APPLYING A QUALITATIVE FRAMEWORK OF ACCEPTANCE OF PERSONAL ROBOTS

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APPLYING A QUALITATIVE FRAMEWORK OF ACCEPTANCE OF PERSONAL ROBOTS

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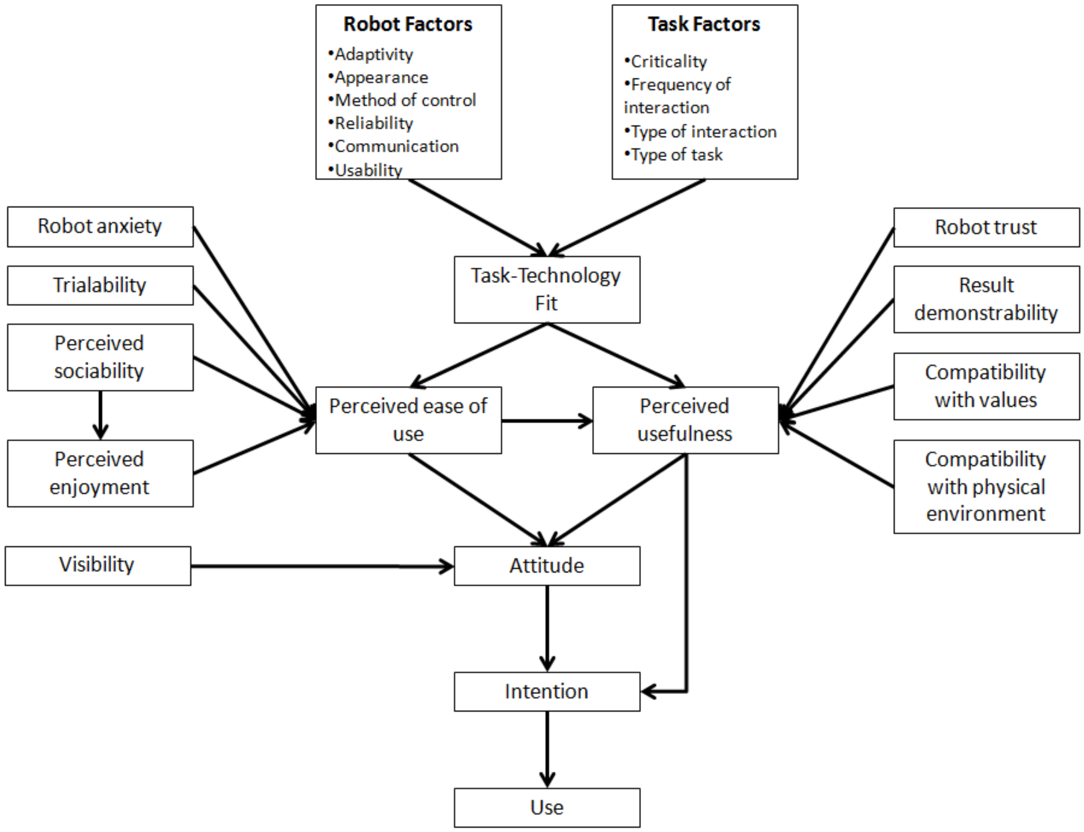
SUMMARY

Personal robots are becoming increasingly part of everyday life. From 2012 to 2015, it is expected that over 21.4 million personal robots will be sold (IFR Stat Dept, 2012). A personal robot is a robot that assists or entertains people in domestic or recreational settings (Thrun, 2004). For example, a Deere Tango E5 is a personal robot developed by Deere & Company to assist people with mowing their lawns. Personal robots can help people live safer, more efficient and comfortable lives. However, such benefits cannot be achieved if people do not use, or accept, personal robots. The use of a technology is predominantly influenced by an individual's intention to use it, which is influenced by his or her attitudes toward it (Davis, 1989). Presently, the key factors that impact the use of personal robots are not fully understood. The purpose of this dissertation research is to understand the factors important for acceptance of personal robots and their relationships.

The Smarr, Fisk, and Rogers' (2013) framework of robot acceptance was developed from a thorough review and synthesis of the robot acceptance, human-robot interaction, and technology acceptance research literatures. The framework contains human, robot, and context factors that were theoretically important to understand robot acceptance (see framework in figure on next page). To begin to test this framework, two studies were conducted to better understand personal robot acceptance from two complementary approaches.



Smarr, Fisk, & Rogers (2013) framework of personal robot acceptance.

The purpose of the usage study was to conduct an in-depth investigation of 14 people's attitudinal, intentional, and behavioral acceptance of a personal robot (i.e., Deere Tango E5 robot lawn mower) at their home over six weeks. Qualitative and quantitative data were collected through a Pre-Use and Post-Use Interview, questionnaires, robot usage logs, and weekly diaries. Surprisingly, attitudinal and subjective behavioral acceptance of the personal robot were high whereas intentional acceptance was low, which does not support well-researched patterns of acceptance (e.g., Davis, 1989). This pattern did not change over the six weeks of using the robot mower. The reasons for this surprising pattern of the types of acceptance can be explained by participants' responses during interviews and weekly diaries. Many reasons were mentioned (e.g., perceived usefulness and ease of use) including 16 of the 20 factors in the Smarr et al. (2014) framework; thereby, conceptually validating the framework.

The purpose of the survey study was to use a breadth approach to investigate 280 individuals' initial attitudinal and intentional acceptance of a personal robot with different levels of reliability and communication of feedback. An online survey was used to measure acceptance and factors identified in the Smarr et al. (2013) framework as important for acceptance. The robot mower's reliability and communication of feedback was manipulated via a text description during the survey. These robot factors were selected to manipulate because they have the potential to impact individuals' acceptance of a personal robot. Although level of robot reliability did affect attitudinal and intentional acceptance, follow-up comparisons were non-significant. Communication of feedback did not affect acceptance not did its interaction with reliability.

Respondents reported that their attitudinal acceptance of the personal robot was neutral and their intentional acceptance was low. The Smarr et al. (2013) framework explained 60% of variance in intentional acceptance of a personal robot and 57% of attitudinal acceptance. Eleven of the 15 relationships tested were supported at least partially via path analyses. In short, findings largely supported the Smarr et al. (2013) framework in explaining what impacts intentional and attitudinal acceptance.

A better understanding of the acceptance of personal robots is valuable in two major ways. First, from a practical perspective, it can provide guidelines to help designers in developing acceptable robots. Second, from a psychological perspective, it can also inform theories of acceptance by exploring boundary conditions and extending current models.

CHAPTER 1: INTRODUCTION

The presence of robots in our lives has been increasing, as robots have been used to assist people with personal and professional tasks. One application of robots that has recently been experiencing notable amounts of growth is personal robots (International Federation of Robotics Statistical Department [IFR Stat Dept], 2012). In 2011 alone, 2.5 million personal robots were sold and it has been estimated that over 21.4 million will be sold from 2012 until 2015 (IFR Stat Dept, 2012). Personal robots are robots that assist and entertain people within domestic or recreational settings (Thrun, 2004). A Roomba, for example, is a personal robot developed by iRobot to help people vacuum their floors.

Roombas and other personal robots (e.g., robot lawn mowers, toys) have been used by people. By design, personal robots can help people live safer, more efficient and comfortable lives. Yet, these benefits can only be realized if people use, or accept, personal robots. People's attitudes toward a technology influence their intentions to use it, which in turn, influences their use of it (Davis, 1989). Currently, the critical factors that lead to use of personal robots are not completely understood. The purpose of this dissertation is to better understand what factors should be considered when designing a personal robot that people will use and to understand the behaviors, intentions, and attitudes associated with acceptance.

Personal Robots

The definition of a robot has not generally been agreed upon in the literature. For this paper, a robot is an embodied, reprogrammable computational system used to manipulate the physical environment using its sensors, effectors (or actuators), and memory (Sheridan, 1992). Personal robots (sometimes referred to as personal service robots) are a type of robot that assists or entertains people within domestic or recreational settings (Thrun, 2004).

They differ from other robots based on their purpose, operational settings, and capabilities. The two main purposes of personal robots are to help people with personal tasks and to entertain them. They are designed to interact safely with a range of people within the environments that people occupy (e.g., homes; Thrun, 2004). In general, personal robots tend to be capable of more autonomy and social capabilities than other robots. Personal robots usually have more autonomy than other robots to execute tasks without human intervention because they operate within unstructured environments (Schraft, Degenhart, & Hagele, 1993). Lastly, personal robots are often are designed with social capabilities to facilitate human-robot interactions by establishing common meaning with users who may have limited to no training on how to use a robot (Broekens, Heerink, & Rosendal, 2009).

According to Thrun (2004), besides personal robots, there are two other main types of robots: professional service robots and industrial robots. Although professional service robots are somewhat similar to personal robots in that they do help people within human-occupied environments (e.g., the workplace), the purpose of a professional service robot is to assist people with job-based tasks (e.g., surgery, dispensing medications; Thrun, 2004). Job-based tasks fundamentally differ from personal tasks based on the capabilities, skills, and training required from both the robot and its user. For example, a surgeon graduated medical school, finished advanced specialty education, and trained to use a robot effectively before performing robot-assisted surgery on a patient. Furthermore, professional service robots operate in more structured environments (e.g., operating rooms, pharmacies), which do not necessarily require as much autonomy for the robot to operate in as unstructured environments (Schraft et al., 1993). Professional service robots oftentimes interact with trained users so they do not necessitate the same sociabilities as personal robots.

Industrial robots operate within cages away from humans within manufacturing settings. Traditionally, their purpose is to perform jobs that are dirty (e.g., painting tractors), dangerous (e.g., laser cutting), or dull (e.g., welding the same part repeatedly on cars in an assembly line). Interactions with industrial robots require the human to have specialized training or skills. For example, humans communicate with an industrial robot by inputting commands using a programming language code. Industrial robots have low levels of autonomy and sociability because they operate in a highly structured environment and have limited contact with users (e.g., programmer, repairman).

In summary, a personal robot differs from other types of robots in its purpose, operational settings, and capabilities. Personal robots help people with everyday life tasks and entertainment within environments that people occupy (e.g., domestic and recreational settings). They tend to have high levels of autonomy to interact safely with untrained people within unstructured environments. Personal robots can have sociabilities, which are designed to facilitate interactions with untrained people.

Acceptance of Personal Robots

From a practical perspective, designing acceptable robots benefits not only the robot designers but also the users. Personal robots can support people in performing everyday living tasks and ultimately, to live safer, more efficient, and comfortable lives. From a psychological perspective, an important step to designing personal robots for acceptance is to understand the behaviors, intentions, and attitudes associated with acceptance.

Defining Acceptance

Based on the well-researched, social psychological theory of reasoned action (Fishbein & Ajzen, 1975), acceptance is comprised of an individual's attitudes toward a technology (e.g., I like it), intentions to perform a behavior (e.g., I plan on using it), and behaviors (e.g., using it; Davis, 1989). An individual's behavior results from his or her intentions, which are formed from his or her attitudes and beliefs. Although the theory of reasoned action explains behavior very well, favorable attitudes and intentions do not always translate into behavior.

A belief is a representation of the information an individual has about a discriminable aspect of his or her world (Fishbein & Ajzen, 1975). An attitude is a "learned predisposition to respond in a consistently favorable or unfavorable manner" toward any discriminable aspect of the individual's world (Fishbein & Ajzen, 1975, p. 6). An intention is "a person's subjective probability that he [or she] will perform some behavior" (Fishbein & Ajzen, 1975, p. 288). A behavior is an "observable overt act" (Fishbein & Ajzen, 1975, p. 12). For example, a person may think that a personal robot is nice (attitudinal acceptance), decide to buy it (intentional acceptance), and then use the robot (behavioral acceptance).

Qualitative Framework of Robot Acceptance

Personal robots are currently in use to support people in their daily lives. Yet, why some people accept personal robots is not fully understood. An understanding of the factors affecting the acceptance of personal robots is underdeveloped in the literature, and as a result, our appreciation of important factors and their relationships is limited. In general, existing knowledge lacks a holistic view of robot acceptance, including the human, the robot, the task, the environment, time, and the interactions among them. Insights into robot acceptance cannot only benefit theory but can also help guide design of acceptable robots.

From an extensive review and synthesis of empirical literature, Smarr, Fisk, and Rogers (2013) created a theoretically-based qualitative framework identifying key factors and their relationships for acceptance of personal robots (Figure 1.1). The aim of the framework was to provide an understanding of the determinants of an individual's acceptance of a personal robot. That is, the framework detailed the factors important for understanding an individual's acceptance across a range of personal robots entertaining and assisting with everyday living tasks in various environments. A goal of the current research was to start understanding the appropriateness of applying this theoretically-based framework to individuals' acceptance of personal robots.

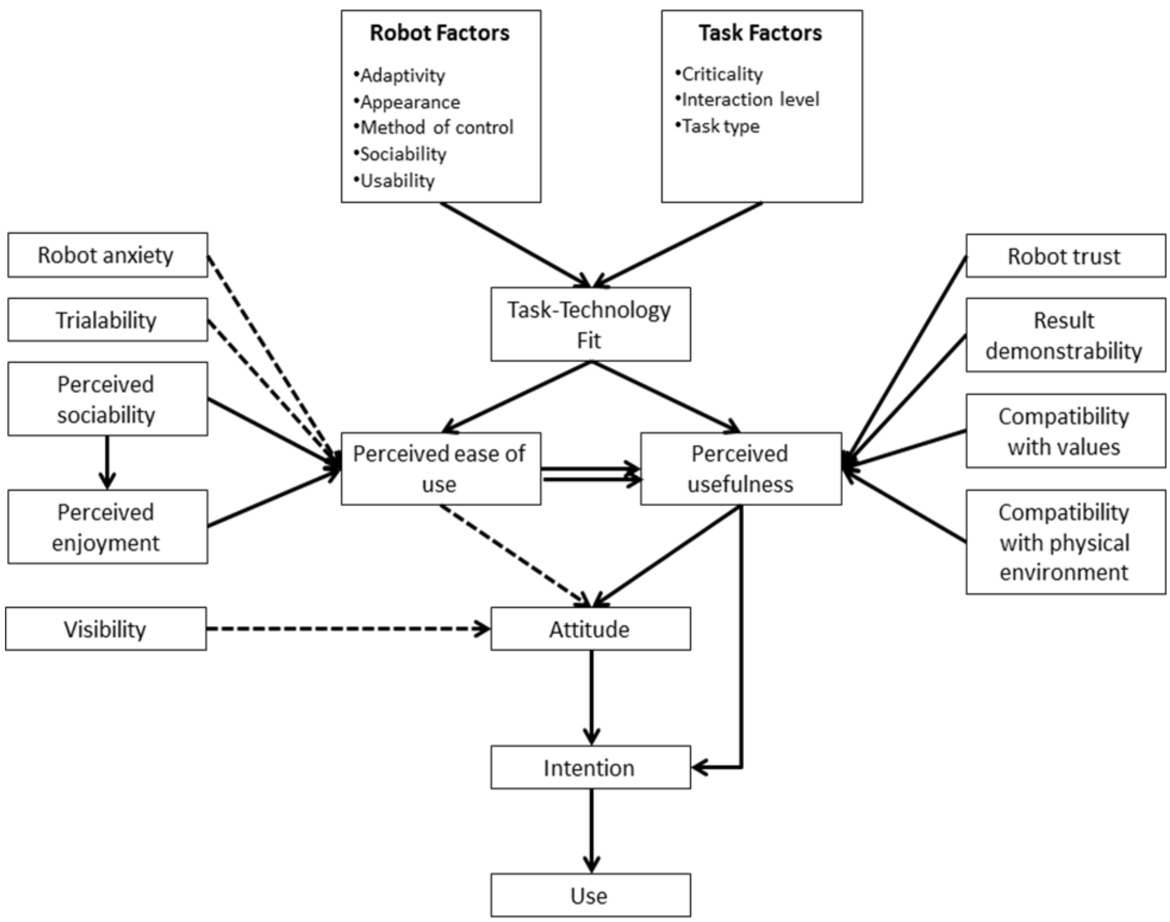


Figure 1.1. A qualitative framework of personal robot acceptance (Smarr, Fisk, & Rogers, 2013). Dotted lines indicate relationships that weaken with experience. The solid, double line indicates relationships that strengthen with experience. The solid, single lines indicate relationships that are not moderated by experience.

To create the qualitative framework, Smarr et al. (2013) conducted a thorough review of the literatures of robot acceptance, technology acceptance, and human-robot interaction to identify factors important for acceptance of personal robots and synthesize them into a framework. Selection of factors was not exhaustive. Instead, selection focused on three types of factors: (1) factors already associated with robot acceptance; (2) factors widely regarded as being associated with acceptance of non-robotic technologies; and (3) factors found to impact interactions between human and robots but not directly examined relative to acceptance. Refer to Smarr et al. (2013) for more details on the framework as well as its development; see Figure 1.1 for the qualitative framework of personal robot acceptance.

In the following sections, the determinants of key factors and their relationships within the Smarr et al. (2013) qualitative framework have been reviewed. The key factors that have been reviewed are: behavioral acceptance, intentional acceptance, attitudinal acceptance, perceived usefulness and ease of use, and task-technology fit. Then, the scope and limitations of the framework have been outlined. Lastly, next steps for testing the framework have been discussed.

Determinants of Use

The Smarr et al. (2013) framework ultimately aimed to determine what factors were important for use (behavioral acceptance) of personal robots. Based on the theory of reasoned action (Fishbein & Azjen, 1975), an individual's intentions are the most important determinant of his or her behavior. That is, a person's behavior can be predicted from his or her intentions to perform said behavior. Intentional acceptance as a positive determinant of behavioral acceptance has been applied to one robot acceptance model (i.e., the Almere Model; Heerink, Kröse, Evers & Wielinga, 2010a). It has also been employed within various technology acceptance models, but most notably within the Technology Acceptance Model (TAM; Davis, 1989; Davis, Bagozzi, & Warshaw, 1989).

Relevant Theoretical Background

The Almere Model was developed by Heerink and colleagues (2010a) to test older adults' acceptance of assistive social robots and virtual agents (i.e., on-screen characters similar to cartoons). In the Almere Model, behavioral acceptance was determined by intentional acceptance, facilitating conditions, and social influences. Intentional acceptance was determined by attitudinal acceptance, trust, and perceptions of usefulness, ease of use, and enjoyment. These aforementioned perceptions were determined by anxiety toward using a robot or virtual agent, and perceptions of a robot or virtual agent's adaptivity, sociability, and social presence.

The strengths of the Almere Model (Heerink, Kröse, Evers, & Wielinga, 2010a) are its succinct, quantitative measurement (e.g., a 41-item Likert-type questionnaire); its application to both robots and virtual agents; and its foundation based on a validated technology acceptance model (i.e., the Unified Theory of Acceptance and Use of Technology [UTAUT]; Venkatesh, Morris, Morris, & Davis, 2003). However, the generalization of the Almere Model is limited, because it has only been tested with older adults living in the Netherlands who have interacted with a social robot or virtual agent performing simple, non-physical tasks for a brief period of time (e.g., 30 minutes). Moreover, it does not incorporate human characteristics (e.g., robot experience), task characteristics (e.g., criticality), or time.

The Almere Model augmented the UTAUT for older adults' acceptance of social robots and virtual agents. Venkatesh et al.'s (2003) UTAUT technology acceptance model resulted from unifying elements from eight different models of acceptance, including TAM. It has four determinants of intentional and behavioral acceptance (i.e., performance expectancy, effort expectancy, social influence, facilitating conditions) and up to four moderators of those relationships (i.e., gender, age, technology experience, and voluntariness of use). Compared to the other eight models in Venkatesh et al. (2003), UTAUT predicted more variance in intentional acceptance (69%) and similar amounts of behavioral acceptance (47%). A recent meta-analysis of UTAUT empirical research found that the model explain similar amounts of behavioral acceptance but considerably less intentional acceptance (Dwivedi, Rana, Chen, & Williams, 2011).

TAM has been the most prominent model of technology acceptance and has been adapted and augmented for various populations, settings, and systems. It was originally adapted from the theory of reasoned action (Fishbein & Ajzen, 1975) to predict the likelihood of an information technology (e.g., computer) being used within the workplace (Davis, 1989; Davis et al., 1989). Like the theory of reasoned action, TAM proposed that an individual's actual use of a technology (behavioral acceptance) was determined by his or her intent to try a technology (intentional acceptance) which is in turn, determined by an individual's attitude (attitudinal acceptance). Acceptance was determined by an individual's perception of how useful the technology was, how easy it was to use, and external variables (e.g., system features, training). TAM is parsimonious yet explains approximately 30% of behavioral acceptance of information technologies in the workplace (Schepers & Wetzels, 2007) and approximately 40% of an individual's intentional acceptance (King & He, 2006; Schepers & Wetzels, 2007; Sun & Zhang, 2006b; Venkatesh et al., 2003).

Empirical Support

For information technologies, intentional acceptance is a significant positive determinant of behavioral acceptance in several technology acceptance models (e.g., TAM, UTAUT; Davis et al., 1989; Dwivedi et al., 2011; Legris, Ingham, & Collerette, 2003; Schepers & Wetzels, 2007; Venkatesh & Bala, 2008; Venkatesh et al., 2003). For robots, the Almere Model supported intentional acceptance as a statistically significant determinant of behavioral acceptance of a robot (Heerink et al., 2010a). Intentional acceptance was measured via a questionnaire, and behavioral acceptance was recorded by the robot when participants logged into the robot for information (e.g., directions, weather; Heerink, Kröse, Evers, & Wielinga, 2009). Although the Almere model included intentional acceptance as a determinant of behavioral acceptance, the relationship was not tested in the final model (Heerink et al., 2010a). No other studies were identified in the literature that assessed both intentional acceptance and behavioral acceptance of personal robots.

One gap in the literature was the lack of research on behavioral acceptance of robots and its determinants. There have been a few ethnographic studies investigating themes of people using robot vacuum cleaners in their homes (e.g., Bauwens & Fink, 2012; Fink et al., 2011, 2013; Forlizzi, 2007; Sung et al., 2010). They are an important first step for understanding robot use. However, due to the ethnographic nature of the research, themes related to robot vacuum use were identified but not directly linked to behavioral acceptance. Additionally, in the past, it has been difficult to explore behavioral acceptance of robots because having people interact with a personal robot tends to require more resources than watching a video or seeing a picture (e.g., money, time to program and implement, maintenance), and many robots currently lack the capability to perform behaviors safely around people.

Determinants of Intention

Intentional acceptance was a significant determinant of behavioral acceptance of robots (Heerink et al., 2010a). In addition to behavioral acceptance, the Smarr et al. (2013) qualitative framework also detailed what factors were important for intentional acceptance of personal robots (Figure 1.1). In the framework (Figure 1.1), intentional acceptance was determined by two factors: attitudinal acceptance and perceived usefulness.

Attitudinal Acceptance

Based on the theory of reasoned action, an individual's attitudes are an important positive determinant of their intentions (Fishbein & Azjen, 1975). That is, the more positive a person's attitude toward a robot, the more likely he or she will intend to use that robot. Attitudes guide a person's behavior by filtering information and by shaping his or her perception of the world (Fazio, 1986). Attitudinal acceptance was a determinant of intentional acceptance to the Almere Model and to the original TAM (Davis et al., 1989).

The use of attitudinal acceptance as a mediator between beliefs (e.g., perceived usefulness, perceived ease of use) and intentional acceptance has been inconsistent. In the original TAM, attitudinal acceptance was theorized to mediate between beliefs and intentional acceptance based on the theory of reasoned action. Yet, when Davis et al.

(1989) empirically tested the original TAM, attitudinal acceptance was found to only partially mediate between beliefs and intentional acceptance. As such, attitudinal acceptance was omitted from the TAM. Since then, attitudinal acceptance has been studied less than other types of acceptance within technology acceptance literature.

In a review of the technology acceptance literature, Kim et al. (2009) found the mediating role of attitudinal acceptance to be inconsistent in the 22 studies within which it was measured and that it may be related to an individual's direct experience with the technology. Research on attitude has shown that some attitudes weakly predicted associated behaviors, whereas other attitudes were strongly predictive (Krosnick & Petty, 1995). The strength of an attitude may impact acceptance and the strength of an attitude, in turn, may be positively related to an individual's direct experience with a technology (Kim et al., 2009).

In the robot acceptance literature, attitudinal acceptance was the strongest determinant of intentional acceptance of a personal robot (Ezer, Fisk, & Rogers, 2009a; Heerink et al., 2010a). Greater positive attitude were associated with greater intentional acceptance (Ezer et al., 2009a; Heerink et al., 2010a). Attitudinal acceptance was included in the Smarr et al. (2013) framework because it was theoretically (Fishbein & Azjen, 1975) and empirically justified for robots (Ezer et al., 2009a; Heerink et al., 2010a).

Perceived Usefulness

In addition to attitudinal acceptance, perceived usefulness is also a significant positive determinant of intentional acceptance of robots and other technologies. That is, the more useful a robot seems the more likely an individual will intend to use that robot.

The relationship between perceived usefulness and intentional acceptance has been applied to the Almere Model (Heerink et al., 2010a) and to various technology acceptance models, including TAM and UTAUT (Davis, 1989; Davis et al., 1989; Venkatesh et al., 2003).

Perceived usefulness has been traditionally defined within the context of the workplace as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). Here, perceived usefulness is the degree to which a person believes that using a personal robot would enhance his or her completion of a task. Perceived usefulness has generally been considered to measure the benefits related to a technology and it was positively associated with acceptance (Davis, 1989).

Perceived usefulness has been explored in many HRI studies but surprisingly few have related it to acceptance. Of the few studies, perceived usefulness has a significant positive relationship with intentional acceptance of robots (Cesta et al., 2007, 2011; Ezer et al., 2009a; Heerink et al., 2010a).

For acceptance of information technologies, greater perceived usefulness has been associated with greater acceptance of technology for all three types of acceptance: attitudinal, intentional, and behavioral (Legris et al., 2003). Of the different types of acceptance, the relationship between perceived usefulness and intentional acceptance tended to be the strongest and most consistent, followed by the relationship between perceived usefulness and attitudinal acceptance within TAM (Legris et al., 2003; Schepers & Wetzels, 2007). When attitudinal acceptance was excluded, perceived usefulness had the strongest influence on intentional acceptance across time in TAM and its later extensions, TAM2 and TAM3 (Venkatesh et al., 2003; Venkatesh & Bala, 2008). Perceived usefulness and behavioral acceptance had the weakest (Schepers & Wetzels, 2007) and least consistent relationship but also least investigated (Legris et al., 2003; Schepers & Wetzel, 2007).

Determinants of Attitude

Attitudinal acceptance was included in the Smarr et al. (2013) framework, because it was a significant determinant of intentional acceptance of robots (Ezer et al., 2009a; Heerink et al., 2010a). In addition to behavioral and intentional acceptance, the framework also detailed what factors were important for attitudinal acceptance of personal robots (Figure 1.1): perceived usefulness, perceived ease of use, and visibility.

Perceived Usefulness

Perceived usefulness was not only a determinant of intentional acceptance of personal robots but was also shown to be a determinant of attitudinal acceptance (Ezer et al., 2009a). Within this study, perceived usefulness was the strongest determinant of attitudinal acceptance (Ezer et al., 2009a). However, few robot acceptance studies have examined the relationship between perceived usefulness and attitudinal acceptance so results must be interpreted with care. For acceptance of information technology, perceived usefulness was a determinant of attitudinal acceptance in the original TAM (Davis et al., 1989) and in subsequent research on TAM (Legris et al., 2003; Schepers & Wetzels, 2007).

Perceived Ease of Use

Perceived ease of use was a determinant of attitudinal acceptance in the Smarr et al. (2013) qualitative framework and in the original TAM (Davis et al., 1989). Perceived ease of use is "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320). As perceived ease of use increased, acceptance of technology increased (Davis, 1989), suggesting that a technology that seems easier to use is more likely to be accepted.

Perceived ease of use significantly predicted attitudinal acceptance of a personal robot but not as strongly as perceived usefulness (Ezer et al., 2009a). Perceived ease of use significantly predicted intentional acceptance of a personal robot but not as strongly as either attitudinal acceptance or perceived usefulness did (Ezer et al., 2009a; Heerink et al., 2010a). Similar to patterns of robot acceptance, perceived ease of use was a significant but weaker determinant of attitudinal acceptance for information technologies (Davis et al., 1989; Schepers & Wetzels, 2007), especially for formation of attitudes (Karahanna et al., 1999).

Although perceived ease of use can influence both attitudes and intentions, perceived ease of use was a more consistent determinant of attitudinal acceptance than intentional acceptance for information technologies (Y. Lee, Kozar, & Larsen, 2003; Sun & Zhang, 2006b). Currently, it is unknown if perceived ease of use predicts attitudinal acceptance more consistently than intentional acceptance for personal robots because of the lack of research investigating both of these relationships.

Moreover, the effect of perceived ease of use on attitudinal acceptance changes with increased experience using information technologies (Venkatesh & Bala, 2008).

The effect of perceived ease of use on attitudinal acceptance was stronger for inexperienced users than for experienced users (Taylor & Todd, 1995). Ease of use has been thought to be a more salient hurdle to overcome in early stages of technology use, which is later overcome by the usefulness of the technology (Davis et al., 1989; Venkatesh et al., 2003). Given this trend, it was surprising that there was no significant change in perceived ease of use after using a robot vacuum cleaner for two weeks (Fink et al., 2011). At this time, it is unclear if the relationship between perceived ease of use and attitudinal acceptance weakens over time for personal robots.

Visibility

Visibility was a determinant of attitudinal acceptance in the Smarr et al. (2013) framework and was adapted from Rogers' (2003) diffusion of innovation theory. Visibility is the degree to which a technology is obvious to others (Moore & Benbasat, 1991). A technology that is more readily observed (i.e., greater visibility) is more likely to be accepted (Agarwal & Prasad, 1997; Karahanna et al., 1999; Moore & Benbasat, 1991). For example, a robot mower has greater visibility than a robot bather, because others can observe the benefit of their neighbor's robot mower more readily than a robot that helps a neighbor bathe.

Diffusion of innovations was a theory originally proposed by Everett Rogers in 1962 that explains how, why, and at what rate new ideas, practices, or objects (i.e., innovations) are spread through cultures. Rogers (2003) defined diffusion as "the process by which (1) an *innovation* (2) is *communicated* through certain *channels* (3) *over time* (4) among the members of a *social system*" (Rogers, 2003, p. 11). The italicized terms represent the four main elements of diffusion.

The first element is the *innovation* and it is defined as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers, 2003, p. 12). A technology is a specific type of innovation. The "newness" of an innovation influences the rate of diffusion such that more radical innovations (i.e., a new paradigm for completing a task) create more uncertainty and are less readily adopted compared to more incremental innovations (i.e., similar task paradigm to existing innovations; Rogers, 2003).

The second element of diffusion is the *communication channel*, which can be sharing information through mass media or interpersonal communication (Rogers, 2003). The third element is *time* (Rogers, 2003) which is a particular strength of the innovation diffusion theory as many technology acceptance models do not explicitly incorporate it in their thinking. The fourth element is *social system* and it is defined as "a set of interrelated units [individuals, families, etc.] that are engaged in joint problem solving to accomplish a common goal" (Rogers, 2003, p. 23).

Based on his diffusion of innovation theory as well as decades of research, Rogers' (2003) identified five perceived attributes of an innovation that best explain over half of the variance in adoption (i.e., decisions to make full use of an innovation). In general, technologies that have greater relative advantage, compatibility, trialability, and observability as well as less complexity will be adopted more rapidly than other technologies (Rogers, 2003). The impact of these characteristics can vary across contexts and outcome variables (Rogers, 2003) but all five can impact acceptance (Plouffe, Hulland, & Vandenbosch, 2001). Surprisingly little research in HRI has examined the effects of perceived attributes of innovations on acceptance.

