceived the robot as less useful because the mobile persona is and should remain independent and active. Differences between groups are depicted in Figure 10.

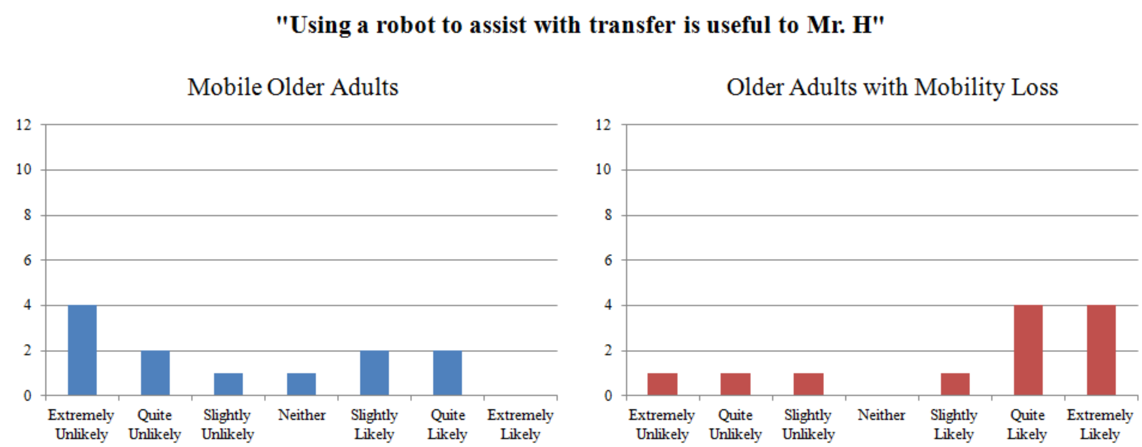


Figure 10. Difference between groups for mobile persona transfer usefulness.

The other tasks (dressing, monitoring, and organizing) showed no significant difference between groups; however the mobile older adult group had a wider range of responses to questionnaire items, overall.

Facilitators and Barriers from Persona-Based Interview

As shown in the previous sections on questionnaire results, differences between participant groups existed in their perceptions of robot assistance for the two personas. Furthermore, the mobile older adults generally had a more varied response to questionnaire items (i.e., range for many questionnaire items was oftentimes 1.0-7.0) compared to the older adults *with* mobility loss. To investigate the reasons *why* older adults held certain preferences and how they made the determinations of usefulness, they were asked to elaborate on their opinions after filling out each questionnaire.

This section of the interview resulted in rich data, with older adults providing many reasons for how they made their usefulness judgments. Facilitators and barriers in this section were further categorized into largely human- and robot- based characteristics. A few comments related to the (social) environment are also mentioned.

In Table 22, the frequency of comments categorized as conditional (e.g., use robot only to limited amount, or use in future), facilitators (e.g., reasons to use the robot), and barriers (e.g., reasons to not use robot) are shown.

Table 22. Number of mentions related to conditionality, facilitators, and barriers.

	Mobile Persona (Mr. H)		
	Mentions of Conditionality	*Mentioned of Facilitators*	*Mentions of Barriers*
Mobile Older Adults	19	58	56
Older Adults *with* Mobility Loss	19	66	25
	Persona *with* Mobility Loss (Mr. L)		
	Mentions of Conditionality	*Mentioned of Facilitators*	*Mentions of Barriers*
Mobile Older Adults	3	115	13
Older Adults *with* Mobility Loss	0	104	9

Note: Frequency of mentions includes all tasks

A number of trends are evident from the data presented in Table 22. First, mentions of conditionality were more common for the mobile persona (Mr. H) compared to the personal with mobility loss (Mr. L). This trend existed for both participant groups (mobile older adults $\chi^2(1, N = 12) = 11.64$, $p < .05$; older adults *with* mobility loss $\chi^2(1, N = 12) = 19.00$, $p < .05$). In other words, participants mentioned that the mobile persona could use the robot to a limited extent or only "as needed."

Second, many more facilitators were mentioned for the persona with mobility loss compared to the mobile persona (mobile older adults $\chi^2(1, N = 12) = 18.78$, $p < .05$; older adults *with* mobility loss $\chi^2(1, N = 12) = 8.49$, $p < .05$), suggesting that the robot was deemed as more useful or more beneficial for the persona with physical limitations.

Third, more barriers were mentioned for the mobile persona compared to the persona with mobility loss (mobile older adults $\chi^2(1, N = 12) = 26.80$, $p < .05$; older adults *with* mobility loss $\chi^2(1, N = 12) = 7.53, p < .05$); in particular the mobile older adults focused on barriers. This suggests the participants perceived the robot as less useful for the mobile, or physically able, persona.

To better understand the facilitators and barriers important in making usefulness judgments, the codes were further organized into human-, robot- and environment-characteristics. Trends in the interview data suggest that a number of categories were important in making the usefulness judgments, and the primary mentioned barriers/facilitators are represented in Figure 11. Although the most commonly mentioned categories are depicted in this figure, it is important to note that the participant responses varied, as shown in the coding scheme (Appendix G). Trends and differences between participant groups and tasks are detailed in the next sections.

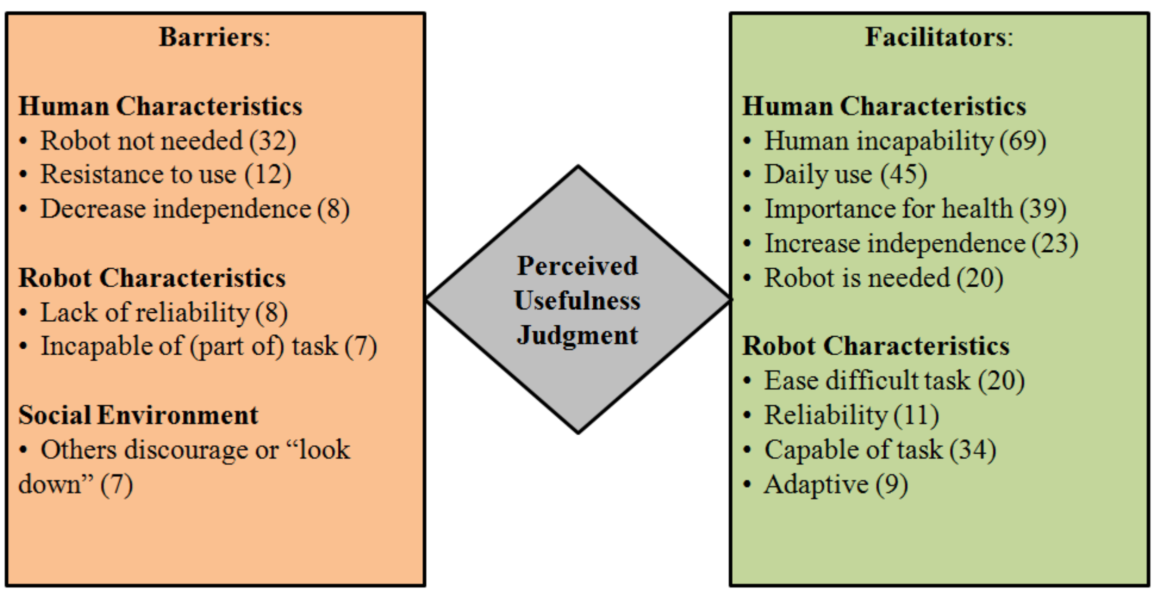


Figure 11. Barriers and facilitators to perceived usefulness judgment (numbers represent frequency of mentions).

Human characteristics that contributed to determining usefulness. The personas' limitations in capability was the most commonly mentioned facilitator (i.e., reason to use an assistive robot) mentioned by both participant groups. This category was in reference to *both* personas (mobile persona = 15 mentions; persona *with* mobility loss = 54 mentions). For example, participants focused on the limitations of the persona *with* mobility loss, and had strong opinions that the robot could compensate for these limitations for all tasks (dressing, monitoring, organizing, and transfer). In fact, a number of participants even stated that robot assistance should be mandatory, for example one mobile participant stated, "*He [persona with mobility loss] should be made to take it actually, compulsory. [Researcher: Tell me more about that.] Well... if he tried to do it [monitoring] himself he'd probably end up in the hospital where as he wouldn't if he had somebody to help him. Kind of like a motorcycle [helmet]... you should have to wear a helmet. Seatbelts are the same way.*"

The participants also noted that the mobile persona, although overall healthy, would have natural age-related limitations, "*he is 75*", and thus tasks around the home become more difficult. Thus, the robot would be useful, albeit to a lesser degree compared to the persona *with* mobility loss. Participants, especially those in walkers/wheelchairs, stressed that eventually the mobile persona would need robot assistance. One older adult *with* mobility loss explained that the mobile persona should use the robot because *"...all I can see this guy [mobile persona, Mr. H] is challenging, he's challenging what's inevitable. Because it's going to happen. It's going to happen quickly. Like me I could do that [transfer] yesterday just like him. The next day I couldn't do it.*"

Another deciding factor was the frequency of use, and participants seemed to deem the robot as more useful if it could assist with a task that is performed daily. These comments were in response to the questionnaire item *Relevance* "Robot assistance with

<task> is important to <persona name> daily life." Thus tasks, such as dressing and organization, were mentioned as useful on a daily basis..

Another aspect of *Relevance* was whether participants thought the persona *needed* the robot. This was both a facilitator and a barrier. The notion of usefulness and need was increased if the task was related to the personas' health. For example, monitoring was a task participants felt was needed by both personas due to the benefit of ensuring the participants' health. One mobile older adult explained, "*But these issues of monitoring are safety issues and so I think he [mobile persona] does need assistance in from a safety standpoint. So that's why I think it's different than the others [other tasks], although he's quite, probably quite capable of doing all of those [monitor own health] it's the backup issue [use a robot as backup].*"

Finally, the barrier 'resistance to use' was primarily mentioned by the older adult participants *with* mobility loss. One older adult *with* mobility loss stated "*She's [persona with mobility loss] so used to being by herself for number one and having someone else there [to help with organization] she would have to adjust. That would maybe take a little bit... you gotta shift that responsibility over to someone else [the robot].... It would take a little time to earn the trust.*" Participants stated that either persona would need time to emotionally accept robot assistance; they based this insight on their own personal experiences of "coming to terms" with using assistive devices (i.e., walkers/wheelchairs).

Robot characteristics that contributed to determining usefulness. The most commonly mentioned robot characteristic was robot capability. In other words, this code indicated whether participants thought the robot could perform the task. This was mentioned often for the tasks of organizing and monitoring. The participants' perceptions were likely influenced by the video, particularly because they viewed the robot manipulating objects (related to organization). Participants mentioned the robot would *not* be capable of determining personal preferences, such as choosing clothing color/outfits or determining objects that have been lost. One mobile older adult stated, "*So I put down a robot that assists with dressing is quite unlikely, cause I doubt if it would have color coordination/style coordination*."

The convenience of using a robot to make a job easier was primarily identified by the older adults *with* mobility loss. They mentioned certain tasks, such as organizing, would no longer be easy for the persona *with* mobility loss to perform, thus the robot could lessen the burden. On the other hand, mobile participants stressed the importance for the mobile persona to perform tasks unassisted, to remain active and fit; "*She's [mobile persona] healthy so actually I think the robot would destroy that. If it started to take on her tasks for her it would take away her strength and not help build her up. I think she needs to go as long as she can on her own strength [transfer]*."

Finally, reliability was mentioned as both a facilitator and a barrier. In fact, participant conceptualized reliability in a variety of ways. Participants in both groups who viewed the robot as useful because of its reliability were under the assumption that a robot's functionality would be completely errorless. For example, "*Well, if a robot's doing it, it will be without error because a robot's not going to make an error so it's quite likely okay"* and *"We ourselves have a quality of error where the robot would have a precise, exact monitoring because they're programmed for this*."

When the robot was thought of as less reliable, this was often in relation to the tasks of transfer and organization. Regarding transfer, both participant groups mentioned that the video showed no indication that the robot could transfer without error. For the task of organization, lack of reliability was discussed for the mobile persona in particular. In these instances, participants mentioned that the robot would not perform the task *as well as* the persona, or get in the way of the persona performing the task themselves. One mobile older adult explained, "*Well, it depends upon how the robot learned about picking up objects and clutter off the floor. If the robot says "ah! I see something on the floor, I'm gonna run over and pick it up and move it", but you [mobile persona] put it there because right at the moment it's what you [mobile persona] wanted to do, then it's not useful.*"

Environmental characteristics that contributed to determining usefulness. Environmental characteristics were coded as relating to the social environment or the physical environment. The physical environment was not often mentioned by participants. However, the social environment was discussed in relation to other people's social influence, In fact, the term 'independence' (human characteristic code) was interpreted in a variety of ways, and was oftentimes entwined with discussion on social environment. The overlap between independence and social environment was spawned from the questionnaire construct of *image* "Robot assistance with <task> will make <persona> seem more independent to others" and *social norm* "People in <persona>'s life (i.e., family and friends) think that she should use a robot to assist with <task>."

The following quote exemplify how independence was viewed both a facilitator and a barrier, and how other people might view the robot as making the persona less independent. "*I'm not clear, does that mean if he [persona with mobility loss] has assistance he will, unlikely that he will need assistance or if he doesn't... I know he needs it and uh, it would not make him more. No, it would make him less independent to others is what I'm... If he has it he will become nothing but dependent... No, if he has robot assistance he will be less independent to others. So does that mean extremely unlikely or extremely likely?*"

Another older adult with mobility loss stated, "*Well, I don't think that she'd [persona with mobility loss] be more independent, like when I went into the wheelchair... Just because I'm in a wheelchair doesn't make me more independent. I'm dependent on certain aspects, like transportation. The rest of it, when I get there, well I push myself along and do it for myself. Mrs. L [persona with mobility loss] is the same thing, she has a robot to make her independent of everyone else. She might be dependent on that robot, but not on others... So I don't think it would make her look better to others, but it should help her.*"

Summary of Key Findings: Part B

Overall both groups, the mobile older adults and the older adults *with* mobility loss, selected robot assistance as being useful for both personas. This suggests that older adults, of varying capabilities, perceive benefits robot assistance. However, the older adults' preferences and reasons for determining usefulness varied as a function of both task and user capability. A summary of key findings and their relation to the dissertation research questions are outlined below:

[R2] *Are constructs shown to be predictive of perceived usefulness of information technology (Venkatesh & Davis, 2000) correlated with perceived usefulness of assistive robots?*

-Are other constructs, such as trust, reliability, and adaptability also correlated with perceived usefulness of assistive robots?

- Key findings about correlations between constructs:
    - Aggregated across tasks and personas, the TAM2 items of image, subjective norm, relevance, and result demonstrability (Venkatesh & Davis, 2000) were positively correlated with one another, and with perceived usefulness of an assistive robot.
    - Also aggregated across tasks and personas, the added items of adaptability, trust, and reliability also positively correlated with each other and perceived usefulness of an assistive robot.
- Key findings about comparing questionnaire responses between personas and participant groups:
    - Overall questionnaire responses suggest that the robot was perceived as more useful for the persona with mobility loss compared to the mobile persona. However, overall participants still recommended that the mobile persona use the robot, especially for the tasks of organization and monitoring.
    - Differences between participant groups existed for the mobile persona receiving assistance with the task of transfer. Here, questionnaire responses indicate that mobile participants perceived the robot as less relevant, adaptive, and useful compared to the participants with mobility loss. Participants with mobility loss focused on the robot being useful for the mobile persona “just in case” of a fall.

[R3] *What are the facilitators and barriers of acceptance that older adults base their perceptions of usefulness?*

-Do the nature of those barriers and facilitators differ between task or between older adults of varying capability?

- Key findings about facilitators and barriers:
  - More facilitators than barriers were mentioned, overall, by both participant groups
  - Mobile older adults were more likely to identify barriers, compared to the older adults *with* mobility loss
  - Facilitators and barriers were largely discussed as human-, robot-, and social environment- related characteristics related to usefulness.
  - Common human characteristics included
    - Facilitators (reasons to use the robot): human incapability, daily use, importance for health, increase independence, and need.
    - Barriers (reasons to not use the robot): lack of need, resistance to use, and decrease independence.
  - Common robot characteristics included:
    - Facilitators: ease difficult task, reliability, robot capability, and adaptability.
    - Barriers: Lack of reliability, and robot (in)capability.
  - Common social environment characteristics included:
    - Social influence of others.
- Key findings about the nature of barriers and facilitators:
  - Barriers and facilitators widely varied, and some themes such as "independence" "social norm" "image" and "reliability" were interpreted by participants in a variety of ways.
  - The capability of the persona was the most commonly mentioned deciding factor of usefulness.