One of the five perceived attributes of innovation is observability, which is defined as "the degree to which the results of an innovation are visible to others" (Rogers, 2003, p. 16). Innovations that were more observable were adopted more often than innovations that were less observable (Rogers, 2003). That is, an innovation was more likely to be adopted if individuals can see it being used and can see the results of using it.

Observability has not been found to be consistently related to adoption or implementation of innovations (Tornatzky & Klein, 1982). The inconsistent relationship between observability and adoption may be because observability encompassed several factors. Moore and Benbasat (1991) found this to be true for information systems. Using Rogers' (1983, p. 232) earlier definition of observability (i.e., "the degree to which the results of an innovation are visible and communicable to others"), Moore and Benbasat (1991) proposed two distinct factors to replace it: visibility and result demonstrability. Visibility is how obvious a technology is to others, whereas result demonstrability focuses on a user's discernment of the tangible results of using a technology. Both visibility and result demonstrability positively impact acceptance (Agarwal & Prasad, 1997; Karahanna et al., 1999; Moore & Benbasat, 1991).

The influence of visibility on attitudinal acceptance of robots has not been systematically examined in the HRI literature. The visibility of using a robot would be less for private use (e.g., inside a home) as compared with public use (e.g., grocery store). German participants reported a diverse set of applications that robots could perform for private use (e.g., healthcare, companionship), public use (e.g., tour guide, translator), and both settings (e.g., security, fetching items; Lohse, Hegel, & Wrede, 2008). Using data from the same study, Hegel et al. (2007) found that the more an application was used in private, the more frequently the HRI took place. This result suggests that users may want to use a robot more to perform tasks in private rather than in public. If personal robots are largely used in private, then they will have less visibility, which may be a potential barrier to consider in acceptance.

A more visible technology provides others the opportunity to see the use of it. Seeing other people use a technology can be a source of information for potential users to form expectations and attitudes toward using the technology (Rogers, 2003). Attitudes toward an object (e.g., robot) tend to become more positive as an individual increasingly sees that object (i.e., mere exposure effect; Zajonc & Markus, 1982). For information technology, visibility was a significant positive predictor of attitudinal acceptance for potential users but not for current users (Karahanna et al., 1999). The effect of visibility on attitudinal acceptance could diminish as an individual gains his or her own source of information through direct experience with a technology (Karahanna et al., 1999).

Determinants of Perceived Usefulness

In the Smarr et al. (2013) framework (Figure 1.1), six factors impact the perceived usefulness of a personal robot: compatibility with physical environment, compatibility with values, result demonstrability, robot trust, task-technology fit, and perceived ease of use. Selection of these six factors were based on the Technology Acceptance Model 3 (TAM3; Venkatesh & Bala, 2008), diffusion of innovation theory (Rogers, 2003), Task-Technology Fit Model (Goodhue, 1995; Goodhue & Thompson, 1995), and TAM (Davis, 1989; Davis et al., 1989).

Technology Acceptance Model 3

TAM3 (Venkatesh & Bala, 2008) is a comprehensive nomological network of the determinants of information technology adoption in the workplace. TAM3 extends the TAM (Davis et al., 1989) by specifying determinants of perceived usefulness (TAM2; Venkatesh & Davis, 2000) and perceived ease of use (Venkatesh, 2000). The determinants fall into four basic categories including individual differences, system characteristics, social influences, and facilitating conditions.

More specifically, the selection of determinants of perceived usefulness was guided by two theoretical processes: social influence and cognitive instrumental processes (i.e., a person's mental assessment of the match between task goals and outcomes of using the technology for achieving task goals; Venkatesh & Bala, 2008). The determinants of perceived usefulness were subjective norm and image (social influences) and perceived ease of use, job relevance, output quality, and result demonstrability (cognitive instrumental processes).

In TAM3, the determinants of perceived ease of use were selected based on an anchor and adjustment framework (Venkatesh & Bala, 2008). Individuals use their general computer beliefs to "anchor" their initial perceptions of ease of use for using the system. The anchor determinants of perceived ease of use were control beliefs (computer self-efficacy and perceptions of external control), and individual differences in general computer beliefs (computer anxiety and computer playfulness).

The individuals then use system-specific beliefs to "adjust" their initial perceptions of ease of use after gaining direct experience using the new system. The adjustment determinants of perceived ease of use were system-specific beliefs (perceived enjoyment and objective usability). Venkatesh and Bala (2008) proposed that the determinants of perceived usefulness do not influence perceived ease of use and vice versa (i.e., no cross-over effects). Despite its comprehensiveness, TAM3 still accounts for only slightly greater amounts of variance in intentional acceptance (40-53%) and behavioral acceptance (31%-35%) compared with the parsimonious TAM (Venkatesh & Bala, 2008).

Compatibility

Compatibility has been one of the five perceived attributes of innovation in the diffusion of innovation theory that best explain adoption. Compatibility is defined as "the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003, p. 15). Compatibility has been a cognitive instrumental process identified as important for personal robot acceptance and as such, it was a determinant of perceived usefulness in the Smarr et al. (2013) framework (Venkatesh & Bala, 2008). The more compatible a technology is to a person's values, experiences, and needs, the more likely a technology will be accepted (Rogers, 2003; Tornatzky & Klein, 1982).

Some researchers (e.g., Karahanna, Agarwal, & Angst, 2006) have argued that compatibility as defined by Rogers (2003) consists of several distinct factors: compatibility with needs, compatibility with previous ideas, and compatibility with values. The first two are indirectly included in the Smarr et al. (2013) framework. Compatibility with needs is subsumed by perceived usefulness, because compatibility with needs taps into an aspect of perceived usefulness as a technology cannot be viewed as advantageous if it does not meet an individual's needs (Moore & Benbasat, 1991).

Compatibility with previous experience is encapsulated as a moderator for key relationships in the Smarr et al. (2013) framework, such as in UTAUT and TAM3 (Venkatesh & Bala, 2008; Venkatesh et al., 2003). People naturally refer to their existing knowledge to form beliefs (e.g., perceived usefulness) and attitudes about an innovation, which can shape their intentions and behaviors (Fishbein & Ajzen, 1975; Rogers, 2003; Venkatesh & Bala, 2008). How compatible a robot is to a person's previous experience may have differential effects on several factors so a single construct may be inappropriate.

Compatibility with values is defined as the degree to which a technology meets cultural values or beliefs (Rogers, 2003). A lack of compatibility between a technology and a person's values can be a barrier to acceptance (Rogers, 2003). Compatibility of values was a significant positive determinant of perceived usefulness for an information technology in the workplace (Karahanna et al., 2006). Values are also likely to be important for acceptance of robots in the home. Based on an ethnographic study of existing products being used in homes, Forlizzi et al. (2004) recommended that personal robots be compatible with and support the values of independence and dignity for older adults to accept robots in their homes. Research is needed to determine what values are important for personal robots to be compatible with and to support.

Smarr et al. (2013) proposed a fourth type of compatibility important for personal robot acceptance – compatibility with the physical environment. Compatibility with physical environment is defined as "the degree to which using a robot is perceived as congruent with the physical structures of its surroundings (e.g., rooms, floors, furniture)" (Smarr et al., 2013, p. 48). The physical environment in which human-robot interactions take place was important for understanding acceptance of personal robots (Bauwens & Fink 2012; Beer, Smarr et al. 2012; Forlizzi, 2007; Forlizzi & DiSalvo, 2006; Forlizzi et al., 2004; Frennert, Östlund, & Eftring, 2012; Khan, 1998; Sung et al., 2010; Young et al., 2011). For example, people discontinued use of a robot vacuum cleaner because it was not compatible with the physical environment of the home (e.g., rugs, furniture). A robot that was incompatible with the home's physical environment may have been perceived as less useful, which could negatively impact robot acceptance. In short, lack of compatibility with physical environment is a potential barrier to acceptance for personal robots.

Result Demonstrability

Based on diffusion of innovation theory, result demonstrability is defined as the degree to which an individual can measure, observe, and communicate the results of using the technology (Moore & Benbasat, 1991). Result demonstrability focuses on the user's discernment of the tangible results of using a technology (Moore & Benbasat, 1991). Result demonstrability was a type of cognitive instrumental process and was a determinant of perceived usefulness in the Smarr et al. (2013) framework and in TAM3 (Venkatesh & Bala, 2008). It had a positive impact on acceptance (Agarwal & Prasad, 1997; Karahanna et al., 1999; Moore & Benbasat, 1991).

Some people reported, and thus recognized to some degree, that a robot could tangibly benefit their performance of tasks in several ways. For example, one benefit participants reported was that the robot could perform undesirable tasks (e.g., cleaning; Beer, Smarr et al., 2012; Broadbent et al., 2010). If benefits of using robots are readily apparent or communicable to the user (i.e., higher result demonstrability), then robots may be more likely to be perceived as useful. For information technologies, result demonstrability was a significant positive predictor of perceived usefulness over time (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). In light of these observations from HRI studies and results from technology acceptance, it is expected that result demonstrability will have a positive impact on perceived usefulness of personal robots.

Robot Trust

Robot trust was a determinant of perceived usefulness in the Smarr et al. (2013) framework (Figure 1.1). Robot trust is defined as "the attitude that an agent [e.g., robot] will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (J. D. Lee & See, 2004, p. 54). Robot trust was a type of cognitive instrumental process and thereby a determinant of perceived usefulness (TAM3, Venkatesh & Bala, 2008). It is expected that higher levels of robot trust would impact robot acceptance positively.

There has been surprisingly little research examining how trust affects robot acceptance. When younger and older adults were asked about trusting a robot to care for them, most of the participants' responses were related to the usefulness of the robot's capabilities (Ezer, 2008). In a recent meta-analysis of information technology acceptance, trust had a significant positive influence on attitudinal acceptance through perceived usefulness (J.-H. Wu, Chen, & Lin, 2007). That is, an individual may be more likely to perceive a robot or other technology as more useful if it can be trusted to perform a task. Human trust in personal robots may be particularly important for acceptance because trust was arguably more important for environments that were less structured (e.g., home) and for technologies that were perceived as more complex (J. D.

Lee & See, 2004). More research is needed to determine how robot trust influences acceptance of personal robots.

Task-Technology Fit

Task-technology fit was a positive significant determinant of perceived usefulness in the Smarr et al. (2013) framework of personal robot acceptance. Task-technology fit is defined as the match between technology capabilities, task requirements, and individuals' abilities (Goodhue, 1995). This implies that a technology would only be used if it supported (or fit) the user's tasks. In general, greater task-technology fit improved performance of the human-technology system (Goodhue, 1995; Goodhue & Thompson, 1995). If a technology cannot handle the requirements of a task, then task-technology fit decreased (Dishaw & Strong, 1999).

Task-technology fit is a construct in the Task-Technology Fit Model (also referred to as the Technology-to-Performance Model; Goodhue, 1995; Goodhue & Thompson, 1995). This model holds that for a technology to have a positive impact on an individual's performance then the technology must not only be used but also that it must fit with the task it supports (Goodhue, 1995; Goodhue & Thompson, 1995).

When the Task-Technology Fit Model was integrated with TAM (e.g., perceived usefulness, perceived ease of use, attitudinal and intentional acceptance), the amount of variance explained in behavioral acceptance significantly increased above that of either model individually (Dishaw & Strong, 1999). In particular, task-technology fit was a significant positive determinant of perceived usefulness for information technology (Klopping & McKinney, 2004; J.-H. Wu et al., 2007). That is, as task-technology fit increased so did perceived usefulness of an information technology. The factors of the

Task-Technology Fit Model have yet to be applied to robot acceptance, but it is a broad model that can be customized for different tasks and technologies (Fruneaux, 2012).

Perceived Ease of Use

Perceived ease of use was not only a determinant of attitudinal acceptance but also of perceived usefulness, which mediated perceived ease of use's influence on acceptance of robots and information technologies (Davis, 1989; Heerink et al., 2010a; King & He, 2006; Sun & Zhang, 2006b; Venkatesh & Bala, 2008). Assuming the performance of a task is relevant, a technology that seemed easier to use may seem more useful because the technology required less effort (Davis, Bagozzi, & Warshaw, 1992). The effect of perceived ease of use on perceived usefulness strengthens with increased experience with information technologies (Davis et al., 1989; Venkatesh & Bala, 2008). It is unknown whether this relationship strengthens with increased experience with personal robots.

<u>Determinants of Ease of Use</u>

In the Smarr et al. (2013) framework, five factors impact the perceived usefulness of a personal robot: robot anxiety, trialability, perceived sociability, perceived enjoyment, and task-technology fit (Figure 1.1). Selection of these five factors was based on the Almere Model (Heerink, Krose, Evers, & Wielinga, 2010a), TAM3 (Venkatesh & Bala, 2008), diffusion of innovation theory (Rogers, 2003), and Task-Technology Fit Model (Goodhue, 1995; Goodhue & Thompson, 1995).

Robot Anxiety

Robot anxiety is the degree to which an individual is apprehensive when he or she is faced with the possibility of using robots (adapted for robots from Simonson, Maurer, Montag-Torardi, & Whitaker, 1987). Greater anxiety toward a technology was found to negatively impact attitudinal acceptance through perceived ease of use in TAM3 (Venkatesh, 2000; Venkatesh & Bala, 2008) and in the Almere Model (Heerink et al., 2010a). Anxiety is a general belief that an individual holds without necessarily using a robot and can "anchor" a person's initial perceptions of ease of use for using the system (Venkatesh & Bala, 2008).

Anxiety has a significant, negative effect on perceived ease of use and attitudinal acceptance of robots (Heerink et al., 2010a). Anxiety's negative effect on perceived ease of use may be explained from the perspective of resource allocation theory (e.g., Kanfer, Ackerman, & Murtha, 1994). That is, the negative emotion takes up some of the limited attentional resources that people have to devote to the task at hand, thereby increasing the effort needed to complete a task and decreasing perceived ease of use.

Anxiety may be particularly relevant to robot acceptance at this time in history, because robots are a radical technology and people feel more uncertain or anxious about radical innovations than incremental innovations (Rogers, 2003). Similar to how people's views of computers have changed since their introduction, if robots become more commonplace in people's lives, the effect of anxiety on perceived ease of use and acceptance may diminish. Moreover, the impact of anxiety on perceived ease of use decreased with increased experience with a specific technology (Venkatesh & Bala, 2008; Venkatesh et al., 2003). With increasing experience, users may develop more certainty in the effort needed to accomplish tasks thereby decreasing levels of anxiety (Venkatesh & Bala, 2008).

Trialability

Trialability was a determinant of perceived ease of use in the Smarr et al. (2013) framework. Trialability is defined as "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2003, p. 16). Innovations that were more trialable were adopted more often than innovations that were less trialable according to diffusion of innovation theory and research (Rogers, 2003). Yet, trialability was not consistently related to adoption or implementation of innovations (Tornatzky & Klein, 1982).

Lack of experience with technologies may be a reason for people to feel uncertain about using them (Forlizzi et al., 2004). In the minds of potential users, knowing about a technology (e.g., a robot) creates uncertainty about the consequences of using it (Rogers, 2003). To reduce that uncertainty, people seek out and process additional information through direct experience (e.g., using the robot for a trial period), talking with people in their personal social network (e.g., friends), and mass media (e.g., television, newspaper; Rogers, 2003). After uncertainty was reduced from acquiring additional knowledge, trialability may have been less important for more experienced users (Karahanna et al., 1999).

Trialability's influence on perceived ease of use and acceptance of personal robots has not been systematically examined in the HRI literature. A "trial run" of using the robot may influence an individual's perceptions of ease of use with a robot, which could potentially increase his or her attitudinal acceptance (Stafford et al., 2010; Weiss, Bernhaupt, Tscheligi, & Yoshida, 2009). That is, using a robot allows a person to gain direct experience with the robot, which gives him or her more information to evaluate how easy or difficult it is to use the system (Venkatesh & Bala, 2008). As such, the trialability of a personal robot could be used to adjust an individual's initial perceptions of ease of use of a robot.

Trialability may be particularly important while robots are considered a radical technology and attitudes are particularly important for acceptance (Karahanna et al., 1999). Moreover, after individuals interacted with a robot for a few minutes, their emotions became significantly less negative (Broadbent et al., 2010; Stafford et al., 2010). Thus, having direct experience with a robot performing a task even during a trial period may increase attitudinal acceptance of the robot through perceived ease of use.

Perceived Sociability

For the Smarr et al. (2013) framework, a social robot is "an autonomous or semi-autonomous robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact" (Bartneck & Forlizzi, 2004b, p. 592). This definition was chosen because it covered a range of purposes of personal robots and levels of social intelligence without requiring the robot to have human-like social intelligence, which is unlikely for many years. For a robot to be perceived as social, it must have some level of form, communicability, knowledge of social norms, autonomy, or interactivity (Bartneck & Forlizzi, 2004b). Perceived sociability is the degree to which an individual interprets the robot as able to perform behavior that is social (Heerink, Kröse, Evers, & Wielinga, 2010a).

Designing robots to display and understand sociabilities that occur between humans may facilitate HRI. As experts in human-human social interaction, people can apply their existing knowledge of human social models to their interaction with robots (Breazeal, 2003b, 2004; Fong et al., 2003; Rogers, 2003). Thus, a robot with sufficient sociability could make interacting with it seem easier to the user (Heerink, Kröse, Wielinga, & Evers, 2009) because it allows him or her to use existing knowledge (e.g., social models of human-human interaction) or is sufficiently compelling that he or she does not perceive the interaction as effortful (e.g., toy robots; Fong et al., 2003). It remains to be seen if perceived sociability is a determinant for perceived ease of use as this relationship has not been the focus of robot acceptance research.

Also, perceived sociability of robots has been found to significantly predict higher levels of perceived enjoyment within the Almere Model (Heerink et al., 2010a) which may be because more social robots were more engaging or interesting to interact with than less social robots (Heerink et al., 2010a; Heerink, Kröse, Wielinga, & Evers, 2009; Looije et al., 2010). This relationship should be investigated in the future to understand why perceived sociability predicts perceived enjoyment.

Perceived Enjoyment

Perceived enjoyment was a positive determinant of perceived ease of use in the Smarr et al. (2013) framework. Perceived enjoyment is the degree to which using a technology is "perceived to be enjoyable in it's [*sic*] own right, apart from any performance consequences that may be anticipated" (Davis et al., 1992, p. 1113). It was seen as a form of intrinsic motivation whereas perceived usefulness, for example, was seen as extrinsic motivation (Davis et al., 1992). Intrinsic motivation means there is no obvious reinforcement other than performing the activity (Ryan & Deci, 2000). Extrinsic motivation is achieving some valued outcome that is separate from the task itself (e.g., payment; Ryan & Deci, 2000). In general, perceived enjoyment positively affected acceptance of robots (Chesney, 2006; Heerink et al., 2010a; Heerink, Kröse, Wielinga & Evers, 2008; Young et al., 2011) and information technologies (Davis et al., 1992; Van der Heijden, 2004).

The direction of causality between perceived enjoyment and perceived ease of use was inconsistent in the technology acceptance literature. Some researchers supported perceived enjoyment as a determinant of perceived ease of use (e.g., Almere Model, TAM3; Heerink et al., 2010a; Sun & Zhang, 2006a; Venkatesh, 2000; Venkatesh & Bala, 2008), because an individual who enjoys what he or she is doing underestimates the difficulty of using the system (Venkatesh, 2000). In contrast, other researchers support perceived ease of use as a determinant of perceived enjoyment (Chesney, 2006; Davis et al., 1992; Van der Heijden, 2004) because a system that seems easier to use is more likely to be perceived as enjoyable to use (Teo, Lim, & Lai, 1999).

Perceived enjoyment was a determinant of perceive ease of use in the Smarr et al. (2013) framework for two reasons: (1) people who enjoyed interacting with a robot perceive a robot as easier to use (Heerink et al., 2010a); and (2) when perceived ease of use as a determinant of perceived enjoyment was assumed, perceived enjoyment did not fully mediate the effect of perceived ease of use on acceptance of information technologies (Igbaria et al., 1995; Teo et al., 1999).

Task-Technology Fit

Task-technology fit was a significant positive determinant of perceived ease of use of virtual agents and information technologies (Chang, 2008; Dishaw & Strong, 1999; Klopping & McKinney, 2004) in the Smarr et al. (2013) framework. That is, a technology that seems easier to use is likely to have a greater task-technology fit because the technology is compatible with completing tasks. This relationship has yet to be investigated with acceptance of personal robots so it is unclear if current findings with other technologies will generalize to personal robots.

Determinants of Task-Technology Fit

Task-technology fit is a match between technology capabilities, task requirements, and individuals' abilities (Goodhue, 1995). Robot factors and task factories were the two main determinants of task-technology fit in the Smarr et al. (2013) framework. Individuals' abilities were not included in the framework because they have not been reliably shown to impact robot acceptance beyond what can be explained by an individual's experience with a robot (see Smarr et al., 2013 for a discussion). In general, greater task-technology fit improves performance and acceptance of a human-technology system (Dishaw & Strong, 1999; Goodhue, 1995; Goodhue & Thompson, 1995). If a technology cannot handle the requirements of a task, then task-technology fit decreases (Dishaw & Strong, 1999).

Although much of the technology acceptance research has been conducted with information technologies in the workplace, the Task-Technology Fit Model is a broad framework that can be customized to other technologies and tasks (Fruneaux, 2012). The factors of the Task-Technology Fit model have yet to be applied to robot acceptance.

Task characteristics, robot characteristics, and task-technology fit were used in the Smarr et al. (2013) framework to better account for how the task and technology impact acceptance of personal robots.

Task Factors

It is important to consider the task a robot performs, because it can affect perceived usefulness and attitudinal acceptance of a robot (Broadbent et al., 2011; Cesta et al., 2011; Ezer et al., 2009a). Task factors were a significant negative determinant of task-technology fit (Dishaw & Strong, 1999). That is, as task demands increase and technology capabilities remain the same, the task-technology fit decreases (Dishaw & Strong, 1999). Task factors identified as important for personal robot acceptance came from the HRI literature (e.g., criticality, interaction level between the user and the robot, task type). See Smarr et al. (2013) for robot factors that have been considered important for HRI.

Robot Factors

Technology characteristics were significant positive determinants of task-technology fit (Dishaw & Strong, 1999). As technology functionality increases, task-technology fit also increases (Dishaw & Strong, 1999). Robot factors identified as important for personal robot acceptance were based on robot acceptance and HRI literatures (e.g., adaptivity, appearance, method of control, usability, reliability). See Smarr et al. (2013) for robot factors that have been considered important for HRI.

Scope and Limitations of Framework

In this section, the scope of the Smarr et al. (2013) framework of personal robot acceptance has been highlighted. Personal robots have been included within the framework because of their potential for assisting people with everyday living tasks and entertainment. Additionally, personal robots are currently in use by people with over 2.5 million personal robots sold in 2011 alone (IFR Stat Dept, 2012).

The scope of the Smarr et al. (2013) framework included adults from individualistic cultures with limited to no formal training in robot usage, who have discretionary usage of a robot. Children were not included because they do not have the authority and financial means to accept robots without another person predominantly determining this for them whereas adults do. Inherent to their purpose and operational settings, personal service robots will likely interact with individuals with a range of robot training, many without robot usage training (Thrun, 2004).

Different cultures can have different factors that are important for acceptance (Straub, Keil, & Brenner, 1997). In general, culture can be thought of as two types: individualistic and collectivist. Individualistic cultures focus on personal achievement at the expense of group goals whereas members of a collectivist culture focus on group goals above individual interests. Collectivist cultures (e.g., Chinese, Japanese) are outside the scope of the framework because much of the research on acceptance of personal robots has been conducted with individualistic cultures (e.g., Dutch, New Zealanders, Americans).

Lastly, the user group in the Smarr et al. (2013) framework has discretionary usage of a robot (i.e., the freedom to decide to use a robot; Rawstorne, Jayasuriya, &

Caputi, 1998) because users are unlikely to be required to use a personal robot. Discretionary versus mandatory usage of a technology can change what factors are important, what relationships are important, and the extent of the technology use (Ghazizadeh, Lee, & Boyle, 2012; Venkatesh et al., 2003). For example, social norm (i.e., the influence of peers on an individual) is significant for acceptance in mandatory use settings but not in discretionary use settings (Ghazizadeh et al., 2012; Venkatesh et al., 2003).

Additionally, the Smarr et al. (2013) framework focused on the simplest form of human-robot interaction (i.e., interactions between one human and one robot at any point in time). One reason was that the ratio of humans to robots and the composition of robot teams changed the interaction between humans and robots (Yanco & Drury, 2004), which may be likely to affect robot acceptance. Additionally, different human-robot team compositions had different requirements and outcomes inherent to their interactions (Yanco & Drury, 2004).

The Smarr et al. (2013) framework applied to non-professional tasks performed in non-professional settings because it was limited to personal robots. Personal robots assist with personal tasks, whereas professional service robots assist with job tasks (Thrun, 2004). Additionally, personal tasks may require different knowledge and abilities from the robot than job tasks, which often necessitate formal training in the domain, licensures, or specialized skills from both the human and the robot (e.g., surgery, bomb diffusion; Decker et al., 2011). Non-professional environments (e.g., home) were chosen because factors influencing technology acceptance in the home differed from those that influenced technology acceptance in the workplace (Venkatesh & Brown, 2001).

Technology use in the home is different from professional environments because of the variety of people involved in making decisions, the purposes for purchasing technology, as well as the way in which technology is used (Brown, Venkatesh, & Bala, 2006; Venkatesh & Brown, 2001).

Next Steps for Testing Framework

Although the Smarr et al. (2013) framework is theoretically based, it has yet to be empirically tested with people to determine its appropriateness. Evaluation of the Smarr et al. (2013) framework is an important next step to understand if it applies and explains people's actual attitudes, intentions, and behaviors toward accepting personal robots. Therefore, two studies have been conducted to begin to evaluate the ground truth of the framework.

The first study was a usage study to understand the depth of personal robot acceptance through qualitative and quantitative measurements. In this study, 14 participants interacted with a personal robot at their homes for about six weeks. Their attitudinal, intentional, and behavioral acceptance was measured through interviews, questionnaires, a weekly diary, and usage logs.

The second study was designed to understand the breadth of the framework through quantitative measurements. A large-scale online survey study was conducted to measure participants' initial attitudinal and intentional acceptance after learning about a personal robot. The personal robot's level of reliability and communication of feedback was manipulated to understand how that impacts acceptance.

Robot Factors

Characteristics of the robot and how they relate to acceptance are particularly important to study at this point to be able to provide informative guidance for design of future robots as well as to inform acceptance theory. Two robot factors that have the potential to impact personal robot acceptance but need to be research further are reliability and communication of feedback.

Reliability

Personal robots are currently not perfectly reliable and are likely to become so in the near future. That is, personal robots make errors in performing tasks they were designed to perform. For example, a robot vacuum cleaner did not avoid an obstacle it was designed to avoid. The reliability of non-robotic technologies (e.g., automated systems) can impact the way they are used and users' perceptions of them (Beck, Dzindolet, & Pierce, 2007; Dixon & Wickens, 2006; Madhavan, Wiegmann, & Lacson, 2006; Sanchez, Fisk, & Rogers, 2004). Likewise, the reliability of a personal robot is important to understand because it has the potential to influence how individuals use and perceive robots. Yet, robot reliability has been largely overlooked in HRI research (Nielsen, Bruemmer, Few, & Gertman, 2008).

In a recent study, Komatsu et al. (2012) verbally instructed participants either that a robot could tell them the correct position of a coin in a video game 10% (low expected reliability group) or 90% of the time (high expected reliability group). During an exploration phase, participants played the video game with feedback (but no robot) for 40 trials. During the test phase, participants used the video game with the robot (but no feedback) for 20 trials. Participants' behavioral acceptance (i.e., the number of times they complied with the robot's advice) was measured during the test phase. The actual reliability of the robot was about chance (33%). The low expectation group had significantly higher behavioral acceptance (compliance) of the robot (M = 52%) than the high expectation group (*M* = 28.5%). The findings from this study suggested that the expected reliability of a robot can influence people's use of a robot.

Sung et al. (2010) found that reliability was a major theme in participants using robot vacuum cleaners (i.e., iRobot Roombas) in their homes for six months. Participants reported expecting a certain level of reliability from the robot because of its cost and it replaced a previous technology with a high level of reliability (e.g., a standard vacuum cleaner). Moreover, one household (out of 30) stopped using a robot vacuum cleaner because of "frequent technical failures" even though they report being satisfied with its cleaning quality (Sung et al., 2010, p. 424). Additionally, people report in interviews and surveys being concerned about using robots because of the robot's lack of reliability in performing tasks correctly within an environment (Beer, Smarr, et al., 2012; Broadbent, Kuo, Lee, et al., 2010; Broadbent, Tamagawa et al., 2011). Taken together, findings from these studies imply that a robot's lack of reliability could be a potential barrier to continued or initial acceptance of a robot.

In contrast, a study by Eimler et al. (2011) found that 38 participants who saw a rabbit robot commit errors did not differ in their ratings of perceived usefulness and ease of use as compared with 15 participants who did not see a robot commit errors. However, participants rated the robot as having low usefulness and moderate ease of use. This would suggest that reliability may not influence participants' perceptions of robot. However, findings should be interpreted with care, because participants may have thought the robot was not useful regardless of errors combined with inappropriate statistics.

It is unclear from the HRI literature how a personal robot's reliability affects acceptance. Insight may be gleaned from how reliability of other technologies or systems affects their use. From the literature on automated systems, automation reliability can affect human-system performance (Bliss, Dunn, & Fuller, 1995), the use of the automation (e.g., Beck et al., 2007; Dixon & Wickens, 2006), and users' perceptions of the system (Madhavan et al., 2006; Sanchez et al., 2004). An automated system is defined as the "machine execution of […] functions that at one time could only be performed by humans" (Parasuraman, Sheridan, & Wickens, 2000, p. 286). Although there are exceptions, people tend to appropriately use (or depend on) a reliable system more (Bliss et al., 1995); have better human-system performance compared to manual performance (Dixon, Wickens, & Chang, 2005; Maltz & Shinar, 2004); and have more positive perceptions (e.g., perceived reliability, trust; Sanchez et al., 2004).

A person's perception of the reliability of an automated system (i.e., perceived reliability) is formed initially through expectations of an automated system. Expectations of reliability can impact how much a person appropriately uses (or depends) on an automated system (Wickens & Xu, 2002). Expectations can guide attention and information selection (Bowers, Oser, Salas, & Cannon-Bowers, 1996) because people tend to look for information that confirms their expectations (e.g., Jamieson, Lydon, Stewart, & Zanna, 1987).

In study 2 of the current investigation, a personal robot's reliability was manipulated in a text description. Reliability was investigated as a between-subjects variable in three levels: (1) no information about the robot's reliability; (2) the robot was 70% reliability; and (3) the robot was 90% reliability.

The latter two levels of reliability were chosen based on the automation literature as reliability in the HRI literature is under-researched. Seventy percent reliability was selected because it was at the threshold of people using an automated system (Wickens & Dixon, 2007). People generally regard automation that is less than 70% reliable worse than no automation at all (Wickens & Dixon, 2007). In selecting 70% reliability, people are likely to perceive the robot mower as having low reliability but also as something they may still use. In the only other study that manipulates a robot's reliability in a one robot-one human interaction, the low reliability level was 10% (Komatsu et al., 2012), which was inappropriate for the current study because participants are unlikely to want to use the robot.