        - Even the mobile persona's capability was a concern, especially considering age-related changes. Thus the robot would be useful, but to a lesser degree compared to the persona *with* mobility loss.

    - Robot assistance on tasks that are performed on a daily basis was viewed as useful.

    - Perceptions of usefulness and need were more positive when the task was important to a personas health (e.g., monitoring).

    - Older adults *with* mobility loss were concerned with the persona's resistance to use assistive technology.

    - Mobile older adults were more likely to state that the robot decreases independence, and that the personas should continue to do tasks by themselves to remain active.

Closing Questions about Robot Use

Toward the end of the interview, participants answered a few general questions about robot usefulness. As shown in Table 22, participants were relatively open to robot assistance. In particular, 10 of the older adults with mobility loss stated the robot would be useful given their current abilities, whereas only 6 of the mobile older adults stated it would be useful. The 2 participants who replied "no", and 4 of the 6 participants who reported that the robot would conditionally be useful (i.e., a limited amount, or usefulness might increase with time) were in the mobile older adult group. The remaining question responses (see Table 22) also support robot usefulness for both groups, today and in the future. The final question, "Has your opinion about robots changed", suggested that 22 of the 24 older adults had changed their opinion (mobile older adults n=12; older adults *with* mobility loss n=10), and they reported it changed to a more positive regard toward robots. The 2 individuals who stated their opinion did not change (both older adults *with* mobility loss) reported their opinion was neutral or a mix of positive and negative valence.

Table 23. Participant responses to closing questions.

	Mobile Older Adults (n=12)			Older Adults *with* Mobility Loss (n=12)		
Closing Question	Yes	No	Conditional	Yes	No	Conditional
Given current abilities, would a robot be useful to you?	6	2	4	10	0	2
Would you use a robot today?	8	3	1	11	0	1
Think of your physical abilities in 5-10 years, would a robot be useful for you?	10	0	2	12	0	0
Think of your cognitive abilities in 5-10 years, would a robot be useful for you?	9	0	3	12	0	0
Has your opinion about robotics changed?	12	0	0	10	2	0

Finally, considerations for the pre and post Assistive Preference Checklist questionnaires are discussed in Appendix H.

CHAPTER 4: GENERAL DISCUSSSION

Summary of Findings

The generalizability of the Technology Acceptance Model (TAM) construct of perceived usefulness was critiqued in this study to better understand older adults' perceptions of robot use. The results of this investigation inform our understanding of acceptance theory, and aid designers in creating robots that will be more readily accepted and eventually adopted for everyday use.

This research used a multi-method approach to understand perceived robot usefulness. Two groups of older adults participated in this study: (1) mobile older adults, defined as older adults who did not use walkers or wheelchairs, and (2) older adults *with* mobility loss, defined as older adults who used walkers or wheelchairs on a daily basis. The study consisted of two parts. In Part A, all participants first completed an autonomy-selection think aloud task, designed to assess the match between robot autonomy (i.e., operationalized as command/control) and their own needs based on their capabilities/limitations. Then for Part B, participants were interviewed about their perceived usefulness of robot assistance for two hypothetical older adults: a mobile persona and a persona *with* mobility loss. For each persona and task, older adults completed a questionnaire designed to assess TAM and HRI constructs believed to be predictive of perceived usefulness (Venkatesh & Davis, 2000), followed by structured interviews to understand how each participant determined usefulness.

This multi-method approach was designed to address a number of key questions related to older adults' perception of robot usefulness. The first question aimed to evaluate whether a match between user capability and robot capability played a role in usefulness judgments. Perceived usefulness can be described as a person's decision of how well the technology's capability matches their own needs (Venkatesh & Davis, 2000). One hypothesis was that as an individual's capabilities decrease, then the capability of an assistive robot will need to increase (i.e., the robot performs tasks on its own) to better meet the user's needs and home environment/task demands (Thrun, 2004). Findings from this study (Part A) suggest that the match between the user and robot is not this simple.

Older adults *with* mobility loss were more likely to select "I command/control the robot" compared to the other command/control options. The mobile older adults were split between selection of "I command/control the robot" and "the robot commands/controls itself." This is contrary to what was predicted based on the TAM assumption that usefulness is determined by a match between robot capability and user capability. According to this, it was assumed that a robot capable of performing tasks autonomously would be deemed more useful for older adults with disabilities. However, this was not the case. Instead, older adults with mobility loss placed an emphasis on providing command to the robot themselves, to remain in control, and make their own decisions. They indicated that remaining in control would promote their independence.

Even when participants selected "I command/control the robot", they suggested providing an initial command and then monitoring the robots' progress as it completes the rest of the task on its own (e.g., supervisory control, Parasuraman, Sheridan, & Wickens, 2000). Thus, they selected this command/control option based on the ability to remain in control of decision making, not necessarily the physical completion of the task - opposed to commanding/controlling the robot via teleoperation. For both participant groups, the command/control option “Someone else commands/controls the robot” was overall strongly disliked and deemed non-useful, where majority of the older adults expressed a negative affective reaction to this command/control option.

Usefulness of command/control options also varied as a function of task. Tasks that might have a fixed schedule, or could possibly be performed non-invasively (e.g., medication reminders and monitoring), were suggested as ideal for a robot commanding/controlling itself. Older adults preferred this option, because they reported often forgetting and being less consistent in performing these tasks themselves. However, for tasks that involve personal preference, such as cleaning, dressing, or finding lost objects, users found it ideal to command/control the robot themselves. The most variation between groups was found for a robot performing a transfer task. Mobile older adults stated they had no need for assistance with transfer, whereas almost half (N=5) of those with mobility loss indicated that assistance with this task would be useful. For those in the mobility loss group that indicted they did want assistance with this task, preferences for command/control with the transfer task varied.

The second research question addressed by this research was related to whether there was a correlation between questionnaire items believed to be predictive of perceptions of usefulness of information technology (Venkatesh & Davis, 2000) and important in acceptance of and attitudes toward robotics (Broadbent et al., 2009; Ghazizadeh, Lee, & Boyle, 2012; Heerink et al., 2010; Young et al., 2009). In fact, findings from Part B of the study showed that there were positive correlations between each of the questionnaire items, suggesting that the TAM variables included in the questionnaire were also correlated with perceived usefulness of assistive robots. The added items (trust, reliability, and adaptability) were also correlated with perceived usefulness. Furthermore, each of these constructs (TAM and the added variables) were also positively correlated with one another.

The third research question aimed to understand how older adults made perceived usefulness judgments to identify and better understand the nature of the facilitators and barriers of acceptance. Overall, interview data suggested that older adults were positive about the usefulness of robots by suggesting more facilitators compared to barriers in using robots. Their judgments were task specific and complex in nature, suggesting their specific acceptance of robot assistance is dynamic.

Advancing the Understanding of Acceptance in HRI

The Technology Acceptance Model is a widely accepted model with strong empirical support (Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003). Perceived usefulness, specifically, has been shown to be the strongest predictor of behavioral intention (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2000). However, it was an open question regarding to what extent TAM measures of perceived usefulness can be expanded to include assistive robots. Robotic technology is radically different from the workplace information technology usually investigated with TAM.

The findings from this study advance our knowledge of acceptance theory in HRI. Perceived usefulness is defined as a cognitive comparison between the user's needs and the technology's capability (Venkatesh & Davis, 2000). This comparison was not so simple in this study. Users of varying capability reported a range of facilitators and barriers when determining perceived usefulness, and those deciding factors varied by task. Additionally, differences between user groups existed. Older adults *with* mobility loss expressed a preference for providing commands and control to the robot, compared to mobile older adults. Thus, older adults *with* mobility loss placed more emphasis on enhancing their own functionality by remaining in control in addition to reducing effort. This finding is of theoretical importance, because it provides evidence that the cognitive judgment of usefulness varies by user type.