Ninety percent was selected as the high robot reliability level in this study because it was commonly used as high reliability in automation research and was used in Komatsu et al. (2012). There was evidence that people behave differently using systems that are 70% versus 90% reliable (Wickens & Dixon, 2007). Perfect reliability was not chosen as a level, because personal robots (e.g., robot mower) are not currently perfectly reliable. Moreover, they are unlikely to become perfectly reliable in the future, because they interact with untrained users within dynamic, unstructured environments (Schraft et al., 1993; Thrun, 2004).

Although findings from the automation literature can provide a place to start in HRI research, it may not adequately explain acceptance of robots because robots differ in several ways from other technologies (e.g., automated systems, information technologies). In the next section, personal robot's communication of feedback with the context of robot acceptance has been discussed.

Communication of Feedback

The level of communication of feedback was an important consideration in acceptance of personal robots (Young et al., 2009). Scholtz (2003) posited that there were five roles human users have when interacting with, or using, robots (i.e., supervisor, teammate/peer, operator, bystander, and mechanic). In terms of the human, each role differs in the knowledge, information, and expertise individuals are required to have, their permissions with the robot, their goals, proximity to the robot, and their level of interactions with the robot (Scholtz, 2003).

Perception of a robot's current state was particularly important for users in a supervisor role (Scholtz, 2003). The supervisor role was particularly important to study with personal robots, because many of the personal robots currently on the market (e.g., robot mowers) are designed to interact with the user in the supervisor role. The supervisor monitors and controls the overall situation (i.e., the big picture) to keep the robot on track for goal completion (Scholtz, 2003). Supervisors need to know what the current behaviors of a robot are so he or she can intervene or modify the robot's behavior and/or goals (Scholtz, 2003). Despite communication of feedback being potentially important for facilitating individuals' use of personal robots, it has been largely overlooked within the area of personal robot acceptance.

In study 2 of the current investigation, the robot mower's level of communication of feedback was manipulated via a text description. Communication was investigated as a between-subjects variable in three levels: (1) no information about the robot mower's communication abilities; (2) one-way communication from user to robot (no feedback from mower to user); and (3) two-way communication between user and robot.

The latter two levels of communication were based on the automation literature; communication in the human-robot interaction literature has been under-researched, especially in robots not designed for face-to-face conversations with humans. In the human-automation interaction literature, lack of appropriate feedback about the state of automation has been linked to accidents (Sheridan & Parasuraman, 2005). Feedback that was not salient can negatively affect the user's understanding of the automation's behaviors, decrease overall performance, or contribute to accidents (Sheridan & Parasuraman, 2005). A system that provided explicit feedback and increased observability of its states facilitated human-automation cooperation, which benefited overall performance (Skjerve & Skraaning, 2004). For these reasons, it is expected in the current research that individuals have lower acceptance when feedback is less salient (i.e., one-way communication) compared to more salient (i.e., two-way communication). Despite communication of feedback's potential importance in robot acceptance, these relationships have largely been overlooked in the literature.

Interaction of Reliability and Communication of Feedback

The interaction of a robot's level of communication of feedback and reliability could potentially impact robot acceptance. Communication of feedback has also been important for collaboration of technologies and their users. In fact, accidents related to feedback about system state provided by automation were one of the top 5 automation-related issues (out of 100+) in aviation (Funk et al., 1999). Feedback has been one way to facilitate an individual's perception of a system's current state.

Supervisors need to know the robot's current state – especially any deviations or errors – so they can change or intervene in the robot's behavior (Scholtz, 2003). Otherwise, the user may not know that the robot had erred (e.g., battery died), for example, and is no longer working to achieve its goals (e.g., mowing the lawn). Consequently, participants may perceive the robot as less useful and in turn, be less accepting, because the robot's current state has not been communicated appropriately and hindered goal completion.

If a robot's communication of feedback positively impacts the acceptance of a personal robot that has less than perfect reliability, then this may be valuable for not only robot acceptance theory but also for designers of robots. In particular, personal robots are not perfectly reliable and are unlikely to be so because of the unstructured environments (e.g., homes) they operate in and the range of people with whom they interact. Designing a robot with appropriate or salient communication of feedback could help personal robots that are less reliable be more accepted than robots with less salient feedback. That is, robots that are less than 100% reliable still have the potential to help people live safer, more efficient and comfortable lives. Although a robot that is less than perfectly reliable may not be ideal, the benefits of using the robot (e.g., more time and energy to pursue other interests) may outweigh the robot's lower reliability.

Summary of Robot Factors

In sum, knowledge of the impact of robot factors on individuals' acceptance can inform not only theory about important factors in robot acceptance, but can also help guide robot designers in developing acceptable personal robots. Robots factors, such as level of reliability and communication of feedback, could impact how people use, or accept, personal robots. Personal robots are not perfectly reliably and are unlikely to become so anytime soon. Reliability of robots (Komatsu et al., 2012; Sung et al., 2010) and other systems (Beck, Dzindolet, & Pierce, 2007; Dixon & Wickens, 2006; Madhavan et al., 2006; Sanchez et al., 2004) can influence the way robots and other systems are used and users' perceptions of them.

The level of communication of feedback may be important to consider in acceptance of a personal robot (Young et al., 2009). Many personal robots have been designed to interact with humans in a supervisor role (Scholtz, 2003). Supervisors control and monitor the overall situation so the robot's goals are completed so communication of the robot's current state is necessary (Scholtz, 2003). Communication of errors was particularly important for use of a technology because lack of appropriate or salient feedback can negatively impact the users' understanding of the technology's behavior and has been associated with accidents (Sheridan & Parasuraman, 2005). Moreover, explicit feedback has been shown to facilitate human interaction with technology (Skjerve & Skraaning, 2004). Personal robots' level of communication of feedback could potentially impact users' perceptions of them (e.g., perceived usefulness) and their use, or acceptance.

The interaction of a robot's level of reliability and communication of feedback could theoretically impact personal robot acceptance. Currently, robots are not perfectly reliable but they may still be beneficial for their users. That is, an imperfectly reliable personal robot (< 100% reliability) could be more likely to be accepted if the robot has sufficient communication of feedback, especially when it errs. Despite reliability and communication of feedback's potential influence robot acceptance, more research is needed to investigate how robot reliability and communication of feedback impacts acceptance of personal robots. The goal of study 2 of this dissertation was to begin to understand the impact of a personal robot's reliability and communication of feedback impact acceptance.

Robot Lawn Mower

Millions of personal robots have been sold to, and presumably used by, individuals each year (IFR Stat Dept, 2012). One type of personal robot increasingly being sold is robot lawn mowers, which can autonomously cut grass. Robot mowers have mainly been sold in parts of Europe and were estimated to be an approximately $170 million market by the end of 2012, which was an increase of 30% from 2011 (Kinnander, 2012). The market for robot mowers grew at 15 times the rate of conventional mowers in Europe and accounted for approximately 6% of all lawn mowers sold in Germany in 2012 (Kinnander).

The Deere Tango E5 is one of the robot mowers being sold. The Tango typifies many characteristics that are relevant for the current investigations of personal robot acceptance and are within the scope of the Smarr et al. (2013) framework. The Tango is a robot mower that is currently sold and being utilized for personal use. It was designed to autonomously assist people with a personal task (i.e., mowing lawns) in a non-professional setting (i.e., at home). In other words, the Tango is a personal robot. People have discretionary use of the Tango, meaning they have the freedom to choose whether to use the robot. Finally, users do receive some training on how to use the mower from the dealer who sold them the Tango. As such, the current research has used the Tango to understand people's acceptance of personal robots at their homes.

Overview of Studies

The overarching purpose of this dissertation is to begin to understand the factors important for attitudinal, intentional, and behavioral acceptance of personal robots and their relationships. The studies tested a theoretically-based qualitative framework developed by Smarr et al. (2013) as a first step to understand personal robot acceptance. The two studies employed quantitative and qualitative methods to investigate the depth and breadth of individuals' acceptance of personal robots.

Study 1 examined the depth of individuals' personal robot acceptance. Participants used a personal robot (i.e., a robot lawn mower) in their homes for up to six weeks. Participants' attitudinal, intentional, and behavioral acceptance were measured through a combination of interviews, questionnaires, robot mower usage logs, and weekly diaries. The goals of Study 1 were:

1. To measure attitudinal, intentional, and behavioral acceptance of a personal robot at home.
    a. To investigate changes in acceptance over time.
2. To gain a deep understanding of the person, robot, and context factors that are important for acceptance of a personal robot at home before and after use.
3. Conceptually validate the Smarr et al. (2013) framework of robot acceptance.

Study 2 examined the breadth of individuals' personal robot acceptance. A large-scale online survey assessed individuals' initial attitudinal and intentional acceptance of a personal robot (i.e., a robot lawn mower). Two robot factors – reliability and communication of feedback – that potentially impacted individuals' perceptions of a personal robot were manipulated between subjects using text descriptions of a robot. The goals of Study 2 were:

1. To measure initial intentional and attitudinal acceptance of a personal robot used at home.
    a. For three levels of robot reliability (90%, 70%, no information).
    b. For three levels of robot's communication of feedback (two-way, one-way, no information).
2. To determine what person, robot, and context characteristics influence initial attitudinal and intentional acceptance of a personal robot.
3. Statistically validate the Smarr et al. (2013) framework of robot acceptance

CHAPTER 2: USAGE STUDY METHOD

Method

The study described in this section was conducted during the fall of 2013 as part of the author's internship with Deere & Company. Data collection took place from October 2013 to December 2013. This section describes participants, apparatus and materials, and procedures used in the robot mower usage study.

Participants

Seven households of two adults in the Raleigh, NC area participated in study 1 (n = 14). Participants were mostly non-Hispanic, white/Caucasian middle-aged adults (*M* = 51.36 years old, *SD* = 11.58), highly educated, and with relatively high household incomes (most over $125,000/year). Most of them were employed in technical occupations (e.g., computer programmer). See Table 2.1 for more details on participants' characteristics by household. For participating in this study, each household was compensated with a Google Nexus 10 tablet computer, which retailed for approximately $400.

Table 2.1

Usage Study Participant Demographics

House-hold	Gender (Age in Years)	Race	Education	Occupation	Household Annual Income	Household Comp-osition
1	1 male (61) 1 female (59)	2 White/ Caucasians	1 Some college/ Associate's degree 1 Bachelor's degree	Computer programmer Tax analyst	\$175,000-\$199,999	2 significant others
2	1 male (56) 1 female (50)	2 Asians	2 Master's degrees (or other post-graduate training)	Computer programmer Database administrator	Did not wish to answer	2 significant others
3	1 male (57) 1 female (53)	1 Middle Eastern 1 White/ Caucasian	1 Bachelor's degree 1 Master's degree (or other post-graduate training)	2 Managers	\$125,000-\$149,999	2 significant others
4	1 male (55) 1 female (51)	2 *White/ Caucasians	2 Bachelor's degrees	Graphic designer Production artist	\$50,000-\$74,999	2 significant others, **parent, **sibling
5	1 male (58) 1 female (49)	2 White/ Caucasians	1 Some college/ Associate's degree 1 Bachelor's degree	Research & development director Software Manager	\$200,000 or more	2 significant others
6	1 male (60) 1 female (59)	2 White/ Caucasians	1 Bachelor's degree 1 Master's degree (or other post-graduate training)	Business analyst Knowledge engineer	\$175,000-\$199,999	2 significant others
7	1 male (26) 1 female (25)	2 White/ Caucasians	1 Bachelor's degree 1 Master's degree (or other post-graduate training)	Healthcare events manager Structural engineer	\$50,000-\$74,999	2 significant others

*One participant identified as Hispanic or Latino in household 4. The rest of the participants did not identify themselves as Hispanic or Latino.

**Did not participate in this study.

Recruitment

Participants were recruited through referrals and email distribution lists. Each participant had to meet the following criteria to participate:

- Aged 18 years and older
- Does not live with children under 18 years old
- Works full-time (approximately 40 hours/week)
- Not employed by Deere & Company
- Has a section of flat lawn that was at most 0.25 acres
- Does not hire someone outside the household to mow his or her grass

Participants were selected based on the aforementioned criteria to represent individuals who may be likely to use the robot mower in the future. That is, individuals who work full-time and mow their lawns may be likely to use the Tango because they are busy and have disposable income. Participants who have lawns that would allow the Tango to mow well within its limitations of incline and size of lawn were also purposefully selected. The Tango is capable of mowing lawns that have a maximum incline of 20 degrees and are up to 0.4 acres.

Apparatus and Materials

Deere Tango E5

The model year 2013 Deere Tango E5 was the robot lawn mower that was installed in the lawn at each household in the usage study (Figure 2.1) by a trained experimenter to approximate the dealer installation that occurs when someone purchases the Tango. The installations of the mowers were temporary for two reasons: (1) the mowers were returned to Deere & Company at the end of the study; and (2) to minimize damage to participants' lawns. A temporary installation involved securely pegging a boundary wire and charging station to the ground whereas a permanent installation involves digging up part of the lawn and burying wires underground. A boundary wire defined the boundary of each household's lawn within which the Tango mowed. A charging station was also installed along part of the boundary wire so that the Tango could autonomously charge its battery without human intervention.

Figure 2.1 Each participant was asked to interact with this robot lawn mower, the Deere Tango E5.

The Tango had bump sensors and other sensors to detect obstacles, boundaries, and its charging station. It was controlled from a six-line display screen user interface located on the top of the mower (Figure 2.1). From this screen, users could set the Tango's settings (e.g., distance to follow from boundary wire); mode (e.g., mow as scheduled, return to base); and schedule (e.g., days of the week and times to mow). A red, stop button was located near the screen user interface. When the stop button was pressed, the Tango halted its blades and ground motion. More details about the Tango can be found online at http://www.deere.com/wps/dcom/en_INT/products/equipment/autonomous_mower/tango_e5/tango_e5.page.

The seven Tangos used in this study were modified from their original factory condition. A small computer was added to the internal set-up of the Tango to allow for two functions: (1) the logging of mower usage and settings; and (2) the mower to be controlled from a remote user interface on a Google Nexus 10 tablet computer (picture of Tango modification in Appendix A). Although participants were informed of these modifications to the Tango, they were not shown the modifications. Nothing about the external appearance of the Tango was changed.

The Tangos used software version 3.1.0 for the first 2 weeks of the study. The software was updated to version 3.4.0 between weeks 2 and 3, because most participants reported issues with the Tango mowing according to its schedule and connecting with the Nexus 10 tablet. Participants were informed via email that the researcher was working with Deere to resolve the scheduling and tablet connection issues after week 1. After the Tangos' software were updated, participants were emailed during week 3 that the issues should now be resolved but that their ability to change the Tango's mowing mode from the Nexus 10 was no longer available.

The usage log on the Tango recorded participants' objective behavioral acceptance (or use) of the Tango. However, due to technical issues with software and hardware (e.g., SD card failures, software updated), usage was only recorded sporadically during weeks 3-6. Therefore, the usage data will not be analyzed in detail. The usage log is available upon request from the author, because the log file is very large.

<u>Pre-Use Interview Materials</u>

The interview consisted of questionnaires and group interviews between one researcher and the two members of the household participating in this study (details in Table 2.2). See Appendix B for materials used in the Pre-Use Interview.

Table 2.2

Description of the Materials Used During the Pre-Use Interview

Material	Purpose(s)	Data Collection Method	Constructs measured	Adapted from
Experimental Equipment Form[1]	Deere & Company form to borrow experimental equipment.	Form	Not applicable	Not applicable
Robot Experience Questionnaire	To describe participants' familiarity with and usage of 14 different robots.	Questionnaire	Robot experience	Smarr et al., 2014
Pre Lawn Questionnaire	To describe characteristics of participants' lawns. To assess participants' attitudes' toward their lawn, including how satisfied they were with their regular lawn care and how important lawn care was to them.	Questionnaire	Lawn characteristics Attitudes toward lawn care before using the Tango	Not applicable
Pre-Use Interview: Lawn and Robot Mowers	To collect information on participants' current lawn care routines and knowledge of robot mowers.	A group interview with one researcher and the two participants living in the same household. It was audio recorded.	Current lawn care routines Robot mower knowledge and experience	Not applicable
Training	To guide training the participants on how to use the Tango safely, the Nexus 10, and the Tango tablet application.	Not applicable	Not applicable	John Deere University Tango course for dealers. Installation manual for dealers. Operator's manual.

Table 2.2 continued

Material	**Purpose(s)**	**Data Collection Method**	**Constructs measured**	**Adapted from**
Pre-Use Interview: Tango	To assess participants' expectations, attitudes, and intentions for using the Tango at their homes.	A group interview with one researcher and the two participants living in the same household. It was audio recorded.	Expectations for using Tango Attitudes toward Tango Intentional acceptance of Tango	Not applicable
Pre Robot Mower Opinions Questionnaire	To assess attitudinal acceptance, intentional acceptance, and the human, robot, and context factors important for acceptance of a Tango.	Questionnaire	Attitudinal acceptance of Tango Intentional acceptance of Tango Human, robot, and context factors important for acceptance of Tango[2]	Ezer, 2008 Ezer, 2008 See Appendix C

[1] Deere & Company has the names of the participants in this study. Deere does not have access to participants' raw data. Data were combined across participants and were not presented or reported in a personally identifying way.
[2] The human, robot, and context factors were selected as important for acceptance of personal robots based on a thorough review of the technology acceptance, robot acceptance, and human-robot interaction literatures (see Smarr et al., 2013 for details). Appendix C contains the factors measured in this study, the items used to measure the factors, and if applicable, where items were adapted from.

Usage of Tango Materials

During usage of the robot, participants' attitudinal and self-reported behavioral acceptance of their Tangos were measured in a weekly diary. The purposes of the weekly diary were to describe the nature of the interaction between the human and the robot mower as well as to investigate attitudinal and behavioral acceptance over time.

Participants were asked to complete a diary once a week instead of after every interaction with the Tango so more in-depth questions could be asked while mitigating a potentially low response rate. See Appendix D for the diary items.

The diary consisted of up to 39 multiple-choice and free response items, depending on whether participants performed certain behaviors or had difficulties. Participants were instructed to respond while thinking about using the Tango and its remote user interface within the past week. Questions assessed participants':

- self-reported use of the robot which informed subjective behavioral acceptance as well as why they used (or did not use) the Tango. These questions measured self-reported behavioral acceptance of the Tango as well as why and under what conditions they interacted with the robot.
- positive aspects of using the Tango
- negative aspects of using the Tango
- self-reported observation of the robot, why they observed the robot, when they observed the robot, and who they observed the robot with (if anyone)
- if any difficulties occurred using the Tango, what the difficulties were, and how they were overcome
- attitudes toward the Tango
- perceived usefulness and ease of use of the mower
- self-reported use of the remote user interface which informed subjective behavioral acceptance of using the remote user interface as well as why they used (or did not use) it
- positive aspects of using the remote user interface
- negative aspects of using the remote user interface
- if any difficulties occurred using the remote user interface, what the difficulties were, and how they were overcome
- participant code
- if planning on emailing pictures to an experimenter

The format of the diary was determined by each participant's preference for either paper format or electronic format (i.e., Google form). All households chose the electronic format except for household 3, who chose the paper format. The diary questions were the same across the two formats. Participants were not asked to put personally identifying information (e.g., name) but to respond using a code determined by participants' favorite color and season (e.g., Orange Autumn).

To mitigate potential memory limitations, an experimenter reminded participants to fill out their diary every week. Reminders were sent according to each participant's preferred format (e.g., email, phone call). All participants preferred to be reminded via email. At least two reminders were emailed to each participant each week. The first reminder was emailed at 9:00am the day before the diary was due. The second reminder was emailed at 9:00am the day the diary was due. If a participant failed to complete the diary by its due date, then additional reminder emails were sent.

Post-Use Interview Materials

The purpose of the interview conducted after the usage period of the Tango robot mower was to measure the change in attitudinal and intention acceptance, as well as human, robot, and context factors important for acceptance from before using to after using the Tango robot.

Similar to the Pre-Use Interview, the Post-Use Interview consisted of questionnaires and group interviews between one researcher and the two members of the household participating in this study (details in Table 2.3). See Appendix E for materials used in the Post-Use Interview.

Table 2.3

Description of the Materials Used During the Post-Use Interview

Material	Purpose(s)	Data Collection Method	Constructs measured	Adapted from
Demographic and Health Questionnaire	To describe participants' demographics, and general health and activity limitations.	Questionnaire	Demographics Health	Ezer, 2008
Technology Experience Profile	To assess participants' use of different technologies	Questionnaire	Technology experience	Barg-Walkow, Mitzner, & Rogers, 2014
Post Lawn Questionnaire	To assess participants' attitudes' toward their lawn, including how satisfied they were with the Tango mowing their lawn.	Questionnaire	Attitudes toward lawn care after the Tango	Not applicable
Post-Use Interview	To assess participants' attitudes and experiences using the Tango at their home. To assess intention to purchase Tango and reasons why or why not.	A group interview with one researcher and the two participants living in the same household. It was audio recorded.	Attitudes toward Tango Experiences with Tango Intentional acceptance of Tango	Not applicable
Post Robot Mower Opinions Questionnaire[1]	To assess attitudinal acceptance, intentional acceptance, and the human, robot, and context factors important for acceptance of a Tango.	Questionnaire	Attitudinal acceptance of Tango Intentional acceptance of Tango Human, robot, and context factors important for acceptance of Tango[2]	Ezer, 2008 Ezer, 2008 See Appendix C

[1] Same questionnaire as used in the Pre-Use Interview except verb tense was changed from future to past tense.

[2] The human, robot, and context factors were selected as important for acceptance of personal robots based on a thorough review of the technology acceptance, robot acceptance, and human-robot interaction literatures (see Smarr et al., 2013 for details). Appendix C contains the factors measured, the items used to measure the factors, and if applicable, where items were adapted from.

Procedure

Participants were tested at their homes. An experimenter asked participants to take them to a quiet place at their homes to fill out questionnaires and to be interviewed. The installation of the Tango and the training to use the Tango took place in the participants' lawns.

Pre-Use Interview

The Pre-Use Interview lasted approximately 3 hours. After signing consent forms, participants completed a form to borrow experimental equipment from Deere & Company. They were then asked to complete the robot experience and pre lawn questionnaires. Next, the two members of a household were interviewed together in a group setting by one researcher about their current lawn care routines and knowledge of robot mowers. The participants were told there were no right or wrong answers and that their answers would not be linked back to them individually. They were audio recorded during the interview.

Participants then helped a researcher install the Tango in their lawn and were trained to use it. They were also trained to use the Nexus 10 tablet and the Tango application remote user interface. During installation and training, participants watched the Tango mow for a few minutes. Installation of the Tango occurred as detailed for households 1-4. However, installation of the Tango took place at the beginning of the Pre-Use Interview for households 5-7 instead of in the middle of the interview because of participants' scheduling limitations during daylight.

Next, participants were again interviewed and audio recorded in a group setting. They were asked about their attitudes toward the Tango and their expectations for using it, as well as their intention to buy a Tango, if it were available. Participants were then asked to complete the pre robot mower opinions questionnaire. Participants were asked to use the robot mower, if they chose, according to operating and safety instructions.

Finally, a researcher reviewed written instructions with the participants on what to expect next and how to get help if participants had any questions or issues. Participants were reminded to complete a weekly diary, to take any relevant pictures/video, and that the Tango would collect data on its usage and settings. Participants were also asked if a researcher could come into their lawns periodically during the study to see if the Tango was still working properly.

Usage of Tango

Participants had the opportunity to use (or not to use) the Tango at their homes for up to 6 weeks. The Tango's usage and settings were logged during this time period. A researcher reminded participants to complete their weekly diaries via email. Participants completed their weekly diaries in their preferred format (i.e., electronic or paper). Participants, who chose the electronic format, submitted their diary as they completed it. Participants who chose the paper format submitted their diaries to a researcher during the Post-Use Interview. If a participant contacted a researcher for help, the date and time of contact, and their participant code, questions, issues, and resolution were recorded. Personally identifying information was not recorded in the weekly diary, the Tango's usage log, or in the researcher's help log.

Post-Use Interview

During the two-hour long Post-Use Interview, participants were asked to complete a demographics and health questionnaire, technology experience profile, and post lawn questionnaire. Next, participants were interviewed in a group setting by a researcher about their attitudes toward using the Tango, their experiences, and their intention to buy a Tango, if available. Participants were asked to complete the post robot mower opinions questionnaire. Participants were debriefed and thanked.

A researcher obtained any pictures or videos taken of the Tango from the participants and uninstalled the mower. A researcher performed a factory reset on the Nexus 10 tablet and returned the tablet to the participants as compensation for their participation.

CHAPTER 3: USAGE STUDY ANALYSES, RESULTS, AND DISCUSSION

Overview of Analyses

Quantitative

Descriptive statistics were conducted using Microsoft Excel 10 and Excel 2007. Statistical tests were conducted using IBM SPSS Statistics 21 and 22. Unless noted otherwise, alpha was set at $p < .05$ for all statistical tests. Bonferroni corrections were applied when appropriate to control for type 1 error.

Qualitative

The Pre-Use Interview, weekly diaries, and Post-Use Interview contained qualitative data. The interviews were transcribed verbatim from digitally recorded audio files; this step was unnecessary for the weekly diaries. Three coding schemes were developed to better understand acceptance of personal robots. Table 3.1 contains more details about the development of coding scheme and intercoder agreement. The coding schemes with definitions are in Appendixes F-H.

A primary coder and a secondary coder independently coded diaries using Excel and coded interview transcripts using MAXQDA10 qualitative data analysis software. Roughly equal number of segments was coded by both coders for each coding scheme to achieve intercoder agreement (Table 3.1). After coding, the primary and secondary coders reviewed disagreements and honed the coding scheme. This process was repeated until at least 80% agreement was reached between coders. For the interview data, the remaining transcripts were coded by either the primary or secondary coder. Transcripts were randomly assigned to either the primary or secondary coder so that each coder received roughly equal pre-use and post-use transcripts.

Table 3.1

Details of Coding Schemes Developed and Used in Qualitative Coding of Usage Study

			Agreement between Two Independent Coders		
Purpose (Coding Scheme Location)	**Approach**	**Scope of Coding**	**% Agree ment**	**# of Segments**	**Data Coded during Scheme Development**
Investigate individuals' experience using a personal robot (Appendix F)	Combined top-down and bottom-up	**Two questions:** What were the positive aspects of using the robot mower this week? What were the negative aspects of using the robot mower this week?	87%	96	All responses in weekly diaries
Conceptually validate robot acceptance framework (Appendix G)	Combined top-down and bottom-up	**Whole transcript:** Pre-Use Interview (part 2); Post-Use Interview	87%	111	Randomly selected: 1 Pre-Use Interview; 1 Post-Use Interview
Understand facilitators of and barriers to intentional acceptance (Appendix H)	Bottom-up	**One question:** Given what you know about the Tango right now. If it were available for purchase, would you buy it? Why or why not?	91%	86	Randomly selected: 2 Pre-Use Interviews; 2 Post-Use Interviews

Characteristics of Participants

Self-Reported Health

In general, participants reported that they were in very good health (*Mdn* = 4.50, Interquartile Range (*IQR)* = 1.75, where 1 = poor, 5 = excellent). They reported seldom being limited by health problems in performing activities (*Mdn* = 1.00, *IQR* = 1.00, where 1 = never, 5 = always). Participants rated their degree of limitation in performing 10 common activities using a 3-point Likert-type scale (1 = not limited at all, 3 = limited a lot). Five participants reported being "limited a little" in performing at least one activity (e.g., bending/kneeling/stooping, climbing several flights of stairs, vigorous activities, walking more than several blocks). The other nine participants were "not limited at all". Taken together, these self-report measures suggest that these 14 participants were relatively healthy and high functioning.

Robot Experience

Participants indicated their experience with 14 different robots (0 = Not sure what it is; 2 = Have only heard about or seen this robot; 4 = Have used or operated this robot frequently). The median was taken across 14 robots for each participant. Then the median was taken across participants to compute a Frequency Profile Score (adapted from Barg-Walkow et al., 2014 for robots). Overall, participants had heard about or seen these 14 robots but had not used them (*Mdn* = 2.00, *IQR* = 0.00).

With respect to individual robots, no participants had used a Tango or another robot lawn mower, but 10 participants had seen or heard of them (Appendix I for more details). On the whole, participants were most experienced (i.e., at least half of the participants have heard/seen robot) with entertainment/toy robots (e.g., Furby; *Mdn* = 2.50, *IQR* = 1.00); domestic/home robots (e.g., Roomba; *Mdn* = 2.00, *IQR* = 0.00); and manufacturing robots (e.g., robot arm in factory; *Mdn* = 2.00, *IQR* = 0.00). In contrast, participants were least experienced (i.e., less than four participants had heard/seen robot) with robot security guards (*Mdn* = 1.00, *IQR* = 0.00); the Deere Tango E5 (*Mdn* = 1.00, *IQR* = 0.75); remote presence robots (e.g., Texai; *Mdn* = 1.00, *IQR* = 0.75); and research robots (e.g., at a university or company; *Mdn* = 1.00, *IQR* = 1.00).

Technology Experience

Participants indicated their experience with 36 technologies within the past year using a 5-point Likert-type scale (1 = not sure what it is, 2 = not used, 3 = used once, 4 = used occasionally, 5 = used frequently). Responses were recoded to combine the first two response options (0 = not used, 1 = used once, 2 = used occasionally, 3 = used frequently). The median of the recoded responses was calculated across all technologies for each participant. Then the median was calculated across participants to compute the Frequency Profile Score (adapted from Barg-Walkow et al., 2014 for a small sample).

Overall, participants used the six types of technologies occasionally (*Mdn* = 2.00, *IQR* = 0.00). Participants were generally most experienced using computer technologies (e.g., email, laptop; *Mdn* = 3.00, *IQR* = 0.38); everyday technologies (e.g., microwave oven, photocopier; *Mdn* = 3.00, *IQR* = 0.50); and communication technologies (e.g., text messaging, video conferencing; *Mdn* = 2.50, *IQR* = 0.50). They reported occasional use of recreation technologies (e.g., digital photography, gaming console; *Mdn* = 2.00, *IQR* = 0.38) and transportation technologies (e.g., airline kiosk, map software; *Mdn* = 2.00, *IQR* = 0.88). Participants were least experienced using health technologies (e.g., blood pressure monitor, pedometer; *Mdn* = 0.25, *IQR* = 1.00).

An additional five technologies assessed participant's experience with Android and non-Android tablet computers and smart phones (see Appendix J for more details). It was important to assess these technologies for the usage study, because participants were given a Google Nexus 10 tablet computer, which runs on an Android operating system, to use as a way to control the Tango. In general, participants reported using the Nexus 10 and non-Android tablets, and Android and non-Android smart phones occasionally (*Mdn* = 1.25, *IQR* = 1.38). They had not used Android tablets that were not the Nexus 10 (*Mdn* = 0.00, *IQR* = 0.00).

Perceptions of Lawn Mowing

For this section of results, responses from individuals within the same household were combined (i.e., the median of responses was taken between the two individuals living in the same household), because their perceptions could not be considered independent from one another (n = 7).

Importance of Lawn Mowing

To understand how important lawn mowing was to participants, they rated the degree of importance of accomplishing seven goals of mowing (i.e., having an acceptable looking lawn; a healthy lawn; acceptable level of sound emitted from mower; a safe mower; amount of electricity consumed; amount of gasoline consumed; and mower maintenance), and overall. The median for each household was calculated overall.

In general, households reported that mowing the lawn was important but not very important (*Mdn* = 4.00, *IQR* = 0.50). One participant said during his Pre-Use Interview that he “like[s] for it [grass] to look good but… there are more important things in life than mowing grass”, which may be representative of participants’ views.

Satisfaction with Regular Mower versus Tango

To assess participants’ satisfaction with Tango and their regular lawn mower, participants indicated their degree of satisfaction with time spent mowing, effort spent mowing, and accomplishment of mowing goals using each mower. Satisfaction was assessed for participants’ regular lawn mower during the Pre-Use Interview as well as for the Tango during the Post-Use Interview. The median scores for each household for satisfaction with using Tango and regular mower were calculated respectively for time and effort spent during the mowing process, and for the accomplishment of seven mowing goals. These goals are the same mowing goals used to assess the importance of lawn mowing, except consumption of gasoline was not assessed for the Tango because the Tango does not use gasoline. Bonferroni corrected Wilcoxon signed-rank tests were used to detect differences in satisfaction between the mowers ($\alpha = 0.017$).

Households did not significantly differ in their satisfaction with overall time ($Z = -2.21$, $p = .03$) and effort ($Z = -2.22$, $p = .03$) spent during the mowing process with the Tango and their regular lawn mower (Figure 3.1). This finding suggests that the households were similarly satisfied with the overall time and effort mowing their lawns using the Tango and their regular lawn mowers.

Households were significantly more satisfied with accomplishing their mowing goals using the Tango compared to using their regular lawn mower ($Z = -2.40$, $p = .016$; Figure 3.1). These findings suggest that participants perceived Tango was better than their regular mower in the overall accomplishment of their mowing goals.

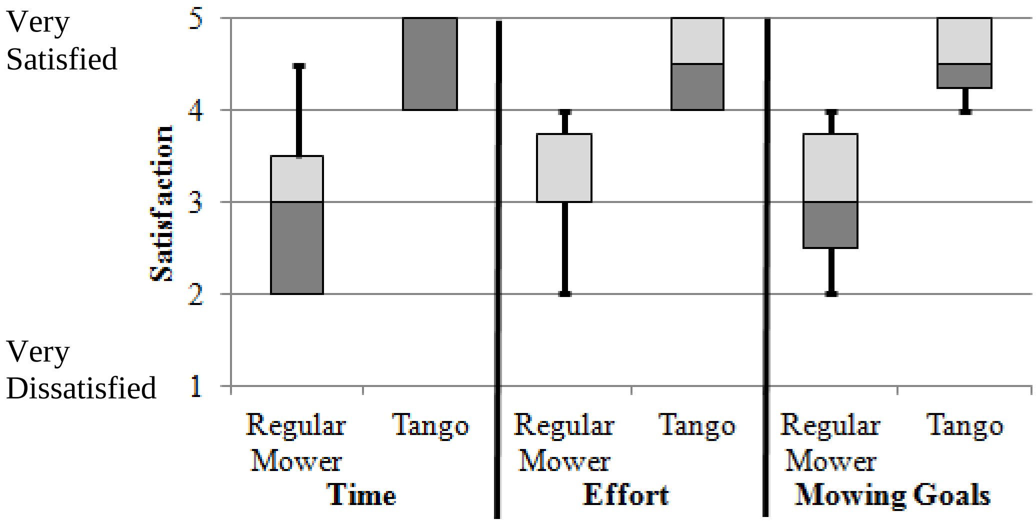


Figure 3.1 Households' median overall satisfaction with time and effort spent during the mowing process and accomplishment of mowing goals using their regular mower versus the Tango. Top error bar = maximum household median response. Light grey box = 3rd quartile of responses. Dark grey box = 1st quartile of responses. Bottom error bar = minimum household median response.

Personal Robot Acceptance

Behavioral Acceptance

A weekly diary was used to assess participants' self-reported behavioral acceptance (or use) of the Tango for five weeks. The number of weeks was summed for each participant and then the median was taken of the two participants' sums within each household. Three households reported using the Tango all five weeks during the study (Figure 3.2). The remaining four households reported using the Tango a median of 3.5-4.5 weeks during the study. Of note, participants in household 5 did not complete 1-2 diaries. These data suggest that participants used the Tango at least once a week for most of the 5 weeks of the study.

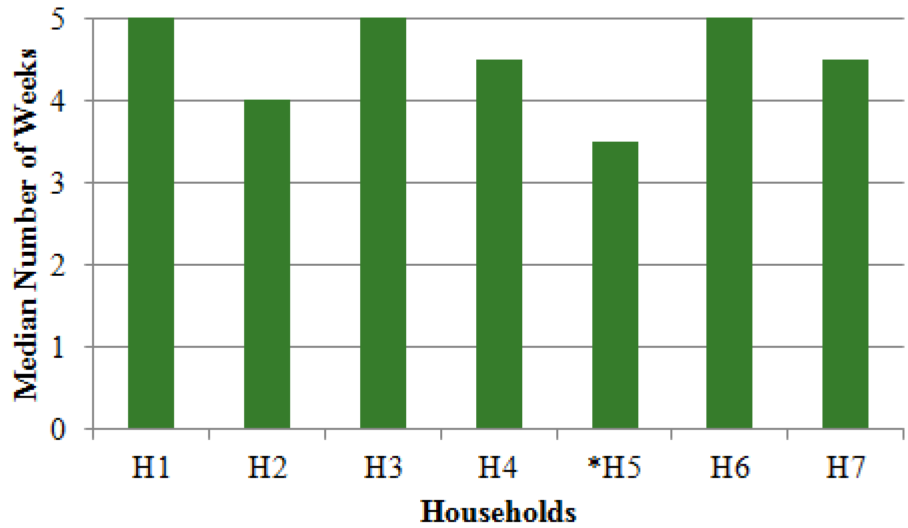


Figure 3.2 Median number of weeks that participants within each household self-reported their use of the Tango. *Missing 1-2 weeks of data for each participant within household 5.

Intentional Acceptance

Participants indicated their intention to purchase a Tango on three items using 5-point semantic differential scales in the pre and post robot mower opinions questionnaires (Ezer, 2008; 1 = low intention to purchase; 5 = high intention to purchase). The median scores for each household for intentional acceptance of the Tango were calculated for pre-use and post-use. The scale had high internal consistency for pre-use and post-use (Cronbach's alpha = 0.99). Using two Bonferroni corrected one-way Wilcoxon sign-rank tests ($\alpha = 0.025$) to compare intentional acceptance versus neutral (= 3), households had a significantly lower intention than neutral to buy a Tango after using it in their homes for 6 weeks ($p = 0.024$; Figure 3.3). Households' intention to buy a Tango before using it in their homes did not significantly differ from neutral ($p = 0.05$). Using a Wilcoxon signed-rank test, there was no significant difference in intentional acceptance from pre-use to post-use ($Z = -0.54$, $p = 0.59$).

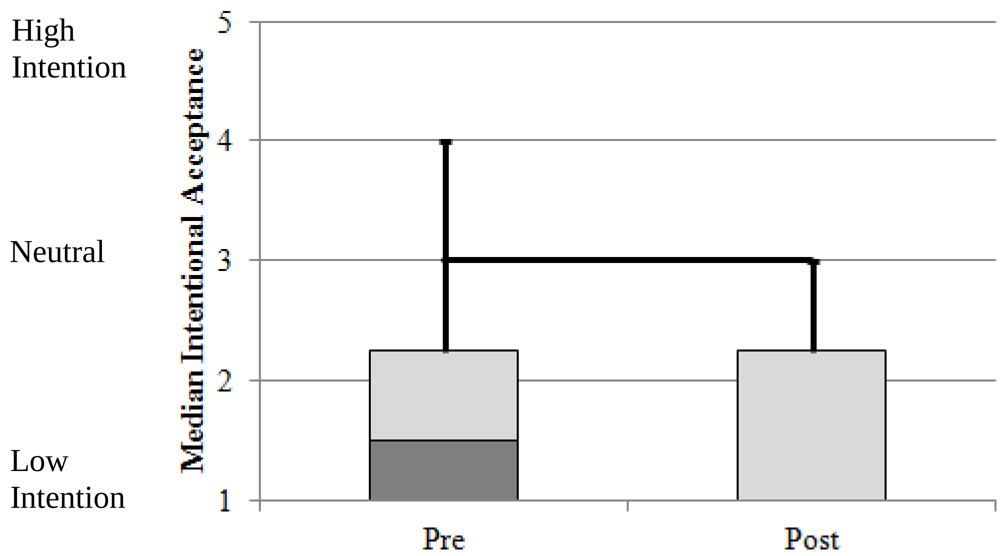


Figure 3.3 Households' median intention to purchase a Tango before and after using it. Top error bar = maximum household median response. Light grey box = 3rd quartile of responses. Dark grey box = 1st quartile of responses. Bottom error bar = minimum household median response. Bold horizontal line = neutral.

During the Pre-Use and Post-Use Interviews, each household was asked "Given what you know about the Tango right now. If it were available for purchase, would you buy it?" Before using the Tango, no households intended to purchase the Tango, five households were unsure/unclear, and two households did not intend to purchase it. After using the Tango for six weeks, four households changed from unsure/unclear to not intending to purchase the Tango. In other words, no households intended to purchase the Tango, one household remained unsure/unclear, and six households did not intend to purchase it after using it for six weeks.

Responses from questionnaires and interviews indicated that the households had low intentional acceptance of the Tango. This study was designed to not only measure participants' level of intentional acceptance, but to also measure the reasons that influence their intentions. Knowing the reasons behind these intentions can guide the design of future personal robots (e.g., Tango) and research studies, as well as hone frameworks of personal robot acceptance.

Reasons for Intentions before Using Tango

Before using the Tango, the five households that were unsure/unclear about purchasing the Tango cited many reasons behind their intention (Figure 3.4). The most frequently mentioned reasons were the perceived high cost of Tango, wanting to use the Tango more before deciding, or wanting the Tango to have a new feature or perform a new task (e.g., have GPS, fertilize lawn; Figure 3.4). The two households that said they would not purchase a Tango before using it were concerned about the perceived lack of security (e.g., being stolen) and high cost (Figure 3.5).

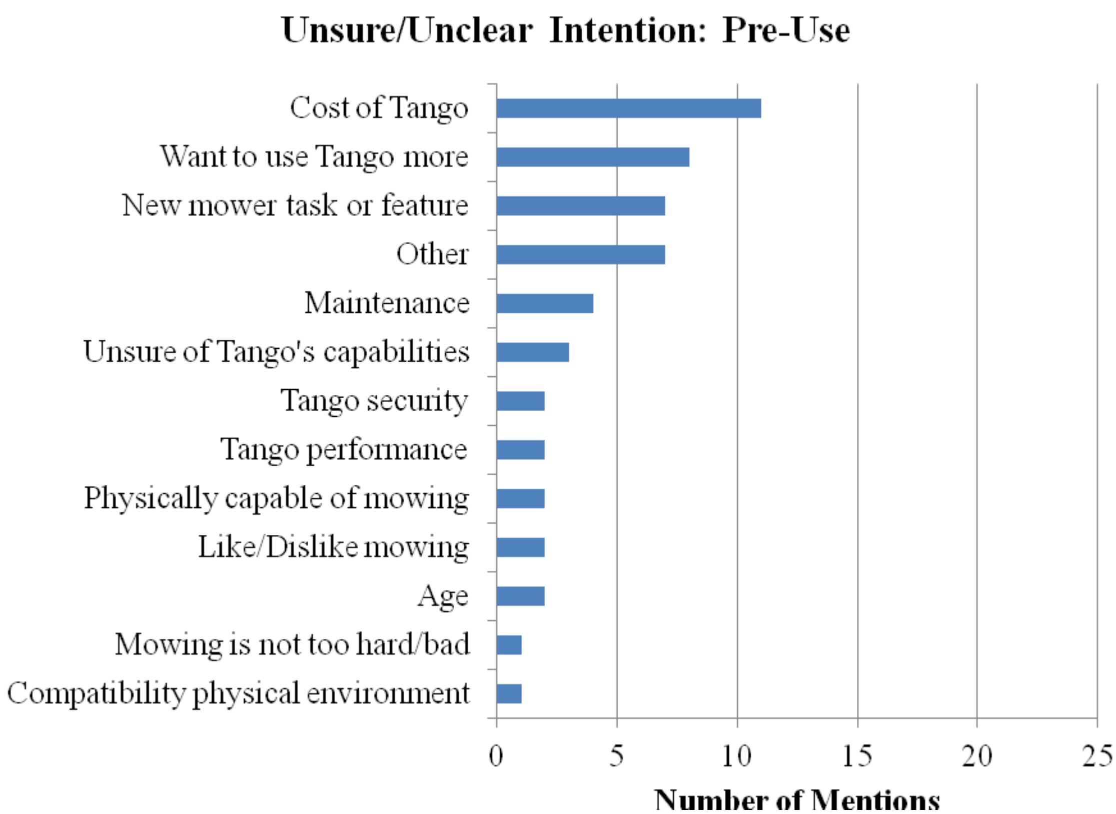


Figure 3.4 The number of times reasons were mentioned for households that were unsure/unclear about their intention to buy a Tango before using it.

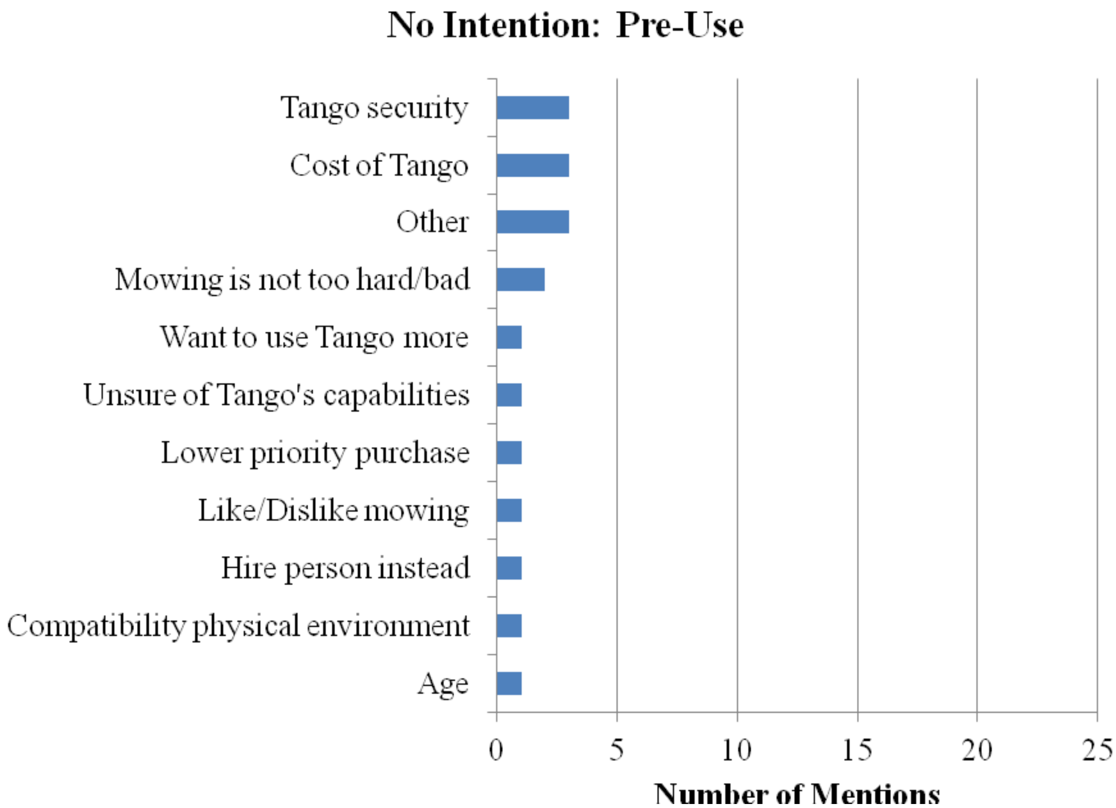


Figure 3.5 The number of times reasons were mentioned for households that did not intend to buy a Tango before using it.

Reasons for Intentions after Using Tango

After using the Tango, the one household that was unsure/unclear about their intention to buy the Tango mentioned they were concerned about the perceived high cost of Tango (Figure 3.6). Yet, they also mentioned that the Tango would be beneficial to have when they get older and can no longer mow their lawn, as well as to alleviate them from performing the disliked task of mowing their lawn.

The six households that did not intend to buy the Tango were concerned about the perceived high cost of Tango and its performance (e.g., mowing as scheduled; Figure 3.7). They also wanted the mower to have additional features or perform additional tasks (e.g., detect rain, mow steep inclines), to be easier to use, and to be more compatible with its environment (e.g., mulch leaves better).

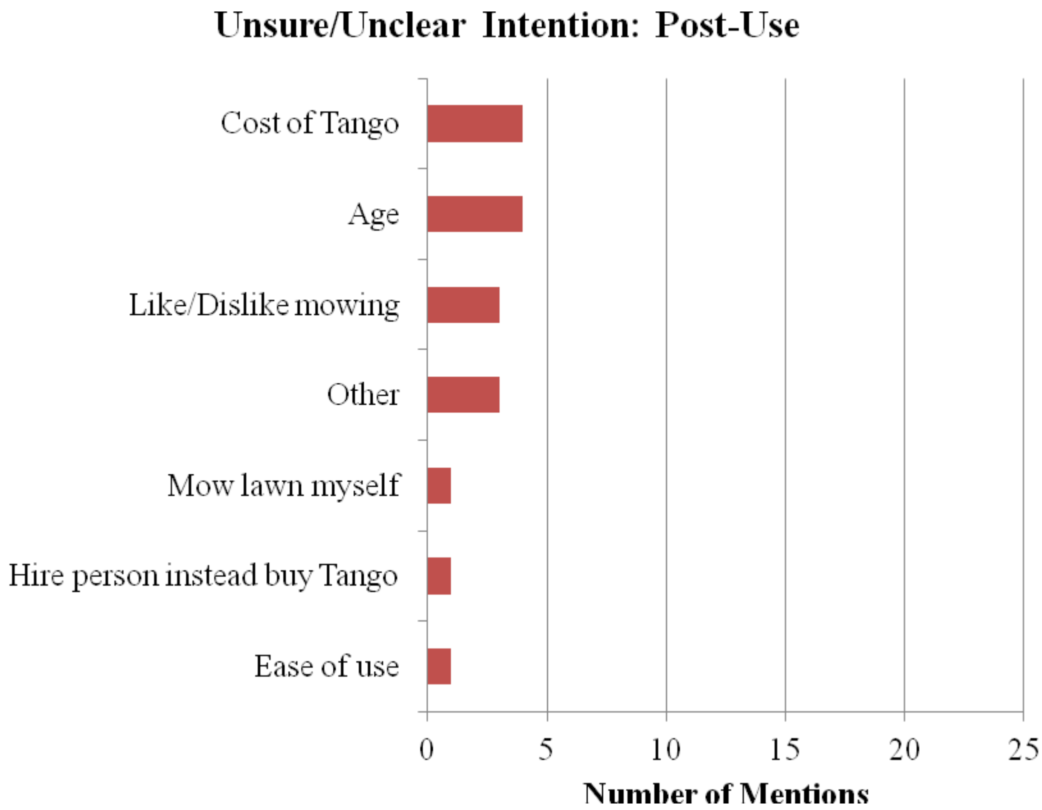


Figure 3.6 The number of times reasons were mentioned for households that were unsure/unclear about their intention to buy a Tango after using it for six weeks.

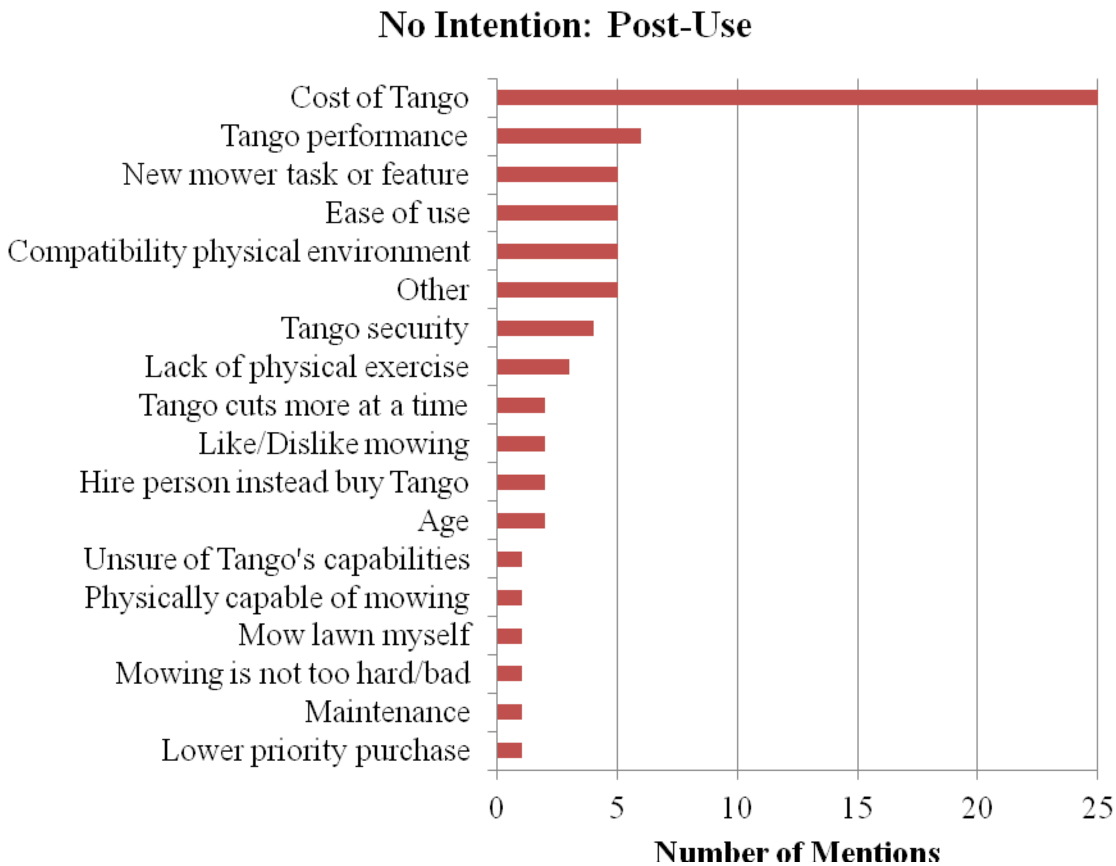


Figure 3.7 The number of times reasons were mentioned for households that did not intend to buy a Tango after using it for six weeks.

Attitudinal Acceptance

Participants indicated their attitudinal acceptance of the Tango on three items using 5-point semantic differential scales (Ezer, 2008; 1 = negative attitude; 5 = positive attitude). The median scores for each household for attitudinal acceptance of the Tango were calculated for pre-use, each week of use, and post-use. The scale exhibited high internal consistency at all points of measurement (Cronbach's alpha > 0.95; details in Appendix K). Seven one-way Wilcoxon sign-rank tests with Bonferroni correction (α = .007) were conducted to investigate if attitudinal acceptance significantly differed from neutral (= 3) each week. Households' reported attitudes that were not significantly different from neutral toward using the Tango pre-use, each week, and post-use ($p > .02$; Figure 3.8). Seven Wilcoxon signed-rank tests with Bonferroni correction ($\alpha = .007$) were used to investigate if attitudinal acceptance changed from pre-use to post-use as well as from week to week. Attitudinal acceptance did not significantly vary from pre to post use, or from week to week ($p > .03$; Figure 3.8).

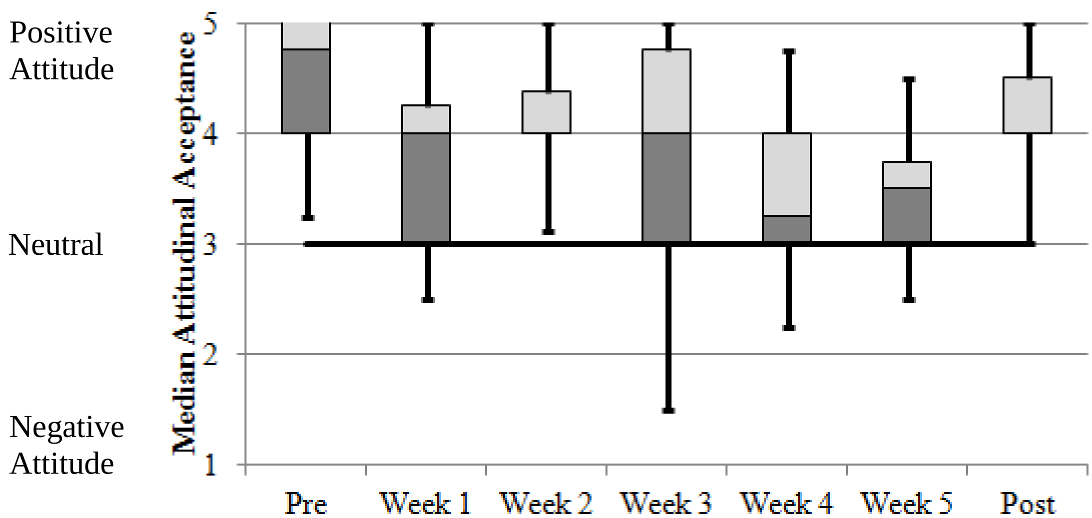


Figure 3.8 Households' median attitudinal acceptance of Tango before, during, and after using it. Top error bar = maximum household median response. Light grey box = 3rd quartile of responses. Dark grey box = 1st quartile of responses. Bottom error bar = minimum household median response. Bold horizontal line = neutral.

Positive and Negative Aspects of Using the Tango

In each weekly diary, participants were asked about the positive and negative aspects of using the Tango over the previous week. The aim was to better understand what aspects play a role in participants' attitudinal acceptance. Participants mentioned a total of 93 positive aspects and 86 negative aspects of using the Tango.

The coding scheme for both positive and negative aspects was organized into four dimensions: person-, robot-, task-, and environment-related. Each dimension included top-down factors that were found to be important in the Smarr et al. (2013) framework of robot acceptance as well as bottom-up factors from participant responses (Figures 3.9-3.12). Factors presented in Figures 3.9-312 indicate they played a role in participants' attitudinal acceptance. Factors with zero entries in Figures 3.9-312 indicate a top-down factor from the Smarr et al. (2013) robot acceptance framework that was not mentioned by participants as a positive or negative aspect of using the Tango. This suggests that these factors from the framework did not play a role in participants' attitudinal acceptance of the Tango.

For the person-related dimension, participants reported positive aspects related to the Tango's usefulness, ease of use, and enjoyment (Figure 3.9). Anxiety toward using the Tango and trusting it were not reported as positives. Low perceived usefulness and ease of use were also mentioned as negative aspects along with not trusting the robot. Anxiety toward using the Tango and enjoyment were not mentioned as negatives.

For the robot-related dimension, the robot's reliability and methods of control (e.g., user interface on Tango, mowing on a schedule) were mentioned as both positive and negative aspects (Figure 3.10). There were no mentions of the Tango's adaptivity, appearance, sociability, or usability as either positive or negative aspects.

The task-related dimension was not mentioned very much except for certain types of interaction with the Tango as negative (e.g., checking on mower, putting mower in charging station; Figure 3.11).

The environment-related dimension was also not mentioned very frequently except for result demonstrability as positive (e.g., the grass was cut well and evenly) and lack of compatibility with physical environment as negative (e.g., Tango not mulching leaves; Figure 3.12).

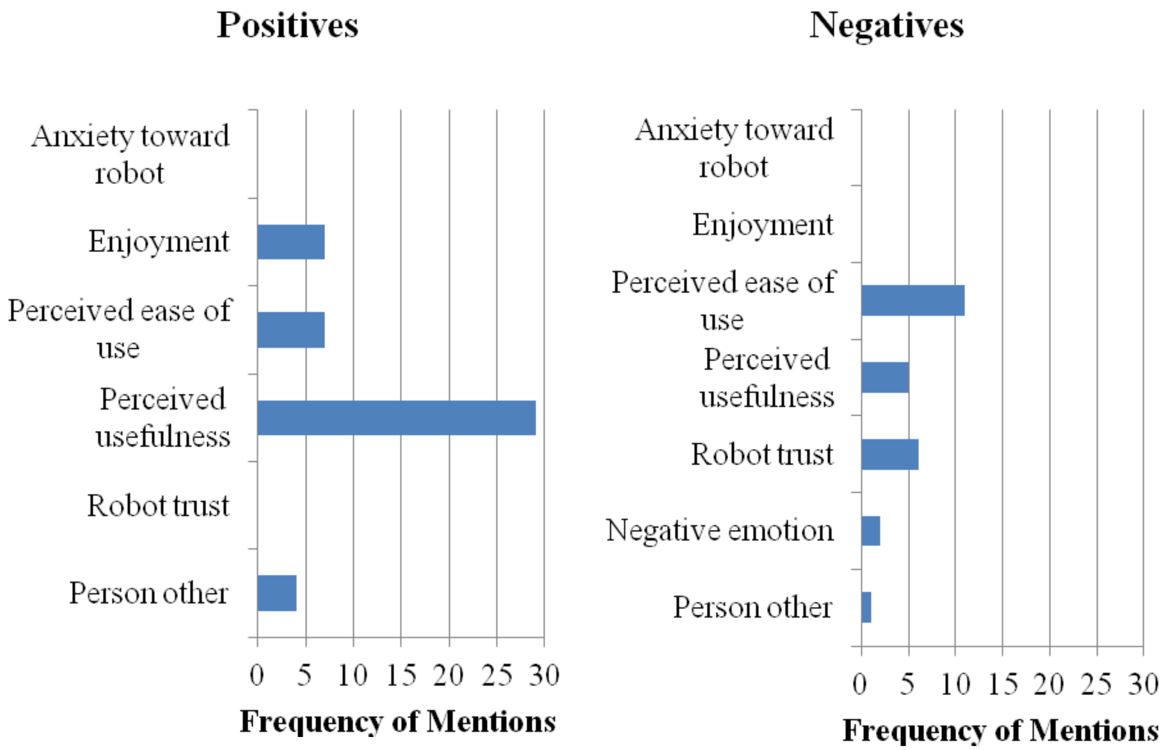


Figure 3.9 Number of times participants mentioned person-related factors as positive or negative aspects of using the Tango.