The adapted TAM questionnaire administered in this study also provides theoretical insight. The positive correlations suggest that TAM constructs might also play a role in perceptions of robot usefulness. These data also support previous research (Broadbent et al., 2009; Ghazizadeh, Lee, & Boyle, 2012; Heerink et al., 2010; Young et al., 2009) suggesting that the added items of trust, reliability, and adaptability are important to consider when measuring user attitudes and acceptance of robots. Despite the positive correlations and possible implications those correlations may have on theory, it is important to consider the major caveat that the statistics were conducted on single questionnaire items (i.e., not multiple items measuring a single construct). This severely limits the power of the statistic. There was not an adequate sample size in this study to imply that these questionnaire items are actually predictive of perceived usefulness (e.g., via regression). Thus, the findings do suggest there is a relationship, but more testing is needed.

Translating the interview data of facilitators and barriers to map onto TAM constructs, a number of interesting trends emerge that can help inform our understanding of acceptance theory. First, the term "independence" and its relationship with the constructs social norm and image was complex. Some participants viewed the robot as *increasing* independence because it decreased the persona's dependence on other people. On the other hand, some participants also stated that the robot might be *decreasing* independence. Using this rationale, the persona would be relying on the robot, rather than themselves, and thus use of a robot would be a clear indication to others of declining capabilities of the user. Further research is needed to investigate whether a stigma would exist for using assistive robotics.

Second, the term "reliability" also created much uncertainty. Some participants believed the robot would be reliable when performing autonomously, and were rather extreme in their opinions. They stated the robot would be completely without error or 100% reliable. This is a dangerous assumption, as no technology will be completely reliable. For those who thought the robot would not be reliable, they discussed unreliability in terms of the likelihood of making an error, and/or comparison of the robots' reliability to that of a human (e.g., the mobile persona might perform the task better than a robot).

Third, the notion of "need" and its relation to the person's capabilities and limitations was a deciding factor in the older adults' judgments. Need can be interpreted as possibly related to *Relevance* (questionnaire item: "Robot assistance with <task> is important to <persona>'s life"), but it also implies an assessment of benefit.

Importantly, the fact that certain constructs created so much uncertainty in participant interview responses provide evidence that the constructs related to perceptions of assistive robot usefulness are complex. The older adult participants recognized the complexity of technological assistance, and considered the interview questions from a multidimensional perspective. Although the questionnaire items were correlated with perceptions of usefulness, there were many ways the constructs were conceptualized in the interview.

While the TAM questionnaire is simple to administer, the actual usefulness judgment was shown to be multifaceted within the context of HRI in assistive settings. This brings to question the internal/external validity of the TAM questionnaire when applied to domains other than information technology. Although the questionnaire is widely used in information technology, the interpretation of the questionnaire items varied between participants, especially applied to complicated domains such as older adult independence, as in the present study. Thus, careful consideration is needed when adapting the questionnaire wording. This insight is not meant to criticize TAM, because the model was not originally designed for this application. Instead, these data suggest that modifications to TAM and the measurements associated with TAM may be required to fully understand acceptance in HRI.

From a practical standpoint, these data provide guidance to designers for choosing a command/control level that matches the target user group and will be deemed as useful. It is important for designers "to know thy user." Users who have mobility loss may be more inclined to choose a command/control option that allows them to remain in control of decision-making. However, mobile older adults may be more likely to use a robot that performs tasks autonomously. Additionally, someone else controlling the robot was not a favorable option by either user group. Preferences for control also varied by task. Based on these data, the robot commanding/controlling itself was preferred for tasks with fixed schedules (e.g., medication reminders). However, human control was preferred for tasks with specific user preferences (e.g., dressing).

Furthermore, some participants held the assumption that the robot would be 100% reliable. This could have catastrophic consequences if the robot makes an error while performing a critical task (e.g., medication management). No machine will be completely reliable, and the user must be prepared to identify potential errors, override, and resume control. It is crucial for designers to set user expectations to match the reality of robot reliability. Thus these data support the need for training, informative error messages, and proper marketing of assistive robots.

Scope, Limitations, and Future Directions

While this study advances our knowledge of robot acceptance, it is critical to recognize the scope, limitations, and future directions of this area of research. First, the goal of this study was to assess older adults of varying physical ability. However, the older adults in the *mobility loss* group varied considerably in their capabilities and limitations. Thus, future studies might benefit from investigating specific types of limitations, or inclusion of additional measures to assess function.

As mentioned previously, the study findings provide important theoretical considerations of measuring TAM questionnaire items. This study included single items of TAM constructs in the questionnaire. However, a larger sample size and multiple questionnaire items measuring the same construct should be included in future studies to increase power. This is particularly important considering the complexity of participant responses in the interview data and their uncertainty in interpretation of the questionnaire wording. Future directions should consider how different questionnaire wording might impact how each item is answered. Such systematic assessment of questionnaire design would help ensure both reliability and validity of adapting TAM questionnaire items to measure acceptance of assistive robotics.

Additionally, the present study used a video of a robot. The video depicted the robot performing tasks without error. This may have impacted participants' perceptions of reliability. Thus, future work could explore in more depth the relationship between perceived reliability and acceptance. Furthermore, a video of the robot is very different from actual interaction. Exposure to robots, particularly considering they are a radical technology, is likely to impact acceptance. Lastly, the command/control descriptions used in this study were vague by design. Further research is needed to explore perceptions of usefulness for specific types of control (e.g., joystick, voice command, touchscreen).

In closing, the findings from this study provide insight on how older adults, of varying capability, perceive assistive robots to be useful. The data suggest that perceptions of usefulness are complex. The older adults' multidimensional perceptive highlight the challenge of developing assistive robotics that are deemed useful, and traditional TAM questionnaire measures of acceptance may not adequately capture this complexity. The findings, although extremely insightful, suggest that more research is needed. Many exciting future directions can be taken to consider measurement of acceptance constructs, reliability of the robot, and specific types of command/control methods.

APPENDIX A: INTERVIEW SCRIPT

Interview Script

Jenay Beer
Robot Autonomy Dissertation

italics = action items or reminders (not said to the participant)

Protocol Materials

Projector (and screen?)
Computer with videos & speakers
Digital audio recorders (2)
Extra batteries (AAA's)
Consent (2)
Debriefing
Questionnaires (bring extra copies & large print versions)
Water
Small snack (e.g., peanut butter crackers)
New participant database forms with contact information on the back
Checks to pay participant
Signs & tape (do not disturb)
Participant's cell phone number
Noise-canceling microphone
Photo releases
Microphone

General Interviewer Prompts (i.e., said only when needed)

- *If participant focuses too much on one thing (e.g., size, speed, safety), capture their point then say: "Thank you for your comments about _______, what are your thoughts about [re-ask question]?"*
- *If participant focuses on their own (or someone they know) needs, instead of the persona then say: "thank you for your comments. Now considering Mr(s)____ abilities, what are your thoughts about [re-ask question]?*
- *If participant is having difficulty answering the question (particularly likert scales), then say: "Please, take a moment and think about it. Then give me your best guess."*
- *Prompt: Tell me more about that.*
- *Prompt: Can you tell me what you mean by ___<repeat participant's wording>___*
- *Prompt: Remember to think of Mr(s)___ abilities and how a robot could assist them with the task of _________.*
- *Prompt: At the end of this interview, you can ask anything you want about the PR2.*

Greet Participant

- *Escort participant to testing room*
- *Provide participant with water and ensure that they parked where they were supposed to. Ask participant if they would like to use the restroom before starting the experiment.*
- *Ask participant to sit at table to fill out informed consent and questionnaires.*

Informed consent & questionnaires

- *Administer Informed Consent*
- Do you mind if I take pictures during parts of today's study? We may use this for presentations or on a website to show how we set up the research study.
    - *If participant doesn't mind, then have them sign the photo release.*
- *Experimenter collects 3 mailed questionnaires, & checks for completeness:*
    - *Demographics and health*
    - *Technology experience*
    - *Robot familiarity/usage*
    - *Assistance Preference Checklist*
    - *Informed consent copy sent to participant home in packet with questionnaires*

Set up for interview

- To make sure the audio recorder captures everything, we would like to use a microphone. May I clip this microphone to the lapel of your shirt?
    - *Clip microphone 2-3 inches from person's mouth (if possible). Make sure microphone is tilted away from the person's shirt.*

General Introduction

Thank you for participating in our study. Before we get started I would like you to please turn off your cell phone, so we do not have any interruptions. Thank you.

Welcome. My name is Jenay, and I work at Georgia Tech. I'm a graduate student, and this project is for my dissertation. Today we are going to talk about robot assistance.