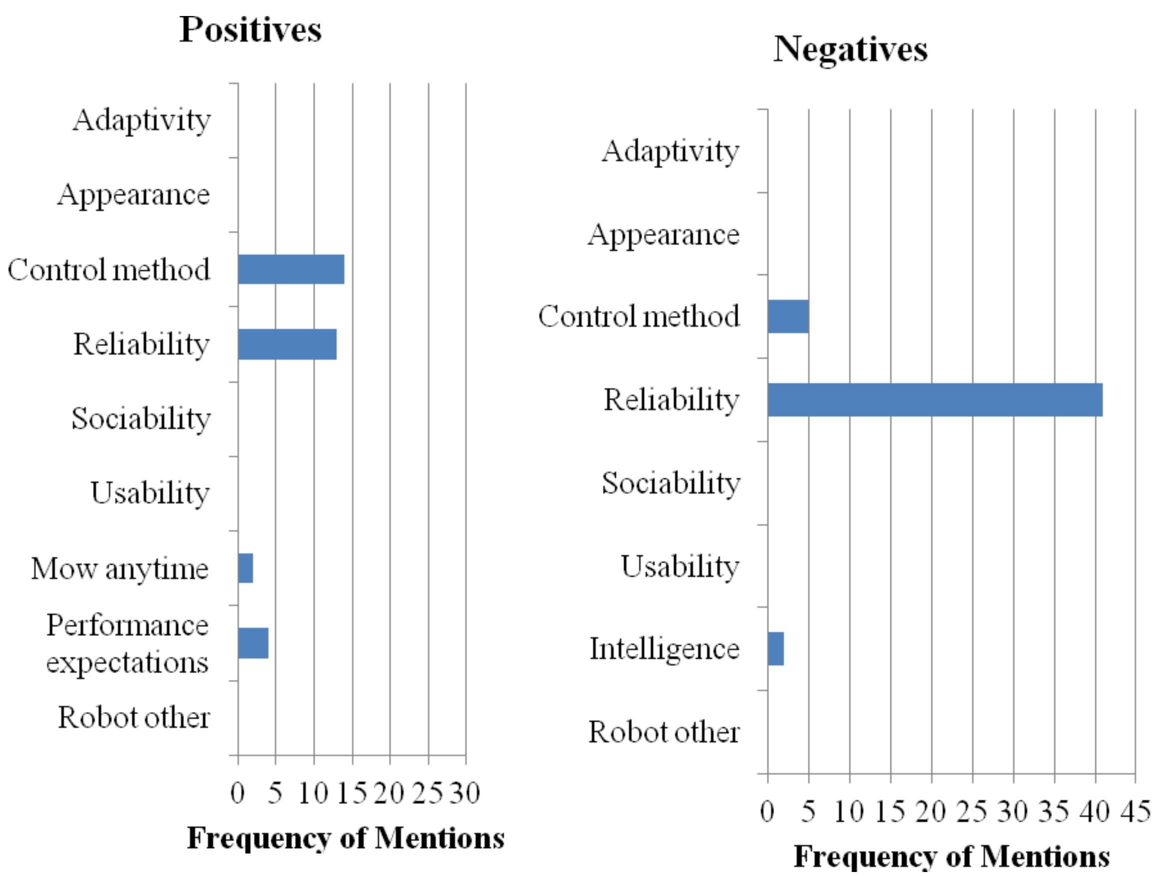


Figure 3.10 Number of times participants mentioned robot-related factors as positive or negative aspects of using the Tango.

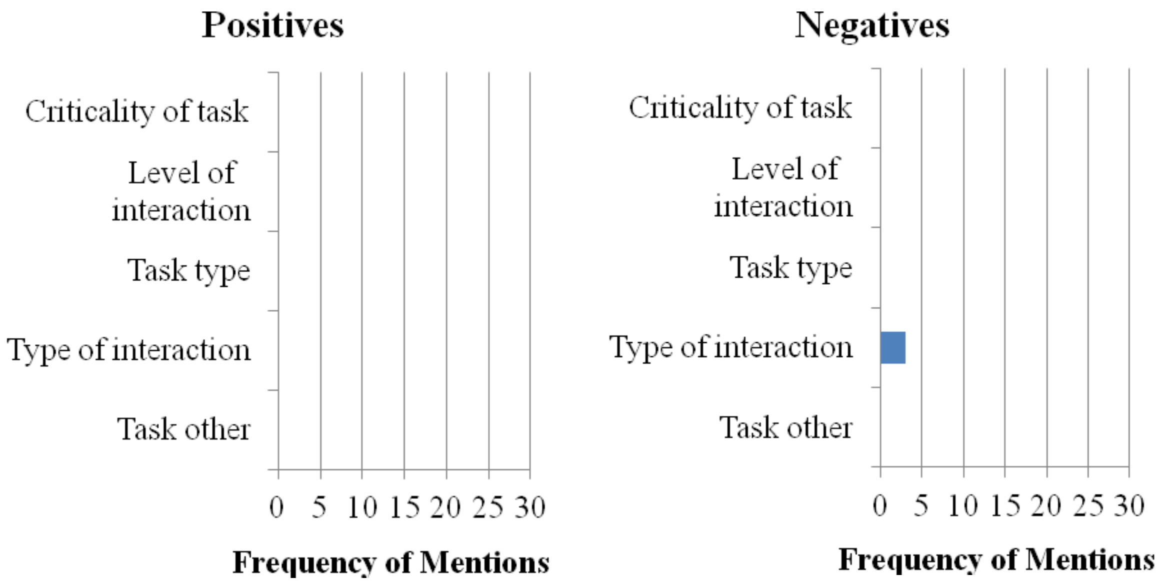


Figure 3.11 Number of times participants mentioned task-related factors as positive or negative aspects of using the Tango.

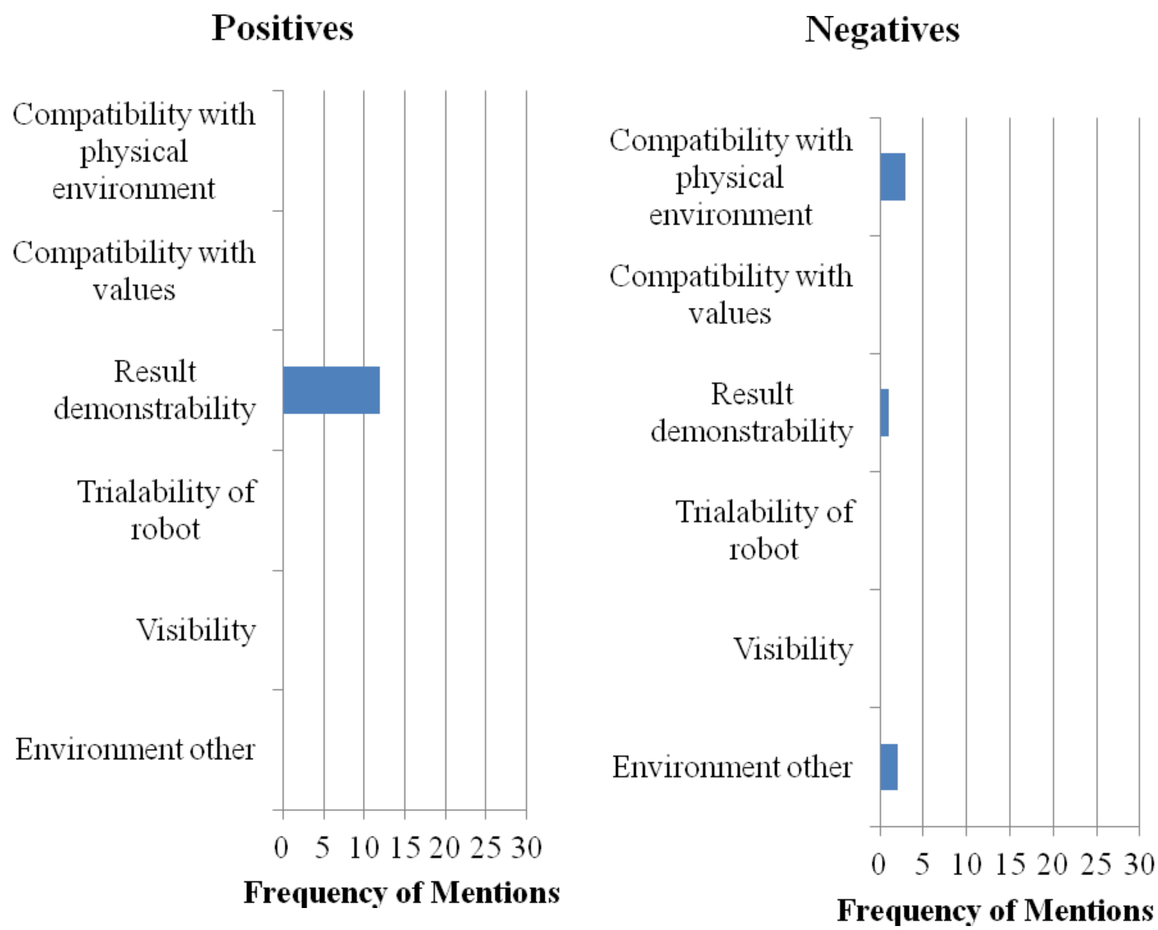


Figure 3.12 Number of times participants mentioned environment-related factors as positive or negative aspects of using the Tango.

Framework Factors Related to Acceptance

Perceived Usefulness and Ease of Use

Perceived usefulness and ease of use were positive determinants of attitudinal and intentional acceptance in the Smarr et al. (2013) robot acceptance framework and in TAM (e.g., Davis, 1989). Participants indicated their perception of the Tango's usefulness and ease of use via 12 items adapted from Davis (1989). The median scores for each household's perceived usefulness and ease of use were calculated for pre-use, each week of use, and post-use. Perceived usefulness (Cronbach's alpha ≥ 0.93) and ease of use (Cronbach's alpha ≥ 0.81) exhibited relatively high internal consistency at all points of measurement (details in Appendix K). Seven Bonferroni corrected ($\alpha = .007$) one-way Wilcoxon signed-rank tests were conducted to detect differences in perceived usefulness compared to neutral (= 4) and perceived ease of use compared to neutral, respectively. Additionally, Wilcoxon signed-rank tests ($\alpha = .007$) were used to investigate if perceptions changed from pre-use to post-use as well as from week to week.

The Tango was perceived numerically as useful and easy to use before use, while using it, and after using it (all medians above 5; Figures 3.13-3.14). However, the Tango was not perceived as significantly useful or easy to use compared to neutral ($p > .02$; Figures 3.13-3.14). The lack of significance may be due to the large variation in participants' perceptions. Perceptions of usefulness and ease of use did not significantly change between pre-use and post-use, or week to week ($p > .06$).

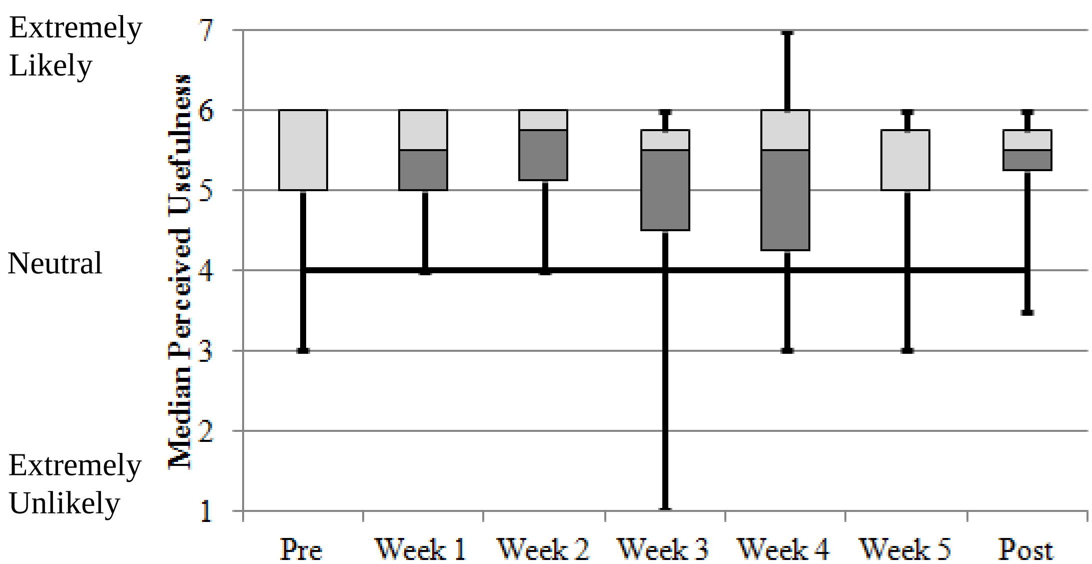


Figure 3.13 Households' median perceived usefulness of Tango before, during, and after using it. Top error bar = maximum household median response. Light grey box = 3rd quartile of responses. Dark grey box = 1st quartile of responses. Bottom error bar = minimum household median response. Bold horizontal line = neutral.

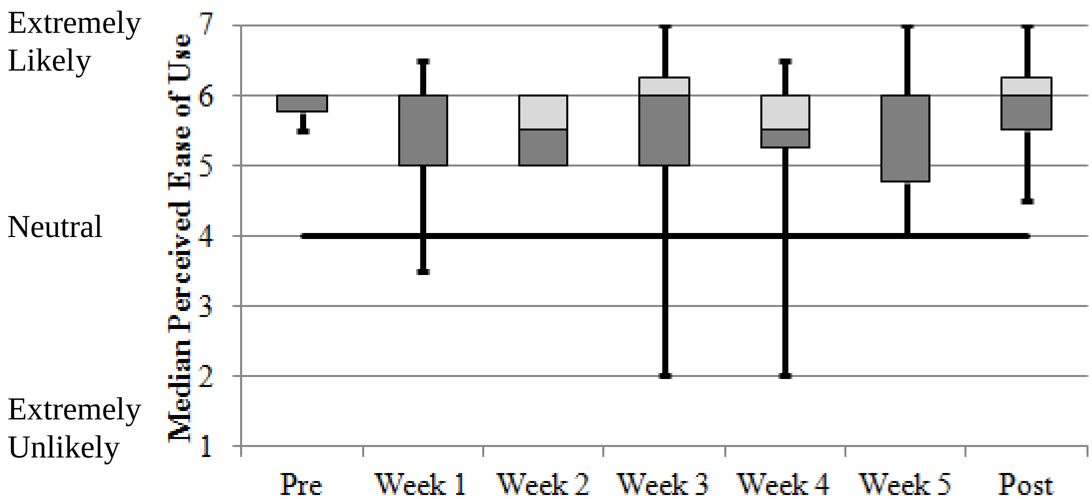


Figure 3.14 Households' median perceived ease of use of Tango before, during, and after using it. Top error bar = maximum household median response. Light grey box = 3rd quartile of responses. Dark grey box = 1st quartile of responses. Bottom error bar = minimum household median response. Bold horizontal line = neutral.

Non-TAM Factors Related to Acceptance

Several non-TAM factors were also identified in the Smarr et al. (2013) framework as important for personal robot acceptance. These perceptions are important to consider because they may have positively or negatively influenced participants' acceptance of the Tango. On the robot mower opinions questionnaires, participants rated their opinions on the factors in Table 3.2 (questionnaire items are in Appendix C). The median of each household's responses was calculated for each factor pre-use and post-use. With only seven households, internal consistency of the factors varied widely over time (Appendix K).

Bonferroni corrected Wilcoxon signed-rank tests ($\alpha = .003$) were used to investigate changes from pre-use to post-use (Table 3.2). No factors significantly changed from pre-use to post-use ($p > .003$).

The following general patterns were observed in the data (Table 3.2). For the person-related dimension, participants trusted the Tango; enjoyed using the Tango; and had low anxiety toward using the Tango. For the robot-related dimension, participants perceived the Tango as usable and reliable. They liked the Tango's appearance and thought it neither sociable nor unsociable. The display screen on the mower was perceived as a good way to control Tango and the Tango was perceived as adaptive to what participants need.

For the task-related dimension, participants indicated that the Tango fits the task of mowing their lawns. For environment-related dimension, the Tango was perceived as compatible with participants' lawns. The results of the Tango were apparent to participants and could be easily communicated to other people. The Tango was perceived as compatible with participant values. Participants reported they were able to try out using the Tango and they did not see the Tango used by others in their daily lives.

Table 3.2

Households' Perceptions Before and After Using the Tango

		Pre-Use		Post-Use				
Factor	Dimension	*Mdn*	*IQR*	*Mdn*	*IQR*	*Z*	*p*	n
Robot trust	Person	5.50	1.00	5.50	1.50	-0.97	0.33	7
Perceived enjoyment	Person	5.50	2.00	5.00	2.50	-0.11	0.92	7
Robot Anxiety	Person	1.50	1.00	1.00	1.00	-0.58	0.56	7
Usability	Robot	6.00	3.00	6.00	2.00	-1.73	0.08	7
Perceived reliability	Robot	6.00	1.50	6.00	3.00	-0.38	0.71	7
Appearance	Robot	6.00	1.00	6.50	1.00	-0.28	0.78	7
Perceived sociability	Robot	4.50	1.50	4.00	0.50	-0.68	0.50	7
Method of control	Robot	6.00	1.00	6.50	1.00	-1.51	0.13	7
Perceived adaptivity	Robot	5.00	1.00	5.00	1.50	-1.41	0.16	7
Task-technology fit	Task	6.00	2.00	7.00	1.00	-1.84	0.07	7
Compatibility with physical environment	Environment	5.50	2.00	5.00	3.50	-0.95	0.34	7
Result demonstrability	Environment	6.00	1.50	6.50	1.00	-1.73	0.08	7
Compatibility with values	Environment	7.00	0.50	7.00	0.00	-0.45	0.65	7
Trialability	Environment	6.50	1.00	6.00	1.50	-0.14	0.89	7
Visibility	Environment	1.50	1.00	2.00	4.00	-1.48	0.14	7

Note. Response scale: 1 = strongly disagree; 7 = strongly agree. Reliability information is in Appendix K. *Mdn* = Median of households' responses. *IQR* = Interquartile range. *Z* = Wilcoxon sign-rank test value. *p* = Probability of a type 1 error. n = Number of households that responded.

Conceptual Validation of Framework

The Smarr et al. (2013) personal robot acceptance framework identified factors important for acceptance based on the literature but has yet to be tested. This study was designed to conceptually validate the factors in that framework with robot users by coding what they mention within a discussion of acceptance of a personal robot. It is assumed in these analyses that if participants mention something during interviews then it was important to them. The three main goals of the conceptual validation analysis of the framework were to:

1. Look for users' mentions of factors in the framework (top-down validation of keeping factor in framework).
2. Look for users' mentions of factors related to acceptance that were not included in the framework (bottom-up determination of factors missing from framework).
3. Note factors that were not mentioned by users but were in the framework (may indicate factor is not important and needs removed from framework).

In total, participants mentioned a factor related to acceptance of the Tango 1,741 times. Participants mentioned factors related to acceptance more than twice as much after using the Tango (1,221 mentions) compared to before using it (520). Sixteen of 20 factors were analyzed and conceptually validated (Figures 3.15-3.19). Ten factors, not including "other", were mentioned by participants but were not in the framework. These data suggest that the Smarr et al. (2013) framework was successful in identifying important factors in acceptance of the Tango but that there were opportunities for improvement by adding or removing factors. Of note, additional research is needed to replicate findings before modifying the theoretically-based Smarr et al. (2013)

framework. The conceptual validation data will be discussed in more depth in this section by dimension: person-, robot-, task-, and environment-related.

For the person-related dimension, three of the four factors most frequently mentioned by participants in a discussion of acceptance of the Tango were also in the Smarr et al. (2013) framework (Figure 3.15). Therefore, these factors (perceived usefulness, ease of use, and enjoyment) were conceptually validated. In contrast, four factors, besides “other”, mentioned were not in the framework: the Tango playing a role in interactions between people (e.g., talking about Tango, demonstrating Tango); participants feeling curious or frustrated about using the Tango; and whether the participant was physically capable of mowing their lawn now or in the future. These factors may need to be considered for addition to the framework. Anxiety toward using Tango was not mentioned by participants even though it was in the framework, suggesting removal from the framework.

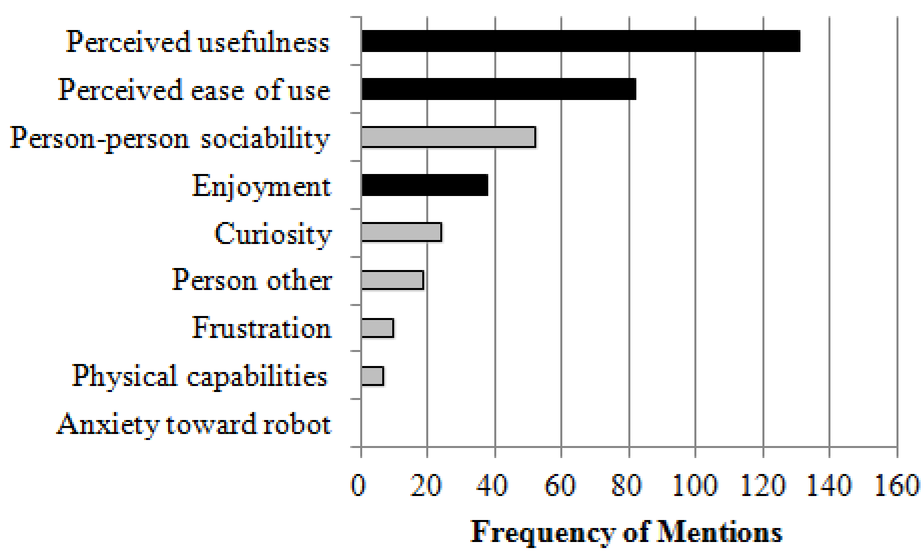


Figure 3.15 The number of times participants mentioned person-related factors within discussions of robot acceptance. Black bars = conceptually validated factor from Smarr et al. (2013). Gray bars = factors mentioned by participants but not in framework.

An emergent dimension that was not in the framework but seems related to person-related factors was "expectations". Categories within this dimension are presented in Figure 3.16. When participants were asked about their expectations of the Tango based on the goals of mowing (e.g., Did the Tango's grass cutting abilities meet your expectations?), participants largely responded that it met their expectations. They also mentioned the Tango exceeded their expectations in some regards (e.g., quieter than expected) and failed expectations in others (e.g., more user effort than expected). Some participants mentioned expectations that were not asked about in the interview. Expectations may be one factor that should be incorporated into the framework.

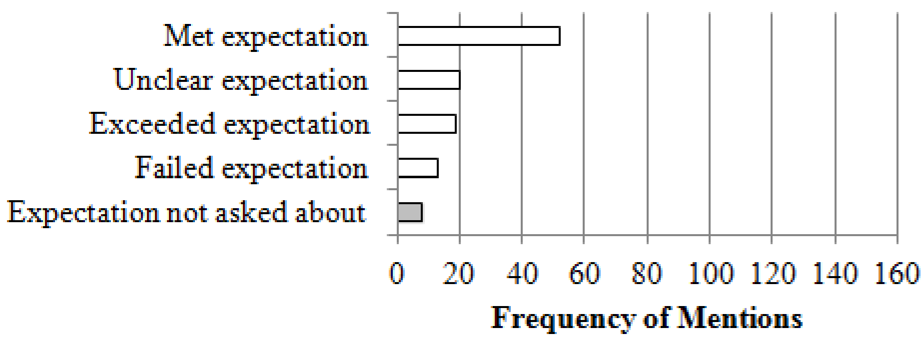


Figure 3.16 The number of times participants mentioned expectations within discussions of robot acceptance. Gray bars = factors mentioned by participants but not in framework. White bars = factors that participants were asked questions about related to mowing goals.

For the robot-related dimension, the two factors most frequently mentioned by participants were conceptually validated: the participants frequently commented on the Tango's level of reliability (good or bad) and the method they used to control robot (e.g., let it run on schedule, they liked making Tango mow with a push of a button; Figure 3.17). Liking the Tango's appearance, trusting the Tango, and the Tango's sociability and adaptivity were also conceptually validated. Six factors, besides "other", were mentioned during the discussion that were not in the framework (gray bars in Figure 3.17). Also, participants were asked about their perceptions of using the Tango to accomplish mowing goals. In doing so, participants were biased into mentioning certain factors (i.e., maintenance, energy consumption, safety, and level of sound; white bars in Figure 3.17). Usability was not mentioned by participants, which may have been due to the nature of the interview questions or participants' comments.

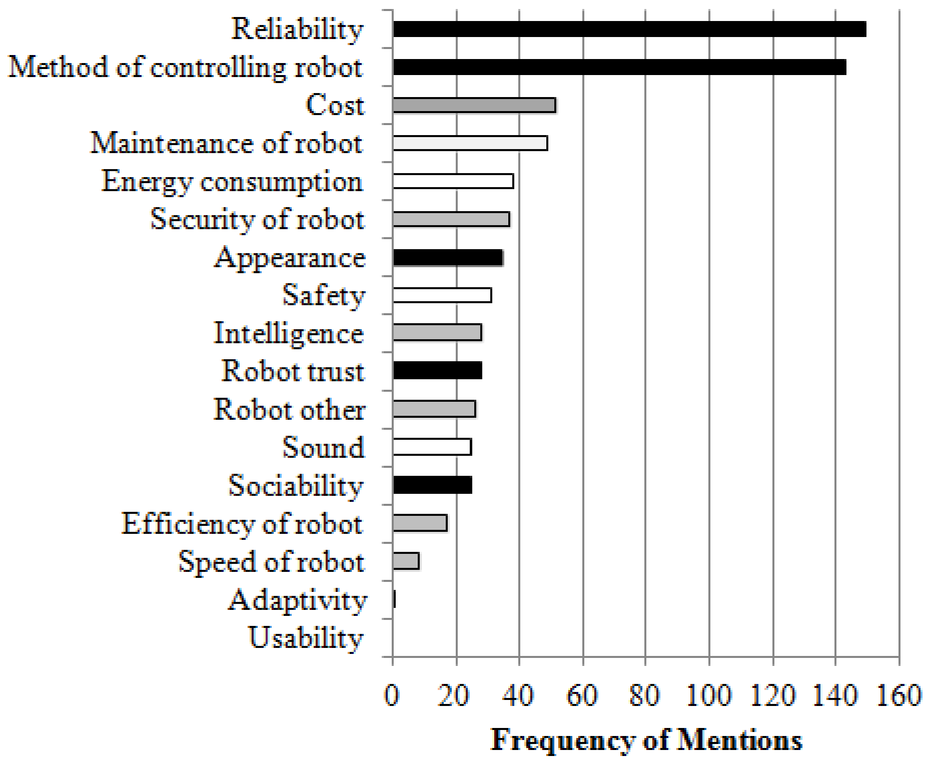


Figure 3.17 The number of times participants mentioned robot-related factors within discussions of robot acceptance. Black bars = conceptually validated factors from Smarr et al. (2013). Gray bars = factors mentioned by participants but not in framework. White bars = factors that participants were asked questions about related to mowing goals.

For the task-related dimension, three of the four factors in the framework were conceptually validated (Figure 3.18). That is, type of task (i.e., new person task, task of mowing, new mower task, task of mulching leaves), type of interaction (e.g., physical impact), and frequency of interaction (e.g., seldom interact with Tango) were mentioned in the interview and in the framework. Criticality of task was not mentioned in the interview but was in the framework.

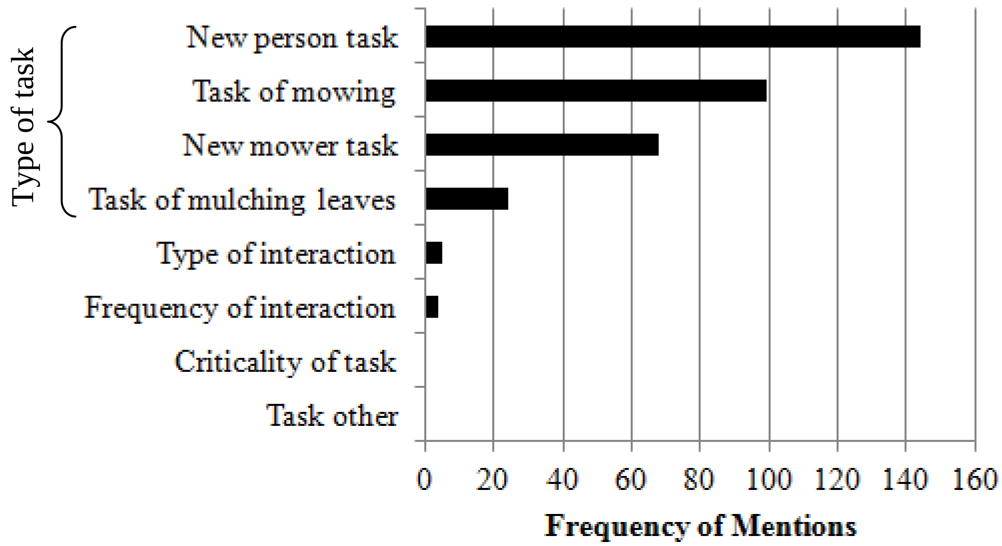


Figure 3.18 The number of times participants mentioned task-related factors within discussions of robot acceptance. Black bars = conceptually validated factors from Smarr et al. (2013).

For environment-related dimension, four of five factors, besides “other”, were conceptually validated (Figure 3.19). Participants mentioned how compatible the Tango was with their lawn; how they could discern the results of using the Tango (e.g., cut grass); how they wanted to try out the Tango before buying it; and how compatible it was with their values (e.g., do not disturb others by mowing at night). Even though it was in the framework, visibility was not mentioned by participants, which was likely due to the Tango not being sold in the United States so participants could not see the Tango used in other people’s lawns.

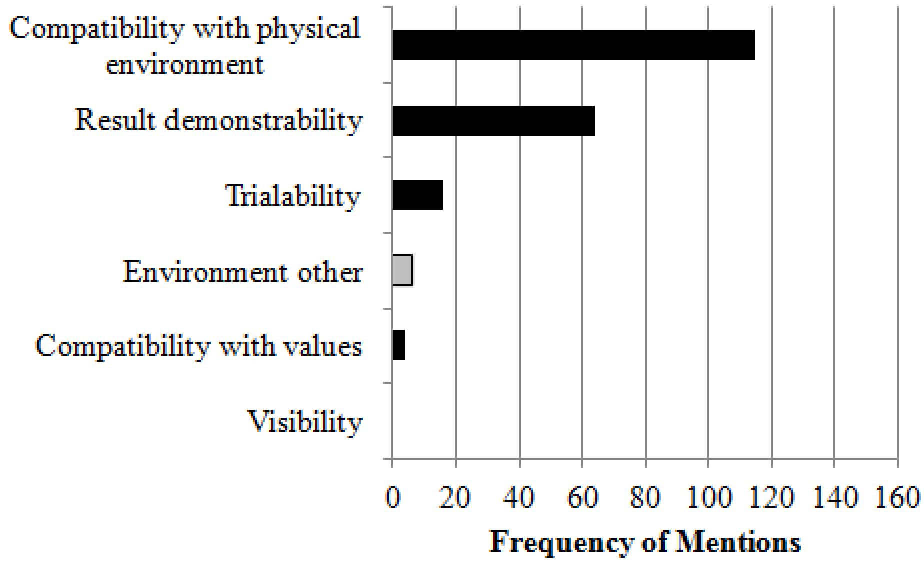


Figure 3.19 The number of times participants mentioned environment-related factors within discussions of robot acceptance. Black bars = conceptually validated factors from Smarr et al. (2013). Gray bars = factors mentioned by participants but not in framework.

Usage Study Discussion

The purpose of the usage study was to conduct an in-depth investigation of adult's acceptance of a personal robot (i.e., Tango) at their home over six weeks. The main goals of the study were to:

1. Measure people's behavioral, intentional, and attitudinal acceptance of a personal robot at their homes.
    a. Examine changes in acceptance over time.
2. Gain a deep understanding of the person, robot, task, and environment factors that were important for acceptance before and after use.
3. Validate the Smarr et al. (2013) framework of personal robot acceptance conceptually.

Behavioral, Intentional, and Attitudinal Acceptance

According to the theory of reasoned action (Fishbein & Azjen, 1975), a person's behavior results from his or her intentions, which are formed from his or her attitudes. This theory forms the core of two frameworks of robot acceptance (Heerink et al., 2010a; Smarr et al., 2013) and many technology acceptance models, including the most prominent one, Davis et al.'s (1989) TAM. Attitude toward robots was the strongest determinant of intentional acceptance for a personal robot (Ezer, Fisk, & Rogers, 2009a; Heerink et al., 2010a). Intentional acceptance predicted objective behavioral acceptance of a robot (Heerink, Kröse, Evers, & Wielinga, 2009). Therefore, it was surprising that this well-researched pattern was not supported in this study. Even though participants reported high self-reported behavioral and attitudinal acceptance of the Tango, they had low intentional acceptance. One HRI study that measured all three types of acceptance found that attitude did not significantly predict intention to use a robot (Heerink, Kröse, Evers, & Wielinga, 2009).

This surprising pattern of the three types of acceptance was found throughout the six weeks of the study, which was not expected for attitudinal acceptance. Other robot acceptance studies have found that attitudes became significantly less negative towards a robot after people interacted with it briefly (Broadbent et al., 2010; Stafford et al., 2010).

Factors Important for Acceptance

The surprising pattern of the three types of acceptance may be explained by participants' responses from the questionnaires, interviews, and weekly diaries. Acceptance is a multifaceted construct that can be impacted by many factors. Although the usage study's findings were rich and informative in their depth and detail, it is important to note that the factors discussed in this section are likely important for acceptance because of participants' mentioned them. However, relationships between factors were not statistically tested.

The Tango was generally perceived as useful and easy to use before, during, and after using it. In previous studies, perceived usefulness was a strong positive determinant of attitudinal (Ezer, Fisk, & Rogers, 2009a) and intentional acceptance of robots (Cesta et al., 2007, 2011; Ezer, Fisk, & Rogers, 2009a; Heerink et al., 2010a). Also, perceived ease of use was a significant positive determinant of attitudinal acceptance of a robot (Ezer, Fisk, & Rogers, 2009a). Consequently, participants' high levels of attitudinal acceptance could have been impacted by their perceptions of the Tango as useful and easy to use. However, high perceived usefulness did not explain participants' low intentional acceptance. Other factors from the literature may account for this.

Additional factors identified from the literature as important to the acceptance of personal robots were assessed in questionnaires. Participants' perceptions of the Tango may have had a positive impact on their acceptance: they trusted the Tango; enjoyed using it; felt low anxiety toward using it; it was usable, reliable, and adaptive to their needs; had a good way to control it; it fit the task of mowing their lawns; discernible results that could be communicated to others; compatible with their lawns and values; and they were able to try using it before buying it. Other perceptions may have had a negative impact on their acceptance: they did not see the Tango being used by other people in their daily lives.

In addition to factors identified from the literature, participants were asked during the interviews why they intended or did not intend to purchase a Tango. Participants who did not intend to purchase the Tango were primarily concerned with its perceived lack of security, its high cost, and its performance. They also wanted it to have new features or perform new tasks, to be easier to use, and to be more compatible with their lawns. Participants who were unsure or unclear about their intentions to purchase the Tango were primarily concerned about its perceived high cost. They also wanted the Tango to have additional features or to be able to perform additional tasks. Yet, they also perceived the benefits of using the Tango, such as not having to mow the lawn (a disliked task), and it could mow their lawn if they could no longer mow as they aged.

Participants were also asked about the positive and negative aspects of using the Tango in their weekly diaries. Understanding these aspects informed why participants reported high attitudinal acceptance of the Tango. That is, positive aspects of using the Tango may have impacted attitudinal acceptance positively whereas negative aspects may have negatively impacted it. Participants reported roughly the same number of positive and negative aspects. The importance participants placed on each aspect is unknown from these data. However, clearly there were overriding factors that influenced intention negatively even with the presence of highly positive attitudinal and behavioral acceptance. Future research should focus on understanding the relative weightings of predictors of acceptance.

Participants mentioned the following aspects as positives of using the Tango: it was useful, easy to use, and enjoyable; its interface was a good way to control it; it was perceived as reliable before using it because there was not much that could go wrong; and you could see the results of using it (e.g., cut grass). Negative aspects of using the Tango were its low perceived usefulness and ease of use; not trusting it to perform tasks; low reliability; the way of controlling it was bad; having to perform new tasks that the person did not do before having the Tango (e.g., check on Tango, put Tango in station); and its low compatibility with its physical environment (e.g., pinecones kept it from mowing parts of the lawn).

Conceptual Validation of Smarr et al. (2013) Framework

The factors related to acceptance that participants mentioned during interviews were examined as a way to conceptually validate the Smarr et al. (2013) framework of personal robot acceptance. Three types of factors emerged from the conceptual validation: (1) factors in the framework that were mentioned by participants (i.e., conceptually validated); (2) factors in the framework that were not mentioned by participants (i.e., not conceptually validated); and (3) factors not in the framework that participants mentioned (i.e., new factors to consider).

Validated Factors from Framework

Most of the framework was conceptually validated. Sixteen of the 20 factors in the Smarr et al. (2013) framework were analyzed and conceptually validated, suggesting that these 16 factors should remain in the framework because they were important enough for participants to mention them during an interview about robot acceptance (green factors in Figure 3.20).

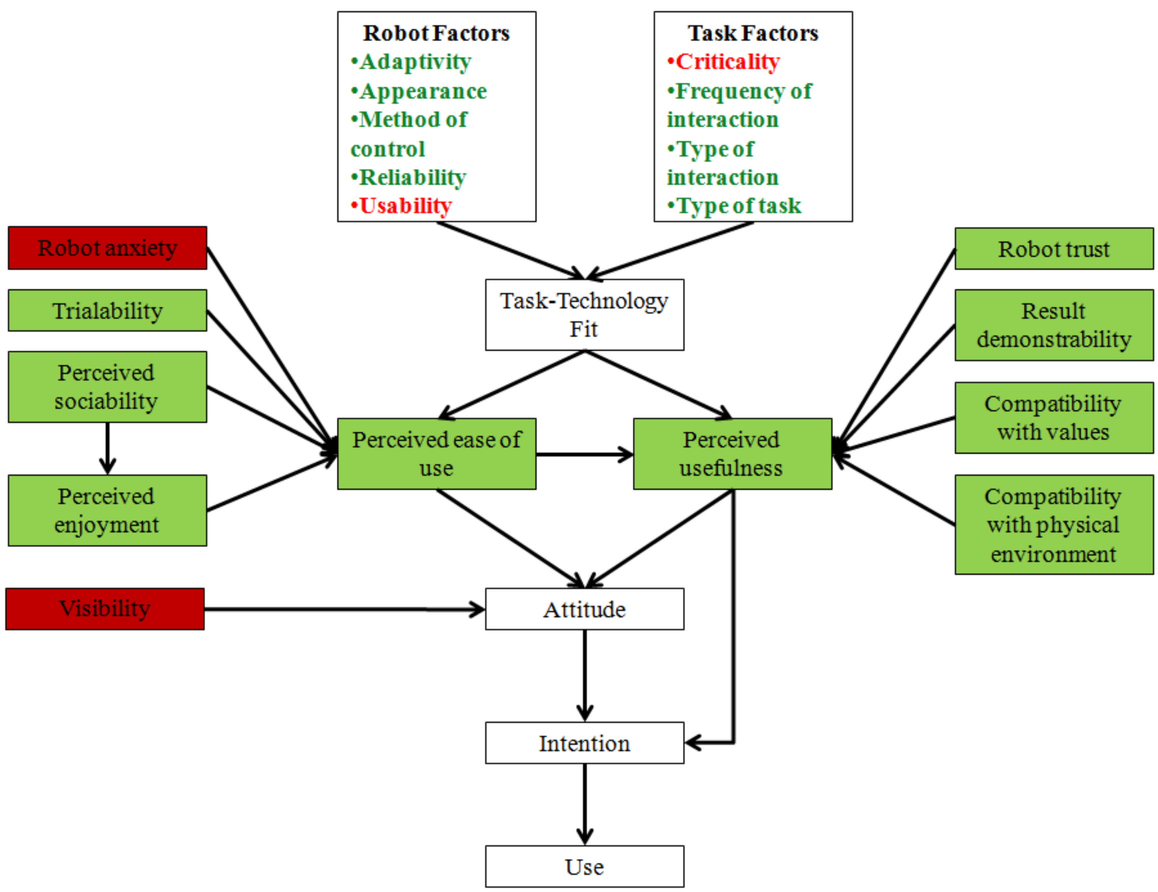


Figure 3.20 Summary of conceptual validation of Smarr et al. (2013) framework. Green = conceptually validated factor. Red = not conceptually validated. White = not assessed in the conceptual validation.

Factors from Framework Not Validated

Four factors out of 20 were not conceptually validated: anxiety toward robot, usability of robot, criticality of task, and visibility of robot (red factors in Figure 3.20). We cannot immediately conclude these factors are not important or that they should be excluded from the model. It may be that the importance of these factors is dependent on the particulars of the robot. There are myriad reasons why they may not have been mentioned for the Tango.

First, participants may have not mentioned anxiety toward using the robot, because they did not feel apprehensive about using the Tango. The lack of anxiousness may have been due to perceiving the Tango as easy to use, their having been trained to use it, and/or having a researcher to contact about questions or issues. Second, the usability of the Tango may not have been mentioned because of the nature of the interview questions or participants' comments. For example, they were not asked to evaluate the interface of the mower but were asked what they did and did not like about using the mower.

Third, even though participants reported that mowing their lawns was important to them, they did not mention criticality of task within the acceptance discussion. This may be because mowing the lawn was not viewed as a critical task. For example, one participant commented that there were more important things in life than mowing his lawn. Last, visibility was likely not mentioned by participants because the Tango was not sold in the United States. Therefore, participants could not see other people using the Tango in their daily lives (e.g., in neighbor's lawns).

Thus, these were not important enough for participants to mention them in this context. However, it is premature to remove these factors for from the framework for two reasons: (1) they were identified from a thorough synthesis of the literature (Smarr et al., 2013); and (2) results are from one study with 14 people's views of one personal robot performing one task in one environment. More research should be conducted to determine if these factors should be removed with larger samples, and different populations, personal robots, tasks, and environments. It is likely that future iterations of the framework will need to account for interactions among factors.

<u>New Factors to Consider</u>

Ten additional factors were mentioned by participants but were not in the framework, indicating that these factors may be considered for inclusion in the framework. The 10 factors were: person to person sociability; curiosity; frustration; decrease in physical capabilities; expectations of robot; cost of robot; security of robot; robot intelligence; and efficiency and speed of robot. These factors may not have been identified previously, because they were specific to the participants, the robot, the task, and/or the environment in this study.

In short, a majority of factors in the Smarr et al. (2013) framework was conceptually validated. However, there were opportunities to improve the framework to account for acceptance of the Tango: (1) to remove or hone factors that are in the framework that participants did not mention; and (2) to add factors that participants mentioned that were not in the framework. However, more research is needed before adding or removing factors from this theoretically-based framework of personal robot acceptance. Future research should extend this research to acceptance of other personal robots to determine if these factors are specific to this robot or to personal robots as a whole.

Although the usage study gave in depth insight into 14 people's level of acceptance a personal robot over time at their homes as well as the reasons why, it did not provide a broad understanding of acceptance. The next study was a survey conducted with a larger sample to better generalize individuals' initial acceptance of a personal robot and to begin to test the Smarr et al. (2013) framework with statistics.

CHAPTER 4: SURVEY STUDY METHOD

The study described in this section took place over nine days during the summer of 2014 (June 23 – July 2). This section describes participants, apparatus and materials, and procedures used in the online survey study.

Participants

Three hundred and six participants completed an online survey. Of the 306 respondents, 26 outliers were removed from analyses because they were more than two standard deviations above or below the sample mean for time to complete the survey, accuracy of perceptions of the text manipulation and video, robot experience, and/or technology experience. No patterns were observed for outliers (e.g., outliers occurred in all conditions). Therefore, a total of 280 participants were included in subsequent analyses. Participants were compensated with 50 SocialSci points for completing the survey, which took an average of 22.35 min (*SD* = 23.79; see the next section for details on SocialSci). Three hundred points can be redeemed for a $5.00 gift card.

Participants were randomly assigned to one of nine experimental conditions that manipulated a robot mower's reliability and communication of feedback. See Table 4.1 for details on participants' characteristics in total and by experimental condition. No statistically significant differences among the groups were found using a Pearson Chi-square test for association and a Bonferroni corrected (α = .004) 3 (reliability) x 3 (communication of feedback) MANOVA.

The following trends were observed for participants (Table 4.1 for details). The gender distribution of participants was roughly equal (51% female, 49% male). Most participants identified themselves as non-Hispanic, white/Caucasians who spoke English as their primary language. A majority of them were either single or married. They mainly worked full-time or were students. They lived in all nine climate-based regions of the United States, but nearly one third of them were from the Northeast region. Participants ranged in age from 18 to 69 years old but were largely in their 20s and 30s. Participants were highly educated as nearly 90% had completed at least some college or Bachelor's degrees. Most participants self-reported they were in good or very good health. Of the 251 participants who specified their annual household income, they ranged from less than $25,000 to more than $200,000, with most participants indicating their household income was between $25,000 and $99,999.

Table 4.1

Survey Participant Demographics by Experimental Condition and Overall

	Experimental Condition (Reliability/Communication)									
Demographics	**90%/ 1-way**	**90%/ 2-way**	**90%/ No info**	**70%/ 1-way**	**70%/ 2-way**	**70%/ No info**	**No info/ 1-way**	**No info/ 2-way**	**No info/ No info**	**Total**
Number of participants	30	30	29	32	30	33	33	32	31	280
% Females‡	50.00	46.67	34.48	59.38	43.33	69.70	48.48	53.13	54.84	51.43
% White/Caucasian	83.33	77.42	86.21	65.63	80.00	78.79	87.88	75.00	74.19	78.65
% Hispanic/Latino	3.33	3.33	0.00	3.13	10.00	9.09	6.06	6.25	3.23	5.00
% English was primary language	96.67	100.00	96.55	93.75	100.00	100.00	96.97	100.00	93.55	97.50
% Single	46.67	70.00	41.38	59.38	73.33	75.76	54.55	62.50	58.06	60.36
% Married	43.33	30.00	48.28	37.50	26.67	18.18	33.33	34.38	32.26	33.57
% Work full-time	43.33	33.33	55.17	56.25	56.67	36.36	48.48	43.75	41.94	46.07
% Student	26.67	33.33	20.69	15.63	26.67	36.36	21.21	28.13	35.48	27.14
M Age in years (*SD*)†	31.13 (10.42)	29.8 (11.60)	32.83 (10.89)	27.97 (7.55)	28.40 (7.84)	31.45 (11.19)	31.94 (10.63)	30.94 (11.88)	28.68 (10.18)	30.35 (10.33)
M Education completed (*SD*)†*	5.60 (1.25)	5.20 (1.19)	6.17 (0.85)	5.75 (1.22)	5.60 (0.86)	5.39 (1.12)	5.70 (1.31)	5.44 (1.39)	5.68 (1.22)	5.61 (1.18)
M Self-reported health (*SD*)†**	3.10 (0.99)	3.43 (1.07)	3.79 (0.86)	3.38 (0.83)	3.43 (0.73)	3.52 (0.97)	3.48 (0.83)	3.44 (0.98)	3.45 (0.93)	3.45 (0.92)

Table 4.1 continued

	Experimental Condition (Reliability/Communication)									
Demographics	**90%/ 1-way**	**90%/ 2-way**	**90%/ No info**	**70%/ 1-way**	**70%/ 2-way**	**70%/ No info**	**No info/ 1-way**	**No info/ 2-way**	**No info/ No info**	**Total**
M Household income***†	2.81 (2.90)	2.96 (2.91)	3.85 (2.56)	2.97 (1.94)	2.70 (2.71)	2.47 (2.79)	2.86 (3.34)	2.64 (3.17)	3.58 (3.36)	2.97 (1.58)

Note. ‡ No statistically significant differences in gender among conditions were found using a Pearson Chi-Square test (χ^2 (8) = 9.93, p = 0.27).

† No statistically significant differences among the conditions were found from a 3 (reliability) x 3 (communication) MANOVA after Bonferroni correction (α = .004).

* Response scale education completed: 1-no formal school; 2-less than high school; 3-high school graduate/GED; 4-vocational training; 5-some college/associate's; 6-bachelor's; 7-master's; 8-doctoral.

** Response scale health: 1-poor; 2-fair; 3-good; 4-very good; 5-excellent.

*** Response scale household income: 1-Less than $25,000; 2-$25,000-$49,999; 3-$50,000-$74,999; ...; 8-$175,000-$199,999; 9 = $200,000 or more; 10-Do not know for certain; 11-Do not wish to answer. Calculations are based on 251 participants' responses, because the latter two response options were not included.

Recruitment

Participants were recruited from SocialSci (www.socialsci.com). SocialSci is an online service that has "communities" of people interested in completing surveys; "communities" are self-defined. This study's survey was listed on the SocialSci homepages of people that were eligible for this study. Eligible people were members of the "community" who had reported to SocialSci that they were 18-59 years old (although some were actually older), living in the United States, and read English. To participate in the survey, respondents self-reported that they met the all of the following criteria:

- 18-69 years old
- Lived in the United States
- Fluent in reading English
- Lived in a home with a lawn
- Someone in the participant's household – or the participant himself or herself – were responsible for mowing the lawn by either mowing it themselves or having someone else mow the lawn (e.g., a lawn service)

Apparatus and Materials

All materials used in this study, except for the video, are in Appendix L. The video is available upon request from the author.

Study Listing

To recruit participants, a survey listing was posted to SocialSci homepages of eligible members of their community (Appendix L). The listing contained the study's title, description (purpose, overview of procedure), eligibility criteria, estimated time to complete, compensation, and the number of participants left before it closed. In the description, participants were informed that the purpose of this study is to better understand people's opinions of lawn mowers. To mitigate self-selection biases for or against robots, participants were not informed that they would be learning about a robot lawn mower. They were also instructed to complete the survey in one sitting otherwise their responses would not be saved and they would not be compensated.

Stimuli

Each participant learned about a robot mower through a text description and a video.

Text Descriptions of Robot Mower

Participants were instructed to “carefully read the description of the robot mower” and that they “may continue to the next page once the timer runs out”. A timer was used to mitigate participants accidentally going to the next page or not reading the description. Specifically, they could not proceed to the next page until the timer elapsed for the following sections of the description: 30 seconds (sec) for no information, 15 sec for reliability, and 15 sec for communication (Table 4.2). They could not revisit previous pages within the survey, because the previous page button was turned off during the survey.

The text description of the robot mower was the same for all participants except for the robot’s level of reliability and communication of feedback. The text after Table 4.2 is the stimuli participants were shown, and Table 4.2 details how the sections of text combine together depending on which group a participant was randomly assigned.

Table 4.2

Sections of Text Corresponding to What Each Group of Participants were Shown

		Communication of Feedback		
		No Info	**One-Way**	**Two-Way**
Reliability	**No Info**	• No Information	• No Information • One-Way Communication	• No Information • Two-Way Communication
	Low	• No Information • Reliability –70%	• No Information • Reliability –70% • One-Way Communication	• No Information • Reliability –70% • Two-Way Communication
	High	• No Information • Reliability –90%	• No Information • Reliability –90% • One-Way Communication	• No Information • Reliability –90% • Two-Way Communication

Note. Info = information.

No Information

Robot mowers are design to help people with mowing their lawns. A robot mower is a machine that cuts the grass (i.e., mows) in your lawn with or without your help. They are currently for sale in Europe but are not yet for sale in the United States. We are interested in finding out more about what people, such as you, think about robot mowers helping them mow their lawns. But first, let us tell you a little about how robot mowers work and some of their features.

A robot mower performs 5 basic tasks during the times you have scheduled the robot to mow:

1. the robot mower leaves its charging station
2. it mows the grass within a preset area
3. it finds its charging station when its battery gets low
4. it pulls into its charging station
5. it re-charges its battery until full while in its charging station

The robot mower will repeat these 5 steps during the times you have scheduled the robot to mow. During the times you do not schedule the robot to mow, the mower will stay in its charging station.

Reliability

> *Of note, X% is 70% for low reliability and 90% for high reliability groups respectively.*
>
> Robot mowers are designed to be safe and dependable, but they can still make errors. The robot mower can complete all of its 5 basic tasks correctly X% of the time. Here are some examples:
>
> 1. the robot mower will correctly leave its charging station when it is scheduled to X% of the time
> 2. the robot mower will correctly mow the grass within a preset area X% of the time
> 3. the robot mower will correctly find its charging station when its battery gets low X% of the time
> 4. the robot mower will correctly pull into its charging station X% of the time
> 5. the robot mower will correctly re-charge its battery until full while in its charging station X% of the time

Communication

> *One-Way Communication (words in italics were not shown to participants)*
> To schedule when the robot mower should mow, you can program its schedule using a screen on the mower. For example, you may set it up to mow between 1:00pm and 4:00pm on three days of the week.
>
> *Two-Way Communication*
> To schedule when the robot mower should mow, you can program its schedule using a screen on the mower. For example, you may set it up to mow between 1:00pm and 4:00pm on three days of the week. If for some reason the robot mower cannot mow during its scheduled time, then the robot mower can also SEND YOU EMAILS about when it is mowing.

Video of Robot Mower

The same 2 min and 12 sec video of a computer-generated robot mower mowing a computer-generated lawn was shown to all participants (Table 4.3). The purpose of the video was to demonstrate what the robot mower could do for two reasons. First, in previous studies individuals, who knew little about a robot, reported having difficulty reporting their perceptions of it (Dario, Guglielmelli, Laschi, & Teti, 1999). Second, the video was chosen because it showed key tasks and was relatively neutral with respect to reliability and communication of feedback. However, the robot mower did not err during the video, which potentially implied high reliability to participants, and a close-up of the robot's user interface was shown, which potentially suggested a way for the robot and human to communicate.

The video file (.mp4) was uploaded to SocialSci and was presented to participants presented within the online survey. Participants were instructed to "carefully watch the whole video of the robot mower" and on how to make the video play. To mitigate respondents from proceeding through the survey without watching the video, the length of the video (2 min and 12 sec) elapsed before they could proceed to the next page of the survey. The video could only be played once to control for the number of times they could see the video. There was no audio to the video.

Table 4.3

Video Overview of the Robot Mower Mowing

Video Chapter		What was shown
	*Close-up of robot mower*	Wheel-level close-up of actual robot mower
	*Bird's eye view of robot performing tasks during one battery charge*	Mowing grass; avoiding obstacles; staying within the boundary; following boundary wire; finding charging station; pulling into station
	*Robot charging*	Close-up of robot's display screen and buttons while robot was charging
	*Bird's eye view of robot performing tasks over several charges*	Starting to mow at a preset location in lawn; mowing in rain and at night; mowing boundary of lawn

Note. The video was adapted with permission from Deere & Company.

Survey

The survey consisted of seven sections used (1) to determine eligibility for the study; and to measure (2) perceptions of the robot mower; (3) robot acceptance; (4) robot experience; (5) technology experience; (6) demographics and health; and (7) lawn mowing background. The survey is in Appendix L.

Study Eligibility

The purpose of this section was to assess whether participants were eligible to participate in this study. Participants were asked whether they were between 18 and 69 years of age, currently lived in the United States, fluent in reading English, currently lived at a home with a lawn, and someone lived in their home was responsible for making sure the grass was mown. Participants responded to each question using "yes" or "no". Participants were eligible if they responded "yes" to all questions.

Perceptions of Robot Mower

The perceptions of the robot mower section collected information on participants' thoughts on the reliability of the robot mower, how to schedule the mower, and what the mower did in the video. The purpose of this section was to measure participants' perceptions of the robot mower after reading a text description and watching a video of it. Multiple choice response scales were used.

Robot Acceptance

The robot acceptance section of the survey was similar to the robot mower opinions questionnaires used in the usage study. The robot acceptance section was intended to measure participants' attitudinal and intentional acceptance of robot mowers. It also was intended to measure characteristics of the human (e.g., perceived enjoyment), robot (e.g., appearance), and context (e.g., compatibility with physical environment) important for acceptance of robot mowers. See Appendix M for items used and if applicable, where adapted.

Attitudinal acceptance was measured using three 5-point semantic differential scales adapted from Ezer (2008). Intentional acceptance was assessed using three 5-point semantic differential scales and one multiple-choice item (i.e., yes, no, unsure) adapted from Ezer (2008).

The remainder of the section measured participants' impressions of the robot for 10 factors of the human, robot, and context: perceived usefulness, perceived ease of use, robot anxiety, perceived sociability, perceived enjoyment, robot trust, compatibility with values, compatibility with physical environment, appearance, and task-technology fit. Eight characteristics that were assessed in the usage study were omitted, because they were not in the Smarr et al. (2013) framework (i.e., emotional attachment, anthropomorphism, tablet method of control), materials testing indicated that people who had not used the robot did not know how to answer (i.e., trialability, visibility, method of control, usability), or it was assessed elsewhere (i.e., perceived reliability). New items were added to those from the survey study so that each factor was assessed by at least 5 items and a secondary iterative reliability analysis could be conducted to inform future research.

To measure participants' perceptions of the robot's usefulness and ease of use, participants responded to 12 items adapted from Davis (1989) and Smarr et al. (2014) using a 7-point Likert-type scale (1 = Extremely Unlikely, 4 = Neither, 7 = Extremely Likely). The remaining characteristics were measured through participants' responses on a 7-point Likert-type scale (1 = Strongly Disagree, 3 = Neither Disagree or Agree, 7 = Strongly Agree). Details on items measuring each factor and their adaptation source (if applicable) are in Appendix M.

Robot Experience

The robot experience section of the survey was the same as the robot experience questionnaire in the usage study (adapted from Smarr et al., 2014). Its purpose was to measure participants' familiarity with and usage of 14 different robots. For each robot listed, participants indicated their level of familiarity and usage on a 5-point Likert-type scale from 0 (not sure what this is) to 4 (have used or operated this robot frequently).

Technology Experience

The technology experience section of the survey measured the frequency which participants have used technology within the last year (adapted from Barg-Walkow et al., 2014). Four technologies related to communication were assessed (desktop/laptop computer, tablet computer, smart phone, and email), because these technologies were related to email, which was mentioned in text descriptions of the robot mower in the two-way communication experimental conditions. For each technology listed, participants indicated their experience within the last year on a 5-point Likert-type scale (1 = not sure what it is, 5 = used frequently).

Demographics and Health

The demographics and health section of the survey captured information about the participants, including gender, age, education, ethnicity, race, primary language, occupation status, marital status, household income, and geographic region of residence in the United States. A health question collected information on participants' self-reported general health. Participants answered using multiple choice and short, free-responses.

Lawn Mowing Background

The lawn mowing section assessed participants' experience with mowing lawns (i.e., how long they have mown grass, who mows their lawn the most in the last year, types of mowers currently using), the size of their property, and their perceptions of lawn mowing (i.e., satisfaction, importance). Participants answered using multiple choice and short, free-responses.

Research Design

The description of the robot was manipulated in a 3 (robot's reliability: 90%, 70%, no information) x 3 (robot's communication of feedback: 2-way, 1-way, no information) between-subjects design. Each participant was randomly assigned to one of the nine conditions. The dependent variables were participants' responses to survey items assessing attitudinal acceptance, intentional acceptance, and human, robot, and context factors important for acceptance.

Procedure

The study's description was listed on the homepage of adults within SocialSci "communities" who were eligible for this study. In the description, these potential participants were informed that their participation would help us better understand adults' opinions about lawn mowers and that the study would take approximately 30 minutes to complete. They were also instructed to finish the study in one sitting. Participants were then asked to read through a consent form and were informed that by completing the survey they were agreeing to participate in the study. To preserve anonymity, participants never provided their names during the study and their internet protocol addresses was never stored by SocialSci.

Next, participants completed questions determining their eligibility for the study. If a participant answered a question indicating he or she was ineligible for the study, he or she was immediately removed from the study. Ineligible participants were thanked for their time but informed that they did not qualify for the study.

If a participant was eligible, then he or she was randomly assigned to one of the nine experimental conditions. They then were instructed to carefully read a text description of a robot lawn mower, which was manipulated based on what experimental condition they were randomly assigned to. While reading the description, a timer had to elapse before a participant could go to the next page in the survey. Depending on the condition participants were assigned to (Table 4.2 for what pages match the condition), 30 sec had to elapse on the “no information” text description page before proceeding, 15 sec for “reliability”, and 15 sec for “communication”. They could not revisit previous pages of the survey.

Next, all participants were instructed to carefully watch the entire video of the robot mower mowing. After the video, participants were asked to answer questions about their perceptions of the mower, robot acceptance, robot experience, technology experience, demographics and health, and lawn mowing background. Finally, participants were thanked, debriefed, and compensated. During the debriefing, they were informed that there were no right or wrong answers and that their answers were kept anonymous. Researchers’ contact information was also given to participants if they had any questions or issues.

CHAPTER 5: SURVEY STUDY ANALYSES, RESULTS, AND DISCUSSION

Overview of Analyses

The observed ratings were aggregated into scale scores that measured common variance using a classical test theory approach and did not assume latent constructs. The scale scores were labeled for operational purposes. Descriptive statistics were conducted using Microsoft Excel 10 and Excel 2007. Statistical tests were conducted using IBM SPSS Statistics 21 and 22, and Base SAS 9.4. Unless noted otherwise, alpha was set at $p < .05$ for all statistical tests. Bonferroni corrections were used when appropriate to control for type 1 error.

Characteristics of Participants

Robot Experience

Robot experience was important to describe, because it can impact participants' attitudes toward a robot (Broadbent et al., 2010; Stafford et al., 2010). Participants indicated their experience with 14 different robots (0 = Not sure what it is; 1 = Never heard about, seen, or used this robot; 2 = Have only heard about or seen this robot; 3 = Have used or operated this robot only occasionally; 4 = Have used or operated this robot frequently). Responses were averaged across all 14 robots for each participant and then averaged across participants to compute a Frequency Profile Score (adapted from Barg-Walkow et al., 2014 for 14 robots).

Overall, participants indicated they had heard about or seen robots but had not used them ($M = 1.58$, $SD = 0.43$). No significant differences in robot experience were found among the experimental conditions using a 3 (reliability) x 3 (communication of feedback) MANOVA with Bonferroni correction ($\alpha = .004$). This lack of direct experience with robots has been commonly reported by participants in HRI studies (e.g., Smarr et al., 2014; Stafford, MacDonald, & Broadbent, 2012).

Technology Experience

Participants indicated their experience with four technologies within the last year using a 5-point Likert-type scale (1 = Not sure what it is, 2 = Not used, 3 = Used once, 4 = Used occasionally, 5 = Used frequently): desktop/laptop computers, tablet computers, phones, and email. Responses were recoded to combine the first two response options (0 = Not used, 1 = Used once, 2 = Used occasionally, 3 = Used frequently). Recoded responses were averaged across all technologies for each participant and then averaged across participants to compute the Frequency Profile Score (adapted from Barg-Walkow et al., 2014 for a subset of technologies).

On average, participants reported using these technologies frequently ($M = 2.63$, $SD = 0.49$). No statistically significant differences in technology experience were found among the experimental conditions using a 3 (reliability) x 3 (communication of feedback) MANOVA with Bonferroni correction ($\alpha = .004$).

Lawn Mowing Background

Participants' lawn mowing background was measured to describe the context in which they viewed the task. Appendix N contains details on participants' mowing background in total and by experimental condition. No statistically significant differences among the conditions were found using a 3 (reliability) x 3 (communication of feedback) MANOVA with Bonferroni correction ($\alpha = .004$). The following trends were observed. Over 90% of participants reported ever mowing grass. They indicated a range of experience in mowing their lawns, but over a third of them had mowed grass for over 10 years. Participants reported that either they or someone they live with mowed their lawns most often. Many participants currently live on properties less than 0.5 acres and use a walk behind gas mower to cut their grass. Although one mower type was used most often, some participants used multiple types of mowers (e.g., riding gas, walk behind electric). They perceived mowing their grass as important and that they were satisfied with it.