Topic and goal

This research is part of a 5-year grant, funded by the National Institutes of Health, in particular the National Institute on Aging. Our goal is to better understand what older adults think about robots. Your information will help us to conduct research on this topic and, ultimately, to develop robots that are more useful.

There are 3 parts to this session:

- First, you will be watching a video of a robot that is currently available.
- Second, we will discuss how a robot might be useful to older adults.
- Third, I will ask you to fill out a questionnaire about robot assistance.

There is no rush for any of these questions. Our session will take approximately 3 hours. It is ok to get up during the session if you need to but there will also be an opportunity to take several breaks during the interview. There are no right or wrong answers. We are interested in your thoughts and opinions. Please feel free to express your opinion, whether it is positive or negative. Some of these questions may seem repetitive, so it is okay if your answers overlap.

Icebreaker and video

Let's start with a just a few general questions.

<START RECORDER>

- What do you know *specifically* about our research at Georgia Tech with robots?

- What do you think it means when I say "a technology is *useful*?"

The type of robot we are going to be discussing today is called a mobile manipulator, which means that the robot we will be discussing today can sense and move around a home environment and can physically interact with the world using its arms and grippers. This robot is designed to help people who may need assistance.

Next I am going to show you a video demonstrating some of the things a robot can do. You have a pen & paper in front of you to write down anything that comes to mind while watching the video. This is a short video, so please pay attention. Please do not talk during it. You will have the opportunity to discuss your thoughts after you watch the video.

Experimenter shows video
Standard response to, "I missed something?" "can it do this or that" or "Can you show that again?": For our discussions today is it not important that you saw every detail or understand everything about the PR2. We want to focus on what would be most useful for the robot to do.

- I want to reiterate that the PR2 is not limited to the tasks you saw in the video. Do you have any questions about the PR2?

Part A: Autonomy-Selection Think Aloud

Okay, now for this part of this interview, I would like you to think of your own abilities. We will discuss how a robot can assist with a task in a variety of ways. Imagine, that you have the option of using a robot to assist you. Imagine cost of the robot is not an issue. The robot is a mobile manipulator, similar to the robot you saw in the video.

We are going to discuss one task at a time. First I will ask you if you would like robot assistance for that task. Then I will present three options for robot assistance: Option A, Option B, and Option C. Each option contains a description of how a robot might assist you with a task. For example, for Option A you command or control the robot. For option B someone else such as a friend, family member, or doctor can control the robot. They can control it remotely, meaning that they don't necessarily have to be in your home to control the robot. Option C the robot commands or controls itself. I would like you to think of your own abilities, and select which option of robot assistance would be most useful for you.

While you are reading through the options, and determining which is most useful, I am going to ask you to think aloud. To do this, just say aloud whatever comes to mind. This is so I can hear what you are thinking as you are determining which option is most useful for you personally.

Okay, let's practice this task with an example.

<present "autonomy sheet" representing the robot options (below). Have participant choose which autonomy card would be the most useful. Remind participant to think aloud. If participant is having difficulty, remind them that there is no right or wrong selection. I just want to hear what they are thinking so I can understand their opinions.>

Option A	Option B	Option C
I command/control the robot	Someone else (remotely) commands/controls the robot	Robot commands/controls itself

Practice task:

Imagine you are at home with a robot. The robot can assist you with the task of **grocery shopping**.

- Would robot assistance with this this task be useful to you (yes no)?
    - If YES, Here are three options for you to command/control the robot. Which would be most useful to you?
    - If NO, So you would NOT want robot assistance, is that right? Why?

<walk participant through options, read aloud each option, and tell them for Option B the "someone else" could be friends, family, doctors, or emergency personnel>
Okay that was a practice round, do you have any questions?
If "No", Okay lets get's started.

Interview Script

Jenay Beer
Robot Autonomy Dissertation

IMPORTANT: See counterbalancing order at and of script; ORDER WILL VARY

Imagine you are at home with a robot. The robot can assist you with the task of **dressing**.

- Would robot assistance with this this task be useful to you (yes no)?
    - If YES, Here are three options for you to command/control the robot. Which would be most useful to you?
    - If NO, So you would NOT want robot assistance, is that right? Why?

Imagine you are at home with a robot. The robot can assist you with the task of **transfer, that is, helping you in/out of chairs or in/out of your bed**.

- Would robot assistance with this this task be useful to you (yes no)?
    - If YES, Here are three options for you to command/control the robot. Which would be most useful to you?
    - If NO, So you would NOT want robot assistance, is that right? Why?

Imagine you are at home with a robot. The robot can assist you with the task of **finding objects and delivering them to you**.

- Would robot assistance with this this task be useful to you (yes no)?
    - If YES, Here are three options for you to command/control the robot. Which would be most useful to you?
    - If NO, So you would NOT want robot assistance, is that right? Why?

Imagine you are at home with a robot. The robot can assist you with the task of **cleaning your floors**.

- Would robot assistance with this this task be useful to you (yes no)?
    - If YES, Here are three options for you to command/control the robot. Which would be most useful to you?
    - If NO, So you would NOT want robot assistance, is that right? Why?

Imagine you are at home with a robot. The robot can assist you with the task of **reminding you to take your medication**.

- Would robot assistance with this this task be useful to you (yes no)?
    - If YES, Here are three options for you to command/control the robot. Which would be most useful to you?
    - If NO, So you would NOT want robot assistance, is that right? Why?

Imagine you are at home with a robot. The robot can assist you with the task of **monitoring your health (i.e., blood pressure)**.

- Would robot assistance with this this task be useful to you (yes no)?
    - If YES, Here are three options for you to command/control the robot. Which would be most useful to you?
    - If NO, So you would NOT want robot assistance, is that right? Why?

Ability Tests

Now that we are done with the first portion of the interview, we can take a 5-minute break

<STOP RECORDER>

<5 min break>

Administer Ability Tests

- Vision
- Reverse digit span
- Digit symbol substitution
- Shipley vocabulary

<5 min break>

PART B: Persona-Based Structured Interview

<START RECORDER>

Persona 1

Next we are going to discuss how a robot, such as the PR2 could help a variety of people. To start, I would like you to read the following description of a hypothetical older adult. Let me know when you are done reading.

Refer to example of first persona (persona H or L – see counterbalancing). Leave the printed persona on table so participant can refer to it at any time. Remember there should be 2 personas total (physical limitations, and no limitations), and the order is counter balanced. Each persona gender should match the participant (i.e., male participants are shown male personas).

- Do you have any questions about Mr(s).____?

Standard response to participants asking for more information about Mr(s).____: All the information I have available about Mr(s).____ is written on this sheet of paper.

Perceived Usefulness Questions. Next we are going to think about different ways a robot could help Mr(s)____ with a variety of tasks.

For this interview, I want you to *specifically* think about Mr(s)___. Please don't comment on how this robot might be useful for someone you might know (i.e., friends/family) or useful for you personally. Later in this interview we will talk about how you personally might use a robot. But for right now, I want you to *only* think about Mr(s)___.

Imagine, Mr(s)_____ has been given a robot to assist her. Imagine cost of the robot is not an issue. The robot is a mobile manipulator, similar to the robot you saw in the video. I want to ask you a few questions about your opinion on a robot assisting Mr(s)_____. In the following questionnaire, I want you to answer for the task specified, and also please think about Mr(s)____ abilities. I will keep this persona here in front of you so you may refer to it.

Interview Script

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The first task is ___________. For this task <*describe task and place task description in front of participant– do this for each task BEFORE administering the perceived usefulness questionnaire*>

Task	Description
Organizing	A robot that assists with house organization can help with the following: • finding lost objects such as remotes, glasses, cell phones, or keys • picking up objects or clutter from the floor • organizing items into containers, such as baskets/bins
Monitoring	A robot that assists with monitoring can help with the following: • monitoring the house for hazards (i.e., smoke) • signal when the stove has been left on • monitor a person's blood pressure, sugar levels, or medication regimen
Dressing	A robot that assists with dressing, can help with the following: • suggesting clothing that is weather appropriate • assisting with zippers or buttons • provide assistance with balance when getting in/out of clothing
Transfer	A robot that assists with transfer can help with the following: • assisting in/out of chairs/bed • assisting in/out of the bathtub • picking up a person who has fallen

*****Administer PU questionnaire******

For questionnaire highlight the task being asked about, and refer back to the persona. Make sure participant understands instructions.