Robot Mower Perceptions

Participants reported their perceptions of the robot mower's reliability after watching a video of the robot mower via a 5-point Likert-type scale (60%, 70%, 80%, 90%, and 100%). Responses were averaged for each reliability condition (Figure 5.1). According to two Bonferroni corrected one-sample t-tests ($\alpha = 0.025$), participants reported significantly lower perceived reliability compared to the 90% they were told in the text description ($t\ (88) = -2.29$, $p = .024$; Figure 5.1). There was no significant difference between participants' perceived reliability in the 70% reliability condition and 70% ($t\ (94) = 1.30$, $p = .20$; Figure 5.1). These findings suggest that the reliability manipulation was successful for participants in the 70% reliability condition but not for those in the 90% condition. Participants in the no information reliability condition reported the average reliability of the robot as 82.71% (Figure 5.1).

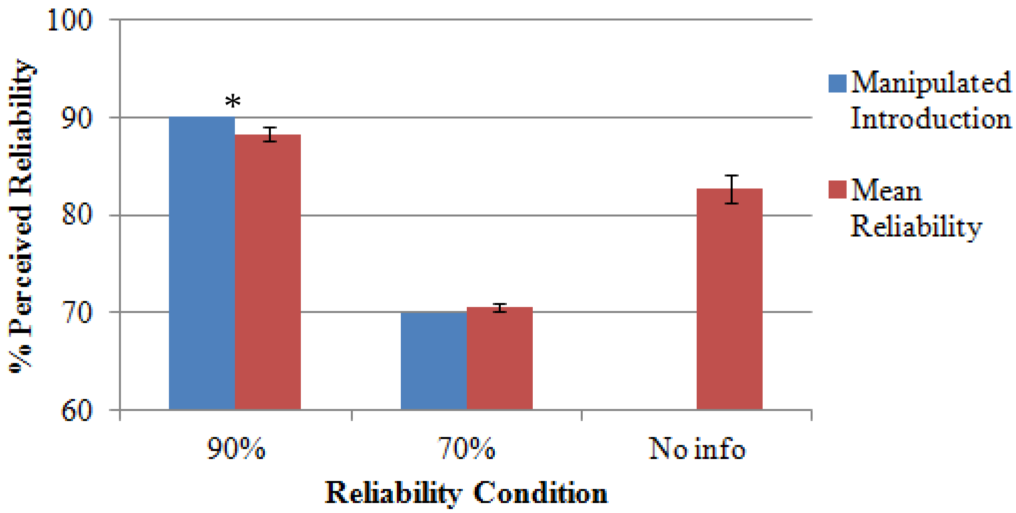


Figure 5.1 Perceived reliability of robot mower by reliability condition. Error bars are standard error of the mean. Info = information. * $p < .05$.

Personal Robot Acceptance

Attitudinal acceptance was measured via three semantic differential scales (1 = negative attitude, 5 = positive attitude) and then averaged. Participants indicated they were neither positive nor negative toward the robot mower ($M = 3.06$, $SD = 1.30$).

Intentional acceptance was assessed using three semantic differential scales (1 = low intention, 5 = high intention) as well as one multiple-choice item (yes, no, or unsure) asking if they would purchase the robot mower if it were available. Averaging across the semantic differential scales, participants had relatively low intention to purchase a robot mower for their homes ($M = 2.31$, $SD = 1.31$). Moreover, 54% of participants said they would not purchase the robot mower, 27% said they were unsure, and 19% said that they would purchase the robot.

Attitudinal acceptance and intentional acceptance were respectively averaged across their three semantic differential items. A 3 (reliability) x 3 (communication of feedback) MANOVA was conducted with attitudinal and intentional acceptance as the dependent variables. After Bonferroni correcting ($\alpha = .025$), the main effect of communication and interaction of reliability and communication were not statistically significant. However, there was a statistically significant main effect of reliability (*F* (4,542) = 3.07, $p = .016$, $\eta_p^2 = .022$). Tukey's HSD comparisons indicated that there were no statistically significant differences between reliability conditions for either attitudinal or intentional acceptance ($p > .025$).

A canonical variate analysis suggested that canonical variable 1 primarily measured intentional acceptance via a correlation of 0.997 ($C_1 = 0.845i – 0.091a$, where i = intentional acceptance and a = attitudinal acceptance). Canonical variable 2 primarily measured attitudinal acceptance via a correlation of 0.721 ($C_2 = -0.812i + 1.185a$).

The following two *non-significant trends* were observed for reliability. First, participants who were told the robot mower was 70% reliable had lower attitudinal acceptance of the robot ($M = 2.84$, $SD = 1.29$) than those who received no information on the robot's reliability ($M = 3.30$, $SD = 1.31$; $p = 0.029$). Second, participants who were told the robot mower was 90% reliable had lower intentional acceptance of the robot ($M = 2.10$, $SD = 1.20$) compared to those who received no information about the robot's reliability ($M = 2.59$, $SD = 1.37$; $p = 0.035$). Henceforth, the experimental conditions are combined in analyses, because there was little support for main effects or interactions of the robot's reliability or communication of feedback on attitudinal or intentional acceptance.

Statistical Validation of Framework

As a step toward beginning to understand the applicability of the Smarr et al. (2013) framework, three analyses were conducted: (1) path analysis on the original items (i.e., items used in the usage and survey study); (2) reliability analysis with original and new items; and (3) path analysis on reliable items. Analyses were conducted in this way to adhere to statistical ethics and practices of not refining measures and testing measures on the same sample (Cureton, 1950). The first analysis was conducted to determine how well the Smarr et al. (2013) framework explains acceptance. The latter two analyses were conducted as an exploration of items and factors to be used in future studies as well as their relationships.

A path analysis was conducted to begin to understand the Smarr et al. (2013) framework explains individuals' initial attitudinal and intentional acceptance of a personal robot. It was chosen over ordinary regression analysis, because path analysis allows simultaneous testing of both direct and indirect effects of one factor on another to be measured (Asher, 1983). Also, path analysis was selected over structure equation modeling, because the observed ratings were not assumed to measure latent constructs and as such, were aggregated as observed scale scores labeled for operational purposes. Finally, this approach is consistent with analyzing robot and technology acceptance (e.g., Dishaw & Strong, 1999; Heerink et al., 2010a).

Path Analysis 1 – Original Items

Each variable was formed by summing the responses to the appropriate items for each participant; no data were missing. Only responses to the 63 original items (i.e., items that were also used in the usage study) were summed into 12 variables. Responses were then standardized and a maximum likelihood path analysis was conducted. Although the path analysis did not show a good fit to the data ($\chi^2 = 252.56$, $df = 30$, $p < 0.0001$; Comparative Fit Index [CFI] = 0.92; Standardized Root Mean Square Residual [SRMR] = 0.09; interpretation of fit followed guidelines from Hu & Bentler, 1999), it did explain much of the variance in intentional and attitudinal acceptance, which was the main focus of this investigation. Future research should consider refining the model (e.g., adding and removing paths) so that it better fits the data.

The amount of variance in intentional acceptance explained by the framework was 60.42% (Figure 5.2). This is greater than the approximately 40% of variance that technology acceptance models typically account for in intentional acceptance

(Venkatesh et al., 2003). However, it is within the range of variance explained by the Almere model of robot acceptance (59%-79%; Heerink et al., 2010a). Additionally, the amount of variance explained by this study's framework was 56.84% of attitudinal acceptance, 55.82% of perceived ease of use, 59.31% of perceived usefulness, and 69.02% of perceived enjoyment.

Of the 15 paths that were tested in the framework (not including error variances), 10 of the paths were statistically significant (Figure 5.2, Table 5.1). All 10 significant paths were in the positive direction, which supports the relationships in the Smarr et al. (2013) framework. For example, the value of 0.35 from perceived ease of use to attitudinal acceptance means that if participants increased mean perceived usefulness by one standard deviation, but everything else was kept the same, their attitudinal acceptance would increase by 0.35 of a standard deviation. In other words, participants who perceived the robot as easier to use also had a more positive attitude toward using it.

Of the five paths that were non-significant in the framework, they were either determinants of perceived ease of use or usefulness respectively (Figure 5.2, Table 5.1). Specifically, the non-significant determinants of perceived ease of use were robot anxiety and perceived enjoyment. Moreover, the non-significant determinants of perceived usefulness were robot trust, result demonstrability, and compatibility with values. All five paths were hypothesized to be significantly positive, except for the path from robot anxiety to perceived ease of use, which was hypothesized to be significantly negative.

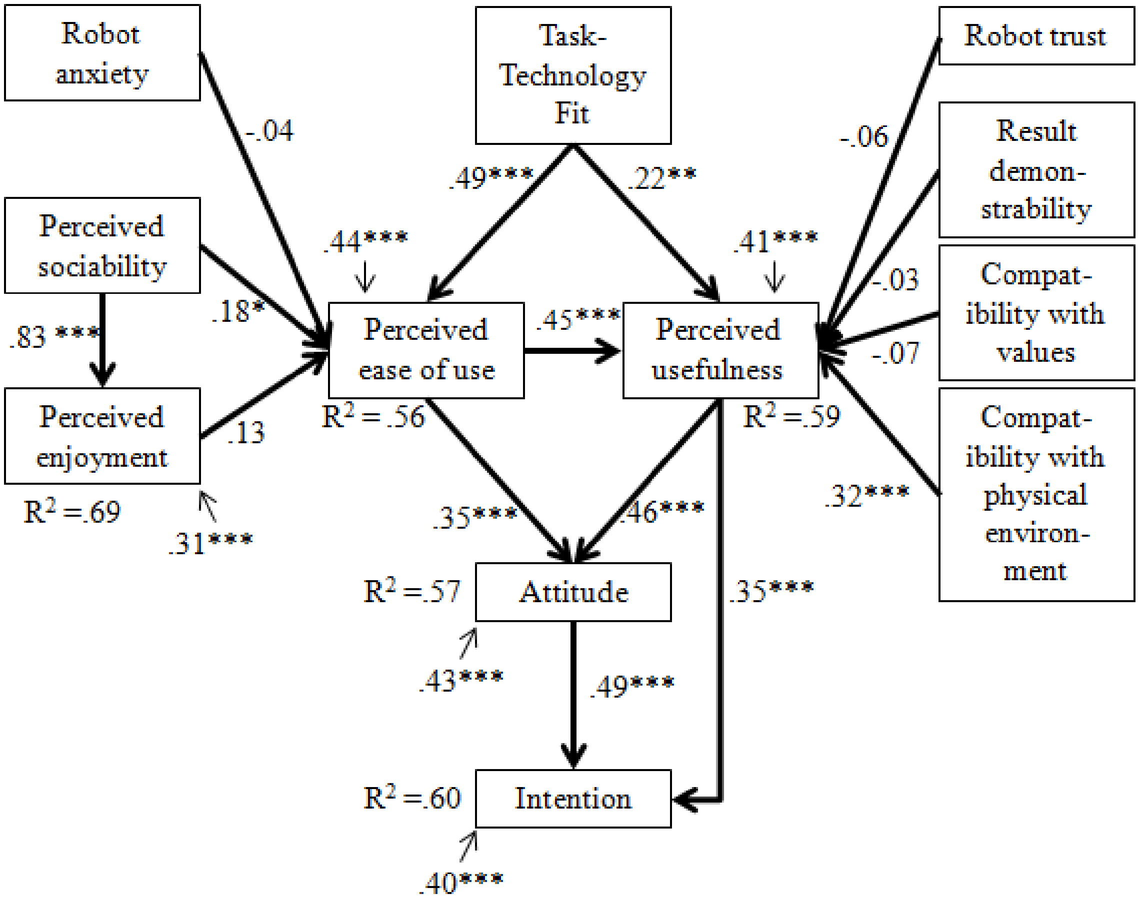


Figure 5.2 Path model of original items (i.e., items that were assessed in both the usage and survey studies). Data are from survey study only (n = 280). Standardized partial regression weights are on paths. Error variances indicate the amount of unexplained variance in endogenous variables. *p < .05. **p < .02. ***p < .001.

Table 5.1

Results of Path Analysis of Original Items

Independent Variable	Dependent Variable	Standard Path Estimate	SE of Estimate	*t*
Perceived sociability	Perceived enjoyment	0.83	0.02	44.80***
Attitude	Intention	0.49	0.05	9.71***
Perceived usefulness	Attitude	0.46	0.05	8.90***
Perceived ease of use	Perceived usefulness	0.45	0.05	8.51***
Task-Technology Fit	Perceived ease of use	0.49	0.06	8.41***
Perceived usefulness	Intention	0.35	0.05	6.63***
Perceived ease of use	Attitude	0.35	0.05	6.63***
Compatibility with physical environment	Perceived usefulness	0.32	0.05	6.07***
Task-Technology Fit	Perceived usefulness	0.22	0.08	2.58**
Perceived sociability	Perceived ease of use	0.18	0.08	2.28*
Perceived enjoyment	Perceived ease of use	0.13	0.07	1.82
Result demonstrability	Perceived usefulness	-0.03	0.05	-0.70
Robot trust	Perceived usefulness	-0.06	0.07	-0.85
Robot anxiety	Perceived ease of use	-0.04	0.05	-0.92
Compatibility with values	Perceived usefulness	-0.07	0.05	-1.53
Residual Variance				
Perceived ease of use	Perceived ease of use	0.44	0.04	11.19***
Attitude	Attitude	0.43	0.04	11.10***
Perceived usefulness	Perceived usefulness	0.41	0.04	10.89***
Intention	Intention	0.40	0.04	10.76***
Perceived enjoyment	Perceived enjoyment	0.31	0.03	10.05***
Compatibility with physical environment	Compatibility with physical environment	1.00		
Compatibility with values	Compatibility with values	1.00		
Perceived sociability	Perceived sociability	1.00		
Result demonstrability	Result demonstrability	1.00		
Robot anxiety	Robot anxiety	1.00		
Robot trust	Robot trust	1.00		
Task-Technology Fit	Task-Technology Fit	1.00		

Note. All the paths in the path analysis SAS PROC CALIS added accounted for all the correction between pairs of exogenous variables. **p* < .05. ***p* < .02. ****p* < .001.

Reliability Analysis

To understand the internal consistency of 12 scale scores, Cronbach's alphas were calculated on 81 items, including 63 original items (i.e., assessed in both usage and survey studies) and 18 new items (Table 5.2). All scales had acceptable internal consistency with Cronbach's alphas ranging from 0.75 to 0.98.

To maximize the internal consistency of the scales, an iterative reliability analysis was conducted. After Cronbach's alphas were computed for the 12 scale scores with all 81 items, then the alphas were examined if an item was deleted from a scale. If the deletion of an item improved Cronbach's alpha for a scale, then that item was deleted before computing alphas in the next round. If the deletion of an item did not improve the internal consistency, then no items were deleted. This continued until no items if deleted would improve internal consistency, which took four rounds.

A total of 11 items were deleted to improve internal consistency of individual scales by 0.004 to 0.036 (Table 5.2). Yet, the range of Cronbach's alphas for the cleaned scales remained the same (0.75-0.98). Moreover, 1-3 items were deleted from six out of 12 scales (perceived enjoyment; compatibility with physical environment; robot anxiety; task-technology fit; robot trust; and compatibility with values). In contrast, no items were deleted from the other six scales during this analysis (intentional acceptance; perceived usefulness; attitudinal acceptance; perceived ease of use; perceived sociability; and result demonstrability).

Table 5.2

Results of Reliability Analysis and Comparison to Literature

	Cleaned Scales						
Scale	**# of Total Items**	**# New Items within Total**	**Cron-bach's α**	**# of Total Items Re-moved**	**# of New Items Re-moved**	**Improv-ement of Cron-bach's α**	**Cron-bach's α in Lit-erature**
Intentional acceptance	3	0	0.98	0	0	0	0.96
Perceived usefulness	6	0	0.98	0	0	0	0.98
Attitudinal acceptance	3	0	0.97	0	0	0	0.91
Perceived enjoyment	6	3	0.96	2	2	0.018	0.89
Perceived ease of use	6	0	0.95	0	0	0	0.94
Compatibility with physical environment	3	1	0.94	3	2	0.011	0.96†
Robot anxiety	6	3	0.94	2	1	0.004	0.84
Task-technology fit	18	0	0.93	2	0	0.005	0.93†
Robot trust	4	2	0.93	1	0	0.019	0.73-0.82
Compatibility with values	5	0	0.91	1	1	0.036	0.70†
Perceived sociability	5	2	0.88	0	0	0	0.71-0.89
Result de-monstrability	5	1	0.75	0	0	0	0.84

Note. See Appendix M for where items were adapted from in the literature.
† Cronbach’s alpha was obtained from the usage study Pre-Use Interview.

Path Analysis 2 – Reliable Items

Each variable was formed by summing the responses to the appropriate items for each participant. Responses to 70 reliable items were included. Responses were then standardized and a maximum likelihood path analysis was conducted. The path analysis did not show a good fit to the data ($\chi^2 = 261.07$, $df = 30$, $p < 0.0001$; CFI = 0.91; SRMR = 0.09; Hu & Bentler, 1999), but it did well for the main focus of this analysis, which was to explain variance in acceptance.

The amount of variance in intentional acceptance explained by the framework was 60.23% (Figure 5.3). Furthermore, the amount of variance explained by the framework was 56.85% of attitudinal acceptance, 55.67% of perceived ease of use, 58.91% of perceived usefulness, and 69.42% of perceived enjoyment. These findings were similar to those from path analysis 1.

Nine of the 15 paths tested in the framework were significant besides the error variances (Figure 5.3, Table 5.3). Eight of the nine significant paths in this path analysis were also significant in path analysis 1. In contrast, there were three main differences in standardized partial regression weights between the two path analyses (Table 5.3): (1) the path from task-technology fit to perceived usefulness is non-significant in this analysis; (2) the path from perceived sociability to perceived ease of use is non-significant in this analysis; and (3) the path from perceived enjoyment to perceived ease of use is significant in this analysis ($p < 0.02$).

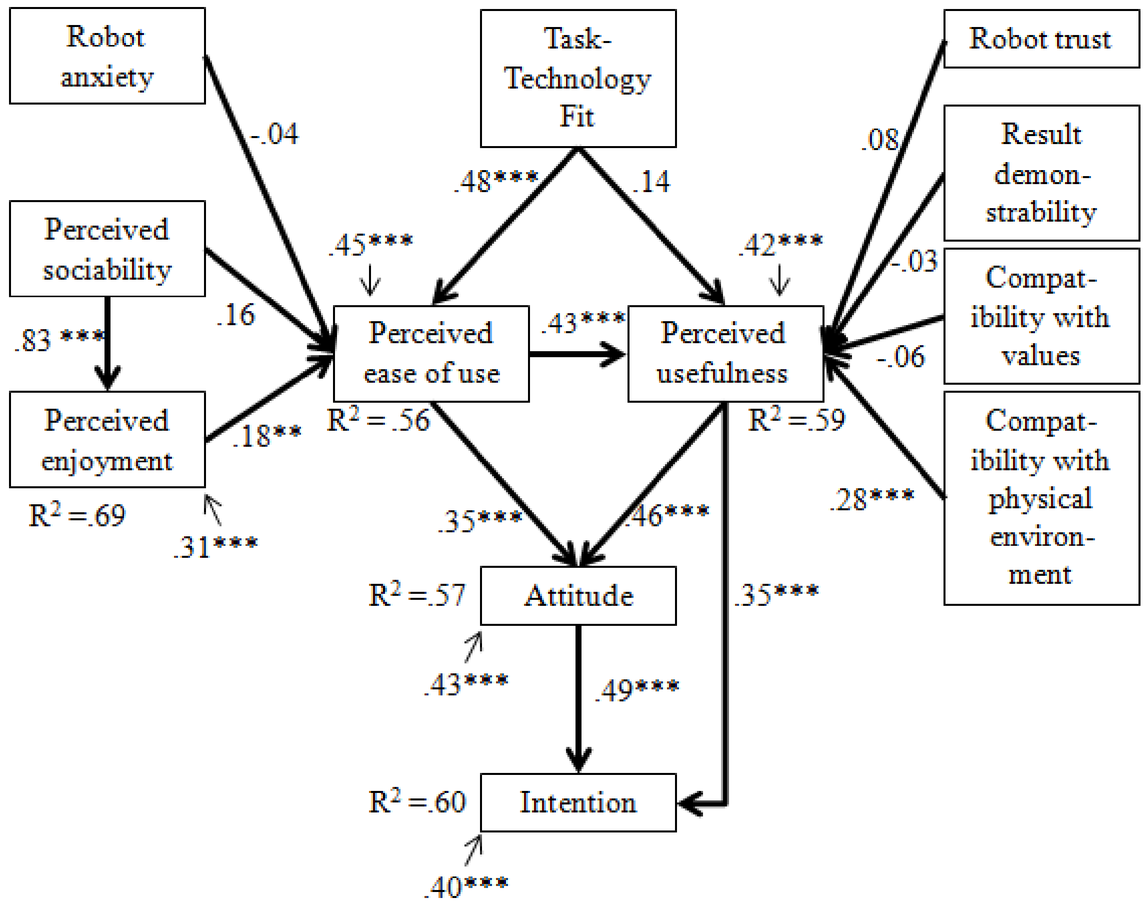


Figure 5.3 Path model of reliable items. Standardized partial regression weights are on paths. Error variances indicate the amount of unexplained variance in endogenous variables. $*p < .05$. $**p < .02$. $***p < .001$.

Table 5.3

Results of Path Analysis of Reliable Items

Independent Variable	Dependent Variable	Standard Path Estimate	SE of Estimate	*t*
Perceived sociability	Perceived enjoyment	0.83	0.02	44.32***
Attitude	Intention	0.49	0.05	9.71***
Perceived usefulness	Attitude	0.46	0.05	8.95***
Perceived ease of use	Perceived usefulness	0.43	0.05	8.07***
Task-Technology Fit	Perceived ease of use	0.48	0.06	8.31***
Perceived usefulness	Intention	0.35	0.05	6.63***
Perceived ease of use	Attitude	0.35	0.05	6.66***
Compatibility with physical environment	Perceived usefulness	0.28	0.05	5.10***
Task-technology fit†	Perceived usefulness	0.14	0.08	1.67
Perceived sociability†	Perceived ease of use	0.16	0.08	1.95
Perceived enjoyment‡	Perceived ease of use	0.18	0.07	2.44**
Result demonstrability	Perceived usefulness	-0.03	0.05	-0.57
Robot trust	Perceived usefulness	0.08	0.07	1.11
Robot anxiety	Perceived ease of use	-0.04	0.05	-0.79
Compatibility with values	Perceived usefulness	-0.06	0.05	-1.34
Residual Variance				
Perceived ease of use	Perceived ease of use	0.45	0.04	11.28***
Attitude	Attitude	0.43	0.04	11.12***
Perceived usefulness	Perceived usefulness	0.42	0.04	10.99***
Intention	Intention	0.40	0.04	10.77***
Perceived enjoyment	Perceived enjoyment	0.31	0.03	10.07***
Compatibility with physical environment	Compatibility with physical environment	1.00		
Compatibility with values	Compatibility with values	1.00		
Perceived sociability	Perceived sociability	1.00		
Result demonstrability	Result demonstrability	1.00		
Robot anxiety	Robot anxiety	1.00		
Robot trust	Robot trust	1.00		
Task-technology fit	Task-Technology Fit	1.00		

Note. All the paths in the path analysis SAS PROC CALIS added accounted for all the correction between pairs of exogenous variables. † Path was significant in path analysis 1 and is non-significant in this path analysis. ‡ Path was non-significant in path analysis 1 and is significant in this path analysis. *$p < .05$. **$p < .02$. ***$p < .001$.

Survey Study Discussion

The purpose of the survey study was to conduct a broad investigation of individuals' initial acceptance of a personal robot (i.e., Tango robot mower). Participants learned about this personal robot by reading a text description and by watching it perform tasks in a brief video. Two robot factors – reliability and communication of feedback – that were hypothesized to impact individuals' perceptions of the robot were manipulated between subjects in the text descriptions. The main goals of the study were to:

1. Measure individuals' initial intentional and attitudinal acceptance of a personal robot that would be used at their homes.
   a. For three levels of robot reliability (90%, 70%, no information).
   b. For three levels of robot's communication of feedback (two-way, one-way, no information).
2. Gain a broad understanding of the person, robot, task, and environment factors that are important for initial acceptance.
3. Statistically validate the Smarr et al. (2013) framework of personal robot acceptance.

Intentional and Attitudinal Acceptance

Participants were generally not very accepting of this personal robot. When participants were asked if they would purchase the robot mower for their homes, 54% of the participants would not, 27% were unsure, and 19% would purchase the robot. Overall, participants reported low intention to purchase the robot as well as neutral attitudes toward using the robot mower. Reasons for why participants had low acceptance can be explained, at least approximately 60% of it, by the significant relationships in the Smarr et al. (2013) framework. The following section details how much acceptance the framework explained as well as what factors directly and indirectly impacted acceptance.

Statistical Validation of Smarr et al. (2013) Framework

A main goal of the survey study was to start to assess how well the Smarr et al. (2013) framework accounted for what influences initial attitudinal and intentional acceptance of a personal robot. The framework was analyzed in three steps: (1) path analysis 1 of scales tested in both the usage and survey studies; (2) reliability analysis of those items and new items; and (3) path analysis 2 of scales constructed from only the reliable items from the reliability analysis. The aim of the last two steps was to explore items, factors, and relationships between factors for future studies.

To test the Smarr et al. (2013) framework, 12 scales (81 items total) were assessed, including attitudinal and intentional acceptance as well as factors identified as important for acceptance from a thorough review of the literature. The internal consistency of all 12 scales was acceptable both before and after conducting the reliability analysis (Cronbach's alphas ≥ 0.75), in which items were removed one at a time to improve internal consistency of the scales. Such high internal consistency is likely facilitated by adapting items from previous research on technology and robot acceptance (refer to Appendix M for adaptation sources).

Variance Explained by Framework

Both path analysis 1 and path analysis 2 explained similar amounts of variance in intentional acceptance, attitudinal acceptance, as well as perceived usefulness, ease of use, and enjoyment (Figure 5.4). Henceforth, trends for both path analyses will be discussed together.

The Smarr et al. (2013) framework explained a similar amount of variance in intentional acceptance (60%) to the Almere robot acceptance model (59%-79%;

Heerink et al., 2010a) and more variance than is usually explained by technology acceptance models (e.g., TAM 40%, TAM3 40%-53%, Task-Technology Fit Model 41%, and Task-Technology Fit Model + TAM 51%; Legris et al., 2003; Venkatesh & Bala, 2008; Venkatesh et al., 2003; Sun & Zhang, 2006b). Moreover, the Smarr et al. (2013) framework explained a majority of variance in attitudinal acceptance (57%), as well as perceived usefulness (59%), ease of use (56%), and enjoyment (69%). These findings suggest that the Smarr et al. framework can account for what impacted most of the intentional acceptance of this personal robot (i.e., Tango robot mower).

Relationships Supported

Eleven of the 15 relationships tested in the Smarr et al. (2013) framework were at least partially supported (Figure 5.4). That is, eight relationships were fully supported (i.e., significant in both path analyses; see Table 5.4 for details and for support from the literature) whereas three relationships were partially supported (i.e., significant in only one path analysis; Table 5.4). Moreover, all relationships were in the direction predicted by the framework (i.e., positive relationships).

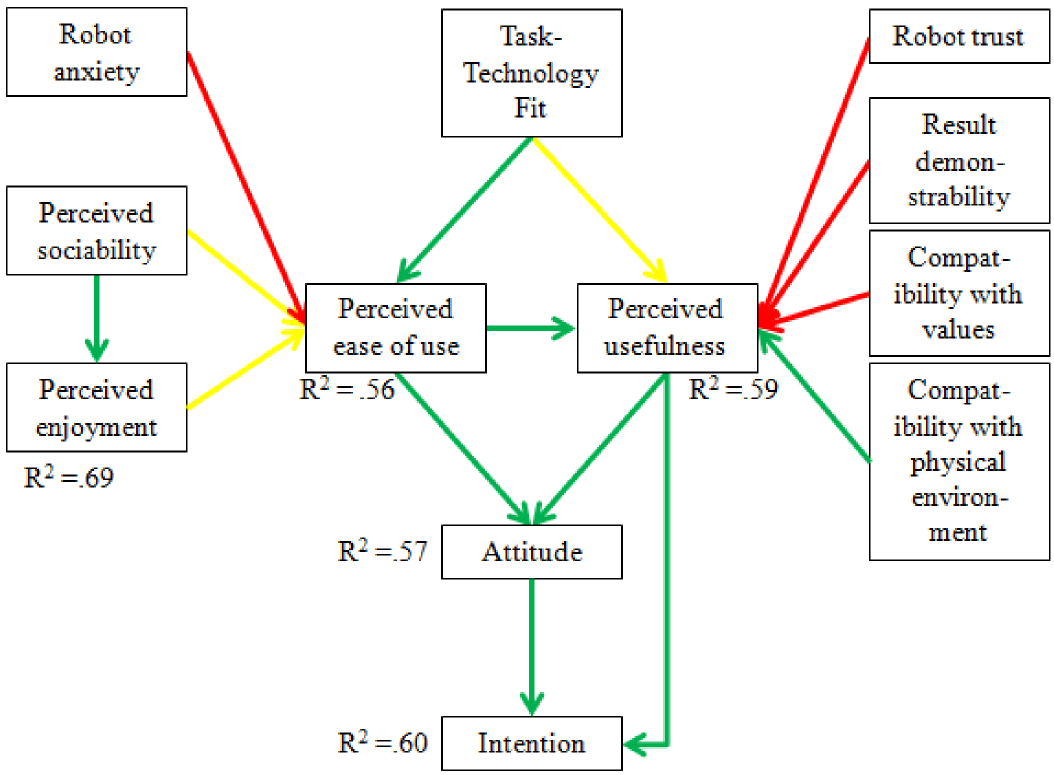


Figure 5.4 Summary of findings from path analyses 1 and 2. Green paths = relationships supported in both path analyses. Yellow paths = relationships supported in one path analysis. Red paths = relationships not supported in either path analysis.

Table 5.4

Significant Paths across Both Path Models and Support in Literature

IV	DV	Relationship in Path Analysis 1	Relationship in Path Analysis 2	Example Support of Positive Relationship from Literature
Perceived sociability	Perceived enjoyment	Positive***	Positive***	Heerink et al., 2010a
Attitude	Intention	Positive***	Positive***	Davis et al., 1989; Ezer et al., 2009a; Fishbein & Azjen, 1975; Heerink et al., 2010a
Perceived usefulness	Attitude	Positive***	Positive***	Davis et al., 1989; Ezer et al., 2009a; Legris et al., 2003; Schepers & Wetzels, 2007
Perceived ease of use	Perceived usefulness	Positive***	Positive***	Davis, 1989; Heerink et al., 2010a; King & He, 2006; Sun & Zhang, 2006b; Venkatesh & Bala, 2008
Task-technology fit	Perceived ease of use	Positive***	Positive***	Chang, 2008; Dishaw & Strong, 1999; Klopping & McKinney, 2004
Perceived usefulness	Intention	Positive***	Positive***	Cesta et al., 2007, 2011; Davis, 1989; Davis et al., 1989; Ezer et al., 2009a; Heerink et al., 2010a; Legris et al., 2003; Schepers & Wetzels, 2007; Venkatesh et al., 2003; Venkatesh & Bala, 2008
Perceived ease of use	Attitude	Positive***	Positive***	Davis et al., 1989; Ezer et al., 2009a; Heerink et al., 2010a; Y. Lee, Kozar, & Larsen, 2003; Schepers & Wetzels, 2007; Sun & Zhang, 2006b
Compatibility with physical environment	Perceived usefulness	Positive***	Positive***	Not applicable because it is a new variable proposed by Smarr et al. (2013)

Table 5.4 continued

IV	DV	Relationship in Path Analysis 1	Relationship in Path Analysis 2	Example Support of Positive Relationship from Literature
Task-technology fit	Perceived usefulness	Positive**	n.s.	Klopping & McKinney, 2004; J.-H. Wu et al., 2007
Perceived sociability	Perceived ease of use	Positive*	n.s.	Heerink et al., 2010a
Perceived enjoyment	Perceived ease of use	n.s.	Positive**	Heerink et al., 2010a; Sun & Zhang, 2006a; Venkatesh, 2000; Venkatesh & Bala, 2008

Note. IV = independent variable. DV = dependent variable. n.s. = $p > .05$. $^{*}p < .05$. $^{**}p < .02$. $^{***}p < .001$.