- Ok, for the task of _______, I see you indicated that it is _____________ (un)likely that the robot would be useful to Mr(s)._______. How did you determine that?

    - *Probe:* What aspects of the task of _____ would the robot be useful? Remember the robot is not limited to what is listed here.
        - Why?
    - *Probe:* What aspects of the task of _____ would the robot be NOT as useful? Remember the robot is not limited to what is listed here.
        - Why?
    - *Probe*: Are there any other comments about the robot's usefulness for Mr(s).____ you might have? You may use this questionnaire as reference *<refer to usefulness questionnaire>*.

- If Mr(s)____ was given a robot to assist specifically with the task of _______, do you think he/she should to use it?

    - *If participant's answer is unclear*: Thank you for your comments. Just so I understand, was your answer "yes he/she should use it", or "no he/she should NOT us it"?

Prompt if participant is talking about themselves: Thank you. Right now, let's consider Mr(s)____, *<repeat question>*.

Okay next I want you to consider the task of ____*next task*______. Again I would like you to fill out this questionnaire, but this time we are going to be discussing ___*task*___.

<<<repeat questionnaire and interviews above for remaining tasks>

When finished with all tasks. Thank you for your input. Let's take a 5 minute break. May I show you to the restroom. Are you thirsty? May I get you something to snack on?

<STOP RECORDER>

< 5 min break>

<<<<<<<<<<<< Interview continues with next persona >>>>>>>>>>>>

Persona 2

Same questions and tasks as persona 1

Closing Questions

Now that we are nearing the end of the interview, I have some questions about how a robot might help you.

- Given your current abilities, would you find a robot, such as the PR2, useful to you?
  - Why?

- Would you use a robot, such as the PR2, in your home if you were given one ***today***?

- Think about your own *physical* abilities in 5 to 10 years, would you find a robot, such as the PR2 useful to you?
  - Why?

- Think about your own *cognitive* abilities in 5 to 10 years, would you find a robot, such as the PR2, useful to you?
  - Why?

- Think about robots in general, not just this particular robot. After today, has your general opinion about robots changed? Why or why not?

Great, this concludes our interview. Now before you leave, I have a short questionnaire for you to fill out, and I will also get your check. Thank you so much for your comments and insights!

Interview Script

Jenay Beer
Robot Autonomy Dissertation

Autonomy Selection Think Aloud

A. Dressing -- adl
B. Transfer -- adl
C. Finding and Fetching Objects – idl cog and phy
D. Cleaning floors – idl phy
E. Monitoring health (i.e., blood pressure) – idl cog and phy
F. Medication Reminders – idl cog

Participant	Task	Task	Task	Task	Task	Task
1	Dressing	Transfer	Med Remin	Find& Fetch	Monitor	Clean floor
2	Transfer	Find& Fetch	Dressing	Clean Floor	Med Remin	Monitor
3	Find& Fetch	Clean floor	Transfer	Monitor	Dressing	Med Remin
4	Clean floor	Monitor	Find& Fetch	Med Remin	Transfer	Dressing
5	Monitor	Med Remin	Clean floor	Dressing	Find& Fetch	Transfer
6	Med Remin	Dressing	Monitor	Transfer	Clean floor	Find& Fetch
7	Dressing	Transfer	Med Remin	Find& Fetch	Monitor	Clean floor
8	Transfer	Find& Fetch	Dressing	Clean floor	Med Remin	Monitor
9	Find& Fetch	Clean floor	Transfer	Monitor	Dressing	Med Remin
10	Clean floor	Monitor	Find& Fetch	Med Remin	Transfer	Dressing
11	Monitor	Med Remin	Clean floor	Dressing	Find& Fetch	Transfer
12	Med Remin	Dressing	Monitor	Transfer	Clean floor	Find& Fetch

Persona-Based Interview

A. Monitoring
B. Organizing
C. Dressing
D. Transfer

Participant	Persona Order	Task	Task	Task	Task
1	HL	Monitoring	Organizing	Transfer	Dressing
2	LH	Organizing	Dressing	Monitoring	Transfer
3	HL	Dressing	Transfer	Organizing	Monitoring
4	LH	Transfer	Monitoring	Dressing	Organizing
5	HL	Monitoring	Organizing	Transfer	Dressing
6	LH	Organizing	Dressing	Monitoring	Transfer
7	HL	Dressing	Transfer	Organizing	Monitoring
8	LH	Transfer	Monitoring	Dressing	Organizing
9	HL	Monitoring	Organizing	Transfer	Dressing
10	LH	Organizing	Dressing	Monitoring	Transfer
11	HL	Dressing	Transfer	Organizing	Monitoring
12	LH	Transfer	Monitoring	Dressing	Organizing

APPENDIX B: PERCEIVED USEFULNESS QUESTIONNAIRE

Imagine that the person described in the persona has the opportunity to use a robot, such as the PR2, to assist with the task specified. Please place an X in the response box that best represents your general opinion (we understand that there may be exceptions).

PERSONA: ____________________ TASK:________________________

1. Robot assistance with _______ will make Mr(s).____ seem more independent to others.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

2. People in Mr(s).____ life (i.e., family or friends) think that she should use the robot to assist with ___________.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

3. Robot assistance with _____ is important to Mr(s).____'s daily life.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

4. The benefits of a robot assisting Mrs. _____ with _______ are apparent.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

5. A robot assisting with ______ will be adaptive to Mr(s)_____ needs.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

Imagine that the person described in the persona has the opportunity to use a robot, such as the PR2, to assist with the task specified. Please place an X in the response box that best represents your general opinion (we understand that there may be exceptions).

PERSONA: ____________________ TASK:________________________

6. A robot assisting Mr(s)_____ with _____ is trustworthy.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

7. A robot will assist Mr(s)._____ with ________ reliably and without error..

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

8. Using a robot to assist with ______ is useful to Mr(s)_____.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

APPENDIX C: DEMOGRAPHICS AND HEALTH QUESTIONNAIRE

Participant ID______________

> Please answer the following questions. All of your answers will be treated confidentially. Any published document regarding these answers will not identify individuals with their answers. **If there is a question you do not wish to answer, please just leave it blank and go on to the next question.** Thank you in advance for your help.

Demographics Questionnaire

Gender: Male ☐1 **Female** ☐2 **Age:** _______

1. What is your highest level of education?

☐1 No formal education
☐2 Less than high school graduate
☐3 High school graduate/GED
☐4 Vocational training
☐5 Some or in-progress college/Associate's degree
☐6 Bachelor's degree (BA, BS)
☐7 Master's degree (or other post-graduate training)
☐8 Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)

2. Current marital status (check one)

☐1 Single
☐2 Married
☐3 Separated
☐4 Divorced
☐5 Widowed
☐6 Other (please specify) __________________

3. Do you consider yourself Hispanic or Latino?

☐1 Yes
☐2 No

3 a. If "Yes", would you describe yourself:

☐1 Cuban
☐2 Mexican
☐3 Puerto Rican
☐4 Other (please specify) _________________

4. How would you describe your primary racial group?

☐1 No Primary Group
☐2 White Caucasian
☐3 Black/African American
☐4 Asian
☐5 American Indian/Alaska Native
☐6 Native Hawaiian/Pacific Islander
☐7 Multi-racial
☐8 Other (please specify) ______________________

5. In which type of housing do you live?

☐1 Residence hall/College dormitory
☐2 House/Apartment/Condominium
☐3 Senior housing (independent)
☐4 Assisted living
☐5 Nursing home
☐6 Relative's home
☐7 Other (please specify) ________________

6. Which category best describes your yearly household income. Do not give the dollar amount, just check the category:

☐1 Less than $5,000
☐2 $5,000 - $9,999
☐3 $10,000 - $14,999
☐4 $15,000 - $19,999
☐5 $20,000 - $29,999
☐6 $30,000 - $39,999
☐7 $40,000 - $49,999
☐8 $50,000 - $59,999
☐9 $60,000 - $69,999
☐10 $70,000 - $99,999
☐11 $100,000 or more
☐12 Do not know for certain
☐13 Do not wish to answer

7. Is English your primary language?

☐1. Yes
☐2. No

7 a. If "No", What is your primary language? ______________

8. What is your primary mode of transportation? (Check one)

☐1. Drive my own vehicle
☐2. A friend or family member takes me to places I need to go
☐3. Transportation service provided by where I live
☐4. Use public transportation (e.g., bus, taxi, subway, van services)

Occupational Status

9. What is your primary occupational status? (Check one)

☐1. Work full-time
☐2. Work part-time
☐3. Student
☐4. Homemaker
☐5. Retired
☐6. Volunteer worker
☐7. Seeking employment, laid off, etc.
☐8. Other (please specify) ______________________________

10. Do you currently work for pay?

☐1. Yes, Full-time
☐2. Yes, Part-time
☐3. No

10 a. If "Yes", what is your primary occupation? ________________________

If retired:

11. What was your primary occupation? ______________________

12. What year did you retire? ________________

Health Information

1. In general, would you say your health is:

☐1	☐2	☐3	☐4	☐5
Poor	Fair	Good	Very good	Excellent

2. Compared to other people your own age, would you say your health is:

☐1	☐2	☐3	☐4	☐5
Poor	Fair	Good	Very good	Excellent

3. How satisfied are you with your present health?

☐1	☐2	☐3	☐4	☐5
Not at all satisfied	Not very satisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied

4. How often do health problems stand in the way of your doing the things you want to do?

☐1	☐2	☐3	☐4	☐5
Never	Seldom	Sometimes	Often	Always

5. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? Check one box for each type of activity.

	Limited a lot1	**Limited a little**2	**Not limited at all**3
a. Bathing or dressing yourself			
b. Bending, kneeling, or stooping			
c. Climbing **one** flight of stairs			
d. Climbing **several** flights of stairs			
e. Lifting or carrying groceries			
f. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf			
g. Vigorous activities, such as running, lifting heavy objects, or participating in strenuous sports (e.g., swimming laps)			
h. Walking **more than a mile**			
i. Walking **one block**			
j. Walking **several blocks**			

6. Are you on post-menopausal estrogen replacement therapy?

☐1 Yes ☐2 No ☐3 Not applicable

7. For each of the following conditions please indicate if you have ever had that condition in your life, have the condition now at this time or never had the condition. Check one box for each condition.

Condition	In your lifetime1	Now2	Never3
a. Arthritis			
b. Asthma or Bronchitis			
c. Cancer (other than skin cancer)			
d. Diabetes			
e. Epilepsy			
f. Heart Disease			
g. Hearing Impairment			
h. Hypertension			
i. Stroke			
j. Vision Impairment			
k. Other significant illnesses (please list)			

Medication Information Form

Please list the medical products that you are currently taking. Include medicinal herbs, vitamins, aspirin, etc., as well as prescription medications (copy names from label if possible).

Below is an example of how to fill out the form. If you take Ibuprofen for Arthritis two times a day, you would fill the form out as shown in the example below.

There is space for up to eight different medications. If you take more than eight medications regularly, please list the rest on the back of the last page.

n	Reason for taking medication	How often do you take this medication? (Please select one)
	Arthritis	[x] Daily 2 ______ times/day [ ] Weekly ______ times/week [ ] Monthly ______ times/month [ ] As Needed

Please turn the page to list your medications

n	Reason for taking medication	How often do you take this medication? (Please select one)

Please turn the page to list your medications

Reason for taking medication	How often do you take this medication? (Please select one)
	☐ Daily ______ times/day ☐ Weekly ______ times/week ☐ Monthly ______ times/month ☐ As Needed
	☐ Daily ______ times/day ☐ Weekly ______ times/week ☐ Monthly ______ times/month ☐ As Needed

APPENDIX D: TECHNOLOGY EXPERIENCE PROFILE

Technology Experience Profile

1. Within the last year, please indicate how much you have used any of the technologies listed below.

		Not sure what it is$_1$	Not used$_2$	Used once$_3$	Used occasionally$_4$	Used frequently$_5$
Communication Technology						
a.	Answering Machine/ Voicemail (e.g., record and retrieve messages)					
b.	Automated Telephone Menu System (e.g., pay bills, refill prescriptions)					
c.	Fax (e.g., receive and send printed documents)					
d.	Mobile Phone (e.g., make and receive calls)					
e.	Text Messaging (e.g., BBM, iMessage, SMS)					
f.	Video Conferencing (e.g., Skype, Facetime)					

		Not sure what it is$_1$	Not used$_2$	Used once$_3$	Used occasionally$_4$	Used frequently$_5$
Computer Technology						
a.	Desktop/Laptop Computer					
b.	Email (e.g., Gmail, Yahoo)					
c.	Photo/Video Software (e.g., editing, organizing; iPhoto, Picture Manager, Photoshop)					
d.	Productivity Software (e.g., Excel, PowerPoint, Quicken, TurboTax, Word)					
e.	Social Networking (e.g., Facebook, MySpace)					
f.	Tablet Computer (e.g., iPad, Touchpad, Zoom)					
Everyday Technology						
g.	Automatic Teller Machine (ATM)					
h.	Photocopier (e.g., Lexmark, Xerox)					
i.	Home Security System (e.g., Ackerman Security System, ADT)					
j.	In-Store Kiosk (e.g., grocery self-checkout, price checker)					
k.	Microwave Oven					
l.	Programmable Device (e.g., coffee maker, thermostat)					

		Not sure what it is₁	Not used₂	Used once₃	Used occasionally₄	Used frequently₅
Health Technology						
a.	Blood Pressure Monitor (e.g., measure blood pressure)					
b.	Digital Thermometer (e.g., measure temperature)					
c.	Health Management Software (e.g., diet, exercise, keep track of weight)					
d.	Heart Rate Monitor (e.g., measure heart rate, pulse)					
e.	Medication Reminder Device (e.g., schedule electronic alerts)					
f.	Pedometer (e.g., measure walking distance)					
Recreational Technology						
g.	Digital Music Player (e.g., iPod, MP3 player, Zune)					
h.	Digital Photography (e.g., camcorder, camera)					
i.	Electronic Book Reader (e.g., Kindle, Nook)					
j.	Gaming Console (e.g., Playstation, Wii, XBox)					
k.	Online Coupons/ Shopping (e.g., Amazon, Groupon, retail stores)					
l.	Recording and Playback Device (e.g., Blu-Ray, CD, DVD, DVR, VCR)					

		Not sure what it is$_1$	Not used$_2$	Used once$_3$	Used occasionally$_4$	Used frequently$_5$
Transportation Technology						
a.	Airline Kiosk (e.g., check in, print boarding pass)					
b.	Bus Tracker (e.g., check location of buses, estimate time of arrival)					
c.	Map Software (e.g., get directions, plan routes; Google Maps, MapQuest)					
d.	Navigation System (e.g., GPS, OnStar)					
e.	Online Travel Reservation (e.g., airline website, Expedia, Travelocity)					
f.	Parking Payment System (e.g., exiting lot, paying for space)					

APPENDIX E: ROBOT FAMILIARITY AND USE QUESTIONNAIRE

ROBOT FAMILIARITY AND USE QUESTIONNAIRE

For the following robots, please indicate your familiarity in terms of hearing about them, using them, or operating them. Please circle only one option.

Robots	Not sure what this is$_0$	Never heard about, seen, or used this robot$_1$	Have only heard about or seen this robot$_2$	Have used or operated this robot only occasionally$_3$	Have used or operated this robot frequently$_4$
Autonomous Car	0	1	2	3	4
Domestic/Home robot (e.g., Roomba)	0	1	2	3	4
Entertainment/toy robot (e.g., Aibo, Furby)	0	1	2	3	4
Manufacturing robot (e.g., robotic arm in factory)	0	1	2	3	4
Military Robot (e.g., search and rescue)	0	1	2	3	4
Personal Robot 2 (PR2)	0	1	2	3	4
Remote presence robot (e.g., Texai, Anybot)	0	1	2	3	4
Research robot (e.g., at university or company)	0	1	2	3	4
Robot lawn mower	0	1	2	3	4
. Robot security guard	0	1	2	3	4
. Space exploration robot (e.g., Mars Rover)	0	1	2	3	4
. Surgical robot (e.g., da Vinci Surgical System)	0	1	2	3	4

APPENDIX F: ASSISTANCE PREFERENCE CHECKLIST

Assistance Preference Checklist (PRE)

We are interested in learning about older adults' preferences for assistance in performing daily living tasks. In particular, we are looking for opinions about human assistance and robot assistance. When completing this questionnaire, please consider your **current abilities** in completing each task.

For each of the following tasks, please provide your opinion about whether you would prefer:

- No assistance
- Human assistance
- Robot assistance

Assume that the robot could perform the task to the level of a human. Please circle the most appropriate response for your general preference (we understand that there may be exceptions).

On the last page, there is space for you to provide additional comments about your preferences for having robot and human assistance.

	I currently do NOT want assistance	*If I currently want assistance*, I would prefer help from...				
		Only a human	Prefer a human	No Preference	Prefer a robot	Only a robot
Activities						
Calling doctor/911	0	1	2	3	4	5
Calling family/friends	0	1	2	3	4	5
Getting in/out of car	0	1	2	3	4	5
Grocery shopping	0	1	2	3	4	5
Running errands	0	1	2	3	4	5
Rising (transfer)						
Getting in/out of bed	0	1	2	3	4	5
Standing up from chair	0	1	2	3	4	5
Chores						
Changing light bulbs	0	1	2	3	4	5
Cleaning bathrooms	0	1	2	3	4	5
Cleaning floor	0	1	2	3	4	5
Cleaning kitchen	0	1	2	3	4	5
Cleaning windows	0	1	2	3	4	5
Doing laundry	0	1	2	3	4	5
Hand washing dishes	0	1	2	3	4	5
Loading dishwasher	0	1	2	3	4	5
Making bed	0	1	2	3	4	5
Pest control	0	1	2	3	4	5
Taking out the trash	0	1	2	3	4	5

	I currently do NOT want assistance	*If I currently want assistance*, I would prefer help from...				
		Only a human	Prefer a human	No Preference	Prefer a robot	Only a robot
Dressing						
Dressing self (clothes)	0	1	2	3	4	5
Tying shoelaces and fixing buttons	0	1	2	3	4	5
Eating						
Lifting cup/glass to mouth	0	1	2	3	4	5
Preparing meals	0	1	2	3	4	5
Using utensils	0	1	2	3	4	5
Grip						
Opening car doors	0	1	2	3	4	5
Opening jars	0	1	2	3	4	5
Turning faucets on/off	0	1	2	3	4	5
Hygiene						
Brushing teeth	0	1	2	3	4	5
Getting on and off toilet	0	1	2	3	4	5
Haircare	0	1	2	3	4	5
Shampooing hair	0	1	2	3	4	5
Taking shower	0	1	2	3	4	5
Taking tub bath	0	1	2	3	4	5
Washing/drying body	0	1	2	3	4	5

	I currently do NOT want assistance	*If I currently want assistance*, I would prefer help from...				
		Only a human	Prefer a human	No Preference	Prefer a robot	Only a robot
Medication management						
Being reminded to take medication	0	1	2	3	4	5
Deciding what medication to take	0	1	2	3	4	5
Taking (administering) medication	0	1	2	3	4	5
Reach						
Bending down to floor	0	1	2	3	4	5
Reaching above head	0	1	2	3	4	5
Walking						
Climbing five steps	0	1	2	3	4	5
Walking on flat ground	0	1	2	3	4	5

2. If the robot could perform only 5 of the tasks listed on the previous pages, which 5 would you want it to do? (you may list from 0-5 tasks)

1) ____________________________

2) ____________________________

3) ____________________________

4) ____________________________

5) ____________________________

3. Please write any comments about how you answered these questions here:

____
____
____
____

4. Are there any additional tasks with which you would like robotic assistance? (you may list from 0-5 additional tasks)

1) ____________________________

2) ____________________________

3) ____________________________

4) ____________________________

5) ____________________________

APPENDIX G: CODING SCHEME

- Part A: Autonomy Selection Think Aloud
  - No Robot
    - Does not need robot
    - Does not want robot
    - Overdependence
    - Robot decreases independence
    - Robot not Safe
    - User enjoys doing task
    - Other
  - Option A
    - Facilitators
      - Make own decisions or remain independent
      - User knows own personal preferences or taste
      - User likes or prefers this option
      - Other
    - Barriers
      - Self is not reliable
      - Inability or lack of knowledge to control robot
      - User does not want to control robot
      - User does not like or prefer this option
      - Other
  - Option B
    - Who
      - Family
      - First responders
      - Friends
      - Medical professional
      - Pharmacist
      - Staff at senior center
      - Other
    - Facilitators
      - Someone else is better at control
      - Expertise of someone else
      - User likes or prefers this option
      - User is or might be incapable
      - Other
    - Barriers
      - Does not need or want someone else involved
      - Other person not present
      - User does not like or prefer this option
      - Someone else will not know how to control
      - Someone else will not know personal preferences

            - Timeliness (too slow)
            - Privacy
            - Does not want to impose on others
            - Does not trust someone else
            - Other
- Option C
    - Facilitators
        - Robot can be (pre)programmed
        - Robot capability
        - Robot is reliable or more reliable than human
        - Robot is trustworthy
        - Robot increases social status
        - Robot saves time or energy
        - User does not enjoy or want to do task
        - User is or might be incapable
        - User likes or prefers this option
        - Other
    - Barriers
        - Robot will not know personal preferences
        - Robot unreliable, less reliable than human
        - Robot incapable of task or part of task
        - User does not want to over-depend on robot
        - Robot is not trustworthy
        - Robot unable to adapt to environment or task
        - Robot will not know schedule
        - User does not like or prefer this option
        - User is or might be incapable
        - Other

Part B: Persona Based Interview

- Conditionality Statement
    - Only use robot if needed or do NOT use on daily basis
    - Persona use robot only if incapable or "Just in case"
    - Other
- Facilitators
    - Human characteristics
        - Human Capability
            - Human incapable, so rely on robot
            - Other
        - User (in)dependence and control
            - Robot increases independence
            - Rather depend on robot than another person
            - Human relieved of making decisions
            - Other
        - User needs

            - Importance | important for health
            - Robot useful (general) | Useful often or daily basis
            - User NEEDS robot
            - Other
        - User wants, personal preferences, and enjoyment
            - User does not enjoy or feel like doing task | user is lazy
            - User WANTS robot
            - Robot fun to use
            - Other
    - Robot characteristics
        - Robot Convenience
            - Robot does mundane or repetitive task
            - Robot saves time
            - Robot makes task easier
            - Usability | ease of use
            - Other
        - Robot Reliability
            - Robot would need to be reliable | safe to complete task
            - Robot is trustworthy
            - Robot is reliable | safe
            - Other
        - Robot Capability
            - Robot is capable (general)
            - Robot changes autonomy over time
            - Preprogram robot
            - Robot is adaptive to user, task, or environment
            - Other
    - Environmental characteristics
        - Social Environment
            - Status symbol | novelty item
            - Other people will encourage use
        - Physical Environment
            - Other
- Barriers
    - Human Characteristics
        - User (in)dependence and control
            - Robot decreases independence
            - User resistant to accept assistance
            - Avoid overdependence on robot | avoid laziness
            - User remain active or do task themselves
            - User does NOT need robot
            - User should make decisions or robot not cable of making decision
            - Other
        - User needs
            - User does NOT need robot
            - Other

User wants, personal preferences, and enjoyment
User does NOT want robot
Only user will know personal preferences
Other
Robot Characteristics
Robot Inconvenience
Robot will take too long
Using robot is harder
Lack of usability | difficulty in use
Other
Robot Reliability
Robot is not reliable | safe
Robot is not trustworthy
Human performance better than robot
Other
Robot Capability
Robot incapable of task, or incapable of aspects of task
Robot is not adaptive to user, task, or environment
Other
Environmental Characteristics
Social Environment
Other people "look down" on using robot
Other people will discourage using robot
Use robot in private or secrecy
Other
Physical Environment
Physical environment too small
Other

APPENDIX H: PRE AND POST ASSISTANCE PREFERENCE CHECKLIST

Data from the pre and post assistance preference checklist were not included in this report because of methodological limitations. The questionnaire was altered from its original design (e.g., Beer et al. 2012, Smarr et al. 2012) to include a column for “I currently to not want assistance.” This led to some confusion among participants regarding the questionnaire layout. Furthermore, some participants selected this option more frequently, stating that they did not want to appear as if they can not complete tasks on their own, contrary to their reports in the interview. Therefore, this altered questionnaire design was confusing and confounded.

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