Two of the three partially supported relationships were significant only in path analysis 1 (i.e., items assessed in both usage and survey studies): (1) task-technology fit → perceived usefulness; and (2) perceived sociability → perceived ease of use. The third partially supported relationship in the framework was significant only in path analysis 2 (i.e., only reliable items assessed): perceived enjoyment → perceived ease of use. This suggests that changing the items in those scales impacted their relationships, but more research is needed to determine if these relationships should remain in the framework.

The most obvious reason why there were differences between path analyses was the items analyzed (i.e., number of items, items included in scale), which influenced the size of the relationships between scales in this study. Items that were added and deleted were examined for patterns and compared to items that were retained for each of the scales (i.e., perceived usefulness, ease of use, and sociability; task-technology fit; perceived enjoyment). No items were deleted or added to the perceived usefulness and ease of use scales for path analysis 2; this is unsurprising because these scales are well-supported in TAM research (e.g., Davis, 1989).

For perceived sociability, two items were added to the scale (i.e., "The robot mower would understand me"; "I would consider the robot mower pleasant") but none were removed during the reliability analysis. No patterns were observed for the two items added, but the items retained in the reliable perceived sociability scale were related to the robot mower being pleasant to interact with or the robot understanding the user.

However, items were deleted for the latter two scales. For task-technology fit, there was no pattern observed for the two items deleted from the scale (i.e., one item related to robot safety, one item related to the amount of effort to use the robot), nor for the items retained for path analysis 2 (i.e., 16 items related to eight goals of mowing, including one safety item and one effort of use item). No items were added to task-technology fit scale. For perceived enjoyment, three items were added to the scale related to degree of enjoyment and fascination participants perceived in their interactions with the personal robot. These three items aligned conceptually with the original items in measuring degree of enjoyment and pleasure in using the robot.

Relationships Not Supported

Four out of 15 relationships tested were not significant in either path analysis even though it was predicted that there would be significant relationships amongst all these relationships. First, anxiety toward using the robot was expected to be a significant, negative determinant of perceived ease of use, such that people with higher robot anxiety also perceive the robot as harder to use (Heerink et al., 2010a). Second, perceived usefulness was expected to be determined not only by compatibility with physical environment, but also by robot trust (Venkatesh & Bala, 2008; J.-H. Wu, Chen, & Lin, 2007), result demonstrability (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000), and compatibility with values (Karahanna et al., 2006).

There are several potential reasons why these relationships were not statistically significant. First, this study was conducted outside the laboratory, which has been found to have lower explanatory power than technology acceptance studies conducted in the laboratory (Sun & Zhang, 2006b). Second, personal robots may be a boundary condition for factors important for technology acceptance. As such, factors drawn from acceptance of non-robotic technologies may not generalize to them. Although personal robots are a type of technology and share many characteristics with non-robotic technologies, robots differ from other technologies in several ways. When compared to information technology (e.g., computers), personal robots typically – not always – behave and move autonomously; are embodied within the human space; have different control methods (e.g., not just keyboard and mouse); exhibit different sociabilities; and people respond to them differently (see Smarr et al., 2013 for a more details on the unique characteristics of personal robots).

Lastly, personal robots are a radical technology. Radical technologies are fundamentally different from existing practices and as such, have different predictors than more incremental technologies (Dewar & Dutton, 1986). However, as a radical technology becomes more prevalent, it becomes more incremental. The Smarr et al. (2013) framework assumed robots were a radical technology but perhaps with the increasing popularity of domestic/home robots (e.g., vacuums, pool cleaners), and entertainment robots (e.g., Furby, AIBO) robots are becoming more incremental. If so, some factors, such as robot anxiety, may play a smaller or different role than it would for radical technologies.

These non-significant paths in the path analysis suggest that the Smarr et al. (2013) framework should be modified to better assess individuals' acceptance of personal robots. However, the first step will be to replicate the present findings and conduct studies with additional samples and personal robots. Such research studies will be necessary to determine what factors and their relationships to include, exclude, or redefine. Additionally, future research could guide inclusion, exclusion, or modification of items measuring factors.

Group differences in acceptance

The robot mower's level of reliability (90%, 70%, and no information on reliability) and communication of feedback (two-way, one-way, and no information on communication) were manipulated between-subjects in the survey study. This study is one of the first studies to directly manipulate either of these factors in a one human – one robot interaction context. Predictions were therefore based on non-robotic technologies (i.e., automated systems). It was expected that robot reliability and communication would impact individuals' acceptance but the extent to which it would generalize to personal robots was unclear.

Significant Effect of Reliability

People tend to appropriately use a reliable automated system more (e.g., Beck et al., 2007; Dixon & Wickens, 2006) and have more positive perceptions of it compared to less than reliable systems (e.g., trust; Sanchez et al., 2004). From the automation literature, we predicted that the higher robot reliability would positively impact individuals' acceptance of a personal robot.

Attitudinal and intentional acceptance significantly differed by the robot mower's level of reliability; however, follow-up comparisons indicated no statistical differences. The *statistically non-significant* trends suggested an interesting pattern: both types of acceptance were numerically higher for no reliability information compared to any reliability information (i.e., 70% reliable for attitudinal acceptance and 90% reliable for intentional acceptance). Perhaps when reliability information is given, regardless of actual level of reliability, it biases people to think about reliability when they may not have otherwise. Just thinking about reliability may negatively influence acceptance of robots. Clearly, generalization of these results is limited, but a future direction would be to determine if this pattern is replicable.

Additionally, participants' perceptions of the robot mower's reliability were assessed after reading the text manipulation. Perception of reliability was similar to what participants' were told in the 70% reliability condition but was significantly less than what participants were told in the 90% reliability condition. This suggests that the manipulation was only partially successful. Barg-Walkow & Rogers (2014) found a similar pattern of findings for baseline perceived reliability of an automated system to the 70% reliability condition in study 2. That is, participants' perceptions of reliability were similar to what they were told (e.g., perceived reliability was about 60% when participants were told the system was 60% reliable).

Perhaps 90% reliability seems too high to be believable for what people expect from a radical technology, such as the robot mower. In fact, participants who were given no reliability information in study 2 perceived the robot as less (i.e., 83%) than 90% reliable. Of note, participants' responses were restricted to 60%, 70%, 80%, 90%, and 100%, because the same responses were used across conditions, and people tend not to use automated systems that are below 70% reliable (Wickens & Dixon, 2007).

Non-Significant Effects

Attitudinal and intentional acceptance did not significantly differ by level of communication of feedback nor was there an interaction of reliability and communication. The Tango was designed to interact with the human user in a supervisor role (Scholtz, 2003). Communication of feedback is particularly important for human supervisors so they can monitor and control the overall situation to facilitate the robot's goal completion (Scholtz, 2003). A supervisor needs to know what the robot's current state – especially any deviations or errors – so he or she can intervene or modify the robot's behavior and/or larger goals (Scholtz, 2003). Lack of appropriate or salient feedback about the a technology's state negatively impacted users' understanding of the automation's behaviors, decreased overall system performance, and has been linked to accidents (Sheridan & Parasuraman, 2005).

In short, communication of feedback is particularly important for humans using the robot mower so appropriate and salient feedback is necessary for effective completion of goals (e.g., mow grass, avoid property damage). Two patterns were expected: (1) higher acceptance of the robot with more salient communication (i.e., two-way communication) compared to less salient communication (i.e., one-way communication); and (2) highest acceptance of a robot with high reliability and more salient communication (i.e., 90% reliable, two-way communication) compared to a robot with low reliability and less salient communication (i.e., 70% reliable, one-way communication).

Some potential reasons why there was not an effect of robot's level of communication of feedback are as follows. First, participants may not have viewed this personal robot from the role of supervisor but from another of Scholtz's (2003) five roles of humans in human-robot interaction (i.e., bystander, teammate or peer, operator, and mechanic). Of note, participants may not have consciously decided what role to view using the robot. Participants may have viewed using the robot mower from the bystander role, because of the "set it and forget it" design philosophy of the Tango as well as it being used outdoors, where human-robot interaction is likely to be less frequent than inside the home. Bystanders do not directly interact with the mower but need some way of understanding the robot's behavior (e.g., does the robot or the person stop when crossing paths?; Scholtz, 2003).

Second, Scholtz's (2003) five roles of humans in human-robot interaction are not mutually exclusive. For example, a supervisor could simultaneously take on the role of peer, which is similar in that peers can give commands to the robot within larger goals but does not have the authority to change the robot's larger goals (Scholtz, 2003). Peers do not need to monitor the robot's larger goals so communication of the robot's state may be less important to peers than supervisors (Scholtz, 2003). In other words, if participants are viewing interactions with the robot mower more strongly or more frequently from the peer role compared to the supervisor role, then communication of feedback may not affect their perceptions of using, or accepting, this robot.

There are several potential explanations for the lack of differences in acceptance due to the interaction of the robot's reliability and communication of feedback. First, despite pilot testing, the manipulation of reliability and communication may have been inappropriate or too subtle to influence acceptance. The survey study manipulations were pilot tested with adults of various ages but were conducted in person in a psychology laboratory. Perhaps pilot participants were more sensitive to potentially subtle manipulations compared to the survey study participants based on their location and interest in participating in psychological research.

Lastly, reliability and communication of feedback may not be important for initial acceptance. For example, consider a person investigating whether to buy a robot vacuum cleaner for their home. Specific features of the robot vacuum (e.g., reliability, communicability) may not be important for initial acceptance of robots until the person can gain knowledge about them (e.g., compare features amongst different robot vacuums) or experience through direct use. Perhaps the robot's reliability and communication of feedback is less important for initial acceptance and more so for continued acceptance, or use. More research is needed investigate if manipulating a robot's reliability and communication of feedback impacts individuals' initial and continued acceptance of personal robots differentially.

CHAPTER 6: GENERAL DISCUSSION

The overarching purpose of this research was to begin to understand the factors that influence acceptance of personal robots and their relationships through testing the Smarr et al. (2013) qualitative framework. Personal robots can help people live safer, more efficient, and comfortable lives, but these benefits remain unrealized if people do not accept robots. If we better understand what factors facilitate or hinder people from accepting personal robots, then we can design more acceptable robots, thereby, increasing acceptance and allowing more people to realize the benefits of using personal robots.

Personal Robot Acceptance

The depth and breadth of personal robot acceptance were examined in a usage study and survey study within the context of the Smarr et al. (2013) framework. The core of this framework is based on TAM (Davis, 1989; Davis et al., 1989), which in turn, is based on the theory of reasoned action (TRA; Fishbein & Azjen, 1975). TRA holds that individuals' attitudes predict their intentions, which thereby predicts their behaviors (Fishbein & Azjen, 1975). This theory was only partially supported by the current research with a robot lawn mower (Deere Tango E5). In support of TRA, attitudinal acceptance was a significant determinant of intentional acceptance in the survey study.

Contrary to TRA, participants who used a personal robot for six weeks had high subjective behavioral and attitudinal acceptance, but low intentional acceptance. The high behavioral acceptance in the usage study may have been partially resulted from participants' self-reporting their usage of the robot, which has been found to inflate behavioral acceptance compared to objective measures (Turner et al., 2010). Although attitudes typically predicted intentions and intentions predicted behaviors, they were not perfect predictors (Fishbein & Azjen, 1975). Besides the usage study, one other study measured all three types of acceptance of a personal robot. They found attitudinal acceptance of a robot significantly predicted the intention to use the robot, which in turn predicted objective behavioral acceptance of a robot (Heerink, Kröse, Evers, & Wielinga, 2009). It is premature to suggest that personal robot acceptance is a boundary condition of TRA and TAM because only two studies have directly examined all three types of acceptance within the same study. More research needs to examine all three types of acceptance simultaneously with personal robots to determine if TRA and TAM can be generalized and under what conditions.

Overall, intentional acceptance was low in both studies. In fact, intentional acceptance was low with more than half of people not intending to purchase the personal robot. In the usage study, seven households' attitudinal acceptance was high and did not change after using the personal robot at home for six weeks. In the survey study, initial attitudinal acceptance was neither positive nor negative for 280 people who learned about the robot while completing a 30 minute online survey. These levels of acceptance may be explained through factors related to the robot, human, and context in the Smarr et al. (2013) framework of personal robot acceptance.

Effects of Robot Reliability and Communication of Feedback on Acceptance

Although a personal robot's level of reliability and communication of feedback was hypothesized to influence people's initial attitudinal and intentional acceptance of it, there were no significant differences other than a main effect of robot reliability. However, inferences about the effects of robot reliability on acceptance were limited, because follow-up comparisons were not statistically significant.

Two potential explanations for the lack of differences in acceptance as a result of the different levels of reliability and communication of feedback are as follows. First, the manipulation of reliability and communication may have been inappropriate or too subtle to influence acceptance. Participants who used the Tango for six weeks at their homes in the usage study mentioned wanting the Tango to be more reliable and requested that it communicate with them about its current state (e.g., started mowing, stopped in lawn).

Second, reliability and communication of feedback may only emerge as important influences on acceptance after people interact directly with the system. In the usage study, when asked about the reasons for their intentions to purchase a robot mower, participants did not mention reliability or communication as a concern before using the robot mower. However, the non-adopters did mention both within two of the three most frequently mentioned reasons for their low intentional acceptance. Manipulations of reliability and communication via direct usage of a robot should be compared with other more indirect methods (e.g., text, video, picture).

Validation of Smarr et al. (2013) Framework

Validation of Framework

Overall, the results of both studies supported the Smarr et al. (2013) framework. Of note, more factors were examined in the usage study than in the survey study because survey study pilot participants had difficulty responding to certain factors (e.g., trialability, visibility) without directly using the personal robot. Statistically, the framework explained much of the variance in initial intentional (60%) and attitudinal acceptance (57%) of a personal robot in the survey study. Eight of the 15 relationships tested in the framework were fully supported (Table 5.4): intentional acceptance was determined by attitudinal acceptance and perceived usefulness; attitudinal acceptance was determined by perceived ease of use and usefulness; perceived ease of use was determined by task-technology fit; perceived usefulness was determined by perceived ease of use, and compatibility with the physical environment; and perceived enjoyment was determined by perceived sociability. All relationships were significantly positive as predicted by the framework.

Conceptually, 16 of the 20 factors in the framework were analyzed and validated in the usage study, implying that these 16 factors were important enough for participants to mention them during an interview about robot acceptance. Six factors were mentioned most frequently both before and after using the robot were all conceptually validated: level of the robot's reliability (good or bad), type of task (i.e., new task for the person to perform, task of mowing), perceived usefulness and ease of use, compatibility with physical environment, and evaluation of a method of controlling the robot. Taken together, these findings suggest that the statistically validated relationships and conceptually validated factors from the Smarr et al. (2013) framework can explain a majority of the individual differences in acceptance for this personal robot.

Framework not Validated

Although these studies were only a first step in understanding personal robot acceptance within the context of the Smarr et al. (2013) framework, there are still opportunities to improve it by adding, removing, or modifying factors and their relationships within the framework. In the survey study, three relationships were partially supported and four were not. Three of the hypothesized determinants of perceived ease of use were partially supported (i.e., robot anxiety, perceived sociability and enjoyment). Additionally, four determinants of perceived usefulness were not supported (i.e., robot trust, result demonstrability, compatibility with values, and task-technology fit), suggesting that these factors may need to be removed from the framework or modified. However, more research is needed to determine if these factors should be removed or how they should be modified.

Moreover, in the usage study, 10 factors were mentioned by participants but were not in the framework, indicating that these factors should be considered for inclusion in the framework. These 10 factors pertained to the robot mediating person-person social interactions, curious to see what the robot does, feeling frustrated when interacting with the robot, robot could do the task if the user is no longer physically capable, expectations of the robot and human-robot interaction, cost of the robot, keeping the robot from being stolen, lack of intelligence exhibited by the robot, efficiency and speed of the robot.

In the usage study, four factors in the Smarr et al. (2013) framework were not mentioned within the discussion of personal robot acceptance. Anxiety toward using the robot was not mentioned in the usage study and was not a significant determinant of perceived ease of use in the survey study, implying that anxiety should be considered for removal from the framework. Usability and visibility of the robot and criticality of the task were not mentioned in the usage study, but this was likely due to the nature of the interview questions, the robot not being sold in the United States, and that mowing is not usually considered a critical task.

a. Why were these factors/relationships not supported? Tie back to intro.
b. Why are factors important in study 1 but not study 2 (or vice versa)?
    i. Why perceived enjoyment is important in study 1 but not study 2?

Limitations of Research

The Smarr et al. (2013) framework was created to explain an adult's acceptance of a personal robot performing a non-professional task (e.g., mowing, entertaining) within a non-professional environment (e.g., home). It was restricted to one human interacting with one robot at any point in time, where the human was not required to use the robot. Users were from individualistic cultures and had little to no formal training on how to use the robot.

Generalization of the Smarr et al. (2013) framework outside of the scope set forth should be made carefully for three reasons. First, different factors may be included or excluded for scopes outside of the framework. Second, the importance of the factors may change. Third, the relationships between factors may change. In the remainder of this section, the boundary conditions of the framework are discussed.

First, this framework may not apply as well to children, people with extensive formal training in using robots, people who are required to use a robot, or those from collectivist cultures. People with these various backgrounds may have different knowledge and goals in using a personal robot than those within the framework's scope. For example, the need to belong was predicted South Koreans' perceptions of a robot's usefulness and ease of use (Park & Pobil, 2013). However, this would likely not apply as well to a member of an individualistic culture accepting robots for his or her personal benefit. Culture can be a boundary condition to acceptance of non-robotic technologies as well (Straub, Keil, & Brenner, 1997). Perceived usefulness predicted system usage for participants from individualistic cultures (Americans and Swiss) but not from a collectivist culture (Japanese; Straub et al., 1997).

Second, although this framework was developed to generalize to all personal robots, it is unknown how well this framework explains acceptance of personal robots that are not the Tango. Characteristics (e.g., mechanical appearance, size) and behavior of the Tango (e.g., greater autonomy, slow speed) influenced participants' acceptance of the robot, especially because they had limited robot experience. In particular, the Tango was designed to require little interaction with humans and was not designed with social capabilities. People had higher intentional acceptance of a more social robot compared to a less social robot (de Ruyter, Saini, Markopoulos, & van Breemen, 2005; Heerink, Kröse, Evers, & Wielinga, 2010b).

Third, although this framework was developed without focusing on a specific task or environment, it is unclear how well it explains acceptance of robots that perform a different task or multiple tasks within different environments. The Tango performed one task (i.e., mowing) in one environment (i.e., in yards). Previous ethnographic research has been conducted with the iRobot Roomba vacuuming floors inside homes (Bauwens &

Fink, 2012; Fink et al., 2011; Forlizzi, 2007; Sung et al., 2010). Differing rates of acceptance between households in those studies were reportedly due, at least in part, to the Roomba's compatibility with its environment and the perceived usefulness of the vacuum. These themes also emerged as important for acceptance in the current research. Taken together, this suggests that although the specifics of the task (e.g., Roomba stuck under couch, Tango unable to mow steep inclines) and environment may different (e.g., carpet, grass), the high level factors (e.g., compatibility, usefulness) are still important. Also, robots that perform multiple tasks are currently research platforms and are likely to remain so for the near future because of the complexity of programming robots to interact with untrained users within a dynamic, unstructured environment.

Lastly, the framework may not generalize to interactions outside of one human and one robot at one point of time because the human-to-robot ratio changes the level and type of interactions that take place (Yanco & Drury, 2004), which may impact acceptance. With more complicated human-robot teams, additional capabilities may be required from both humans (e.g., knowing status and location of multiple robots, coordinating with other humans) and robots (e.g., prioritizing or deconflicting commands from multiple humans, coordinating with other robots).

Advancing a Framework of Personal Robot Acceptance

Although additional research is needed before altering the theoretically-based Smarr et al. (2013) framework of personal robot acceptance, there are four main considerations for the evolution of this framework. First, perceived high financial cost of the Tango was the most frequently mentioned reason for households not intending to purchase a Tango in the usage study. For non-robotic technologies, perceived cost is not incorporated in prominent acceptance models, such as TAM, UTAUT, TAM3, and diffusion of innovation. However, Van Ittersum et al. (2009) found that besides perceived usefulness, perceived cost was the most important predictor of acceptance of agricultural technology. In general, higher perceived cost was associated with lower technology acceptance (e.g., Luarn & Lin, 2005; Van Ittersum et al., 2009).

Perceived cost was not originally included in the Smarr et al. (2013) framework because the HRI and robot acceptance literatures have largely ignored it. This may be due to many personal robots being research platforms and as such, tend to be unique, have higher quality or different sensors than may be necessary for consumers, and are expensive to build. However, if personal robots are to be widely deployed, then perceived cost could be a key direct determinant of acceptance and should be considered within the evolution of the framework.

The second consideration for advancing the Smarr et al. (2013) framework is whether compatibility with physical environment is a component of task-technology fit. Compatibility of physical environment is "the degree to which using a robot is perceived as congruent with the physical structures of its surroundings (e.g., rooms, floors, furniture)" (Smarr et al., 2013, p. 48). Task-technology fit is defined as the match between technology capabilities, task requirements, and individuals' abilities (Goodhue, 1995).

Although similar, compatibility with physical environment focused on the robot's congruence with the environment and had no direct human involvement save for the human's perception of the robot-environment congruence. Future research should consider modifying the definition of and items assessing compatibility of physical environment to more clearly exclude the human's involvement. After doing so, statistical analyses should be conducted to investigate whether acceptance is better explained by the framework when compatibility of physical environment is included or excluded.

Additionally, compatibility with physical environment may be important for certain robots more than others. For example, compatibility with physical environment may be more important for a robot that is mobile or capable of directly manipulating the physical environment (e.g., picking up objects) than a robot that is stationary or does not directly manipulate the physical environment. However, as the current two studies are the only studies that have measured compatibility with physical environment more research is needed to determine if it is more important for certain robots than others.

The third consideration for the evolution of the Smarr et al. (2013) framework is to incorporate perceived behavioral control as a determinant of intentional acceptance from the theory of planned behavior, which is a more general version of the theory of reasoned action (Azjen, 1991). Perceived behavioral control is defined as a person's perceptions of their ability to perform a certain behavior (Azjen, 1991). It could potentially help explain the high attitudinal acceptance and low intentional acceptance in the usage study. There was mixed support for perceived behavioral control as a significant determinant of acceptance (e.g., Mathieson, 1991; Taylor & Todd, 1995). Future research should consider investigating how adding perceived behavioral control to the framework impacts the amount of robot acceptance explained.

As these two studies were a first step to better understanding personal robot acceptance within the Smarr et al. (2013) framework, there are many possible next steps to investigate. First, these studies used one specific personal robot (i.e., the Deere Tango robot mower) that performs one task in the lawn so generalization to all personal robots, tasks, and settings is limited. To increase generalization, acceptance of other personal robots that are used in various environments (e.g., inside and outside the home), tasks (e.g., vacuuming, entertainment, performs one task or multiple tasks), and capabilities (e.g., mobile, sociability).

Second, items were tested and exploratory validation was conducted with the same sample of participants. Items assessing Smarr et al.'s (2013) framework need to be tested on additional samples of people and other personal robots to refine those scales to be as reliable and valid as possible. Also, shortening the questionnaire would be beneficial to reduce the time commitment for both respondents and questionnaire administrators.

Third, these are the first two studies testing the Smarr et al. (2013) framework so additional research needs to be conducted to explore the generalization and boundaries of applying this framework to personal robot acceptance. See the preceding section on limitations for more details. Fourth, manipulating a variable in the framework, such as the robot's sociability or how enjoyable it is use, could provide insight on not only its impact on acceptance but also on other downstream variables, such as perceived ease of use and task-technology fit.

Lastly, Rogers' (2003) asserted in his diffusion of innovation theory that there are five main adopter categories. That is, a person can be classified based on how early they adopt an innovation (e.g., technologies, ideas) as it spreads within a social system. For example, innovators are the first 2.5% of people to adopt an innovation and laggards are the last 16% of people to adopt it (Rogers, 2003). Participants in the current research were not assessed for what adopter category they would be in. Future research, should consider assessing participants' adopter categories for robots or other technologies, because it could give insight into why an individual has low acceptance at a certain time point. For example, a new robot is for sale and a person is a laggard, then she or he is unlikely to adopt the robot until most people have already adopted it.

Conclusion

From a theoretical perspective, both studies informed current understanding of personal robot acceptance and what influences it. Our current view of robot acceptance in the literature is underdeveloped because it generally lacks a holistic conception of the domain, including the human, the robot, the task, the environment, time, and the interactions among them. Therefore, our appreciation of important factors and their relationships is limited. Specifically, the information gained from this research conceptually and statistically tested a theoretically-based qualitative framework of robot acceptance developed by Smarr, Fisk, and Rogers (2013). These data also allowed insight into people's perceptions and why they held these perceptions related to robot acceptance at home. This research may also help inform other theories of acceptance (e.g., TAM3, Almere Model) by exploring boundaries of factors identified as important; extending the existing work to better account for human behavior; and enhancing their overall generalizability.

From an applied perspective, the information gained from this research provided what factors should be considered when designing a more acceptable personal robot. Additionally, some of the measures used in these studies could be adapted and used to identify a robot's opportunities for improvement. For example, if a robot is perceived as not useful, the scores for each of its determinants (e.g., compatibility with physical environment, trust) could let designers know where to focus their improvements.

The main goal of this research was to better understand personal robot acceptance by testing the Smarr et al. (2013) framework. It deepened the understanding of what factors were important for explaining attitudinal, intentional, and behavioral acceptance of a robot mower, the changes of acceptance over time, and began to validate a new robot acceptance framework. Ultimately, results from this study and future studies can help guide the design of acceptable personal robots that can help people live safer, more efficient and comfortable lives.

APPENDIX A: USAGE STUDY - TANGO INTERNAL MODIFICATION

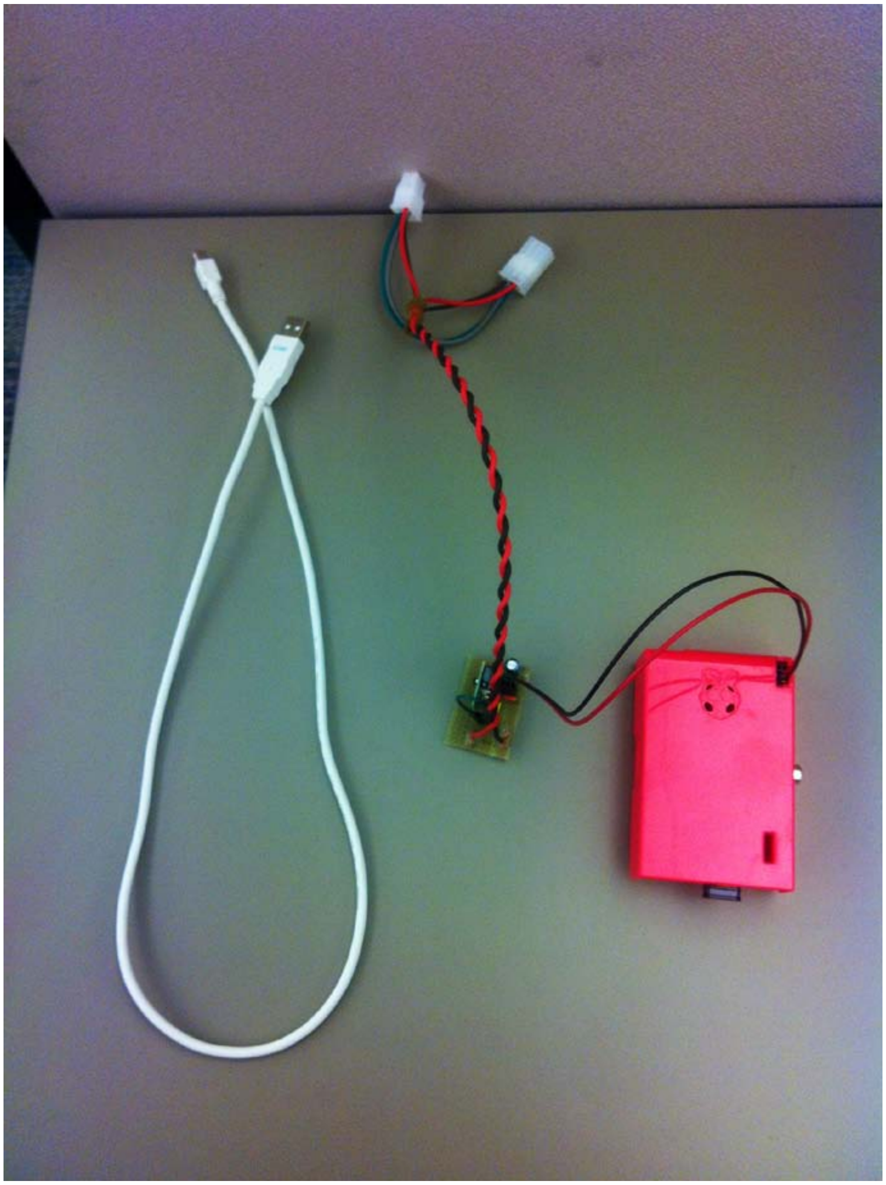


Figure A.1 Components of the small computer added inside the Deere Tango E5 to allow the mower to log usage data and to allow participants to control the Tango from a remote user interface, a Google Nexus 10 tablet computer.

APPENDIX B: PRE-USE INTERVIEW MATERIALS

CONSENT DOCUMENT
Georgia Institute of Technology
Project Title: Human-Robot Interaction for Robot Mowers

Investigators: Wendy A. Rogers, Ph.D. (Principle Investigator);
Tracy Mitzner, Ph.D. (Support Staff); Cory-Ann Smarr (Student Investigator)

Protocol and Consent Title: Human-Robot Interaction for Robot Mowers

Purpose: You are being asked to be a volunteer in a research study. The purpose of this form is to tell you about the tasks you will be asked to do in this research study. Also, this form will inform you about your rights as a research volunteer. Feel free to ask any questions that you may have about the study.

Thank you for your interest in taking part in this research study. Our work could not be done without your help. The goal of our research is to understand people's interactions with and thoughts on robot mowers. We expect to enroll 30 adults in this study.

Exclusion/Inclusion Criteria: To take part in this research study, participants must live with at least one other adult, be fluent English speakers, and be employed full time. Participants must have a flat lawn no greater than 0.25 acres. Participants cannot have children living with them or a lawn mowing service. Participants cannot be employed by Deere & Company.

Deere Tango E5

You will be asked to interact with a Deere Tango E5 robot mower. The Tango is currently for sale in parts of Europe and meets the latest European *draft* standard for autonomous mowers (FprEN 60335-2-107:201X). The Tango you will be asked to use is different from the European version by adding a small computer that will log your usage of the robot mower and its settings. The small computer also allows you to control the robot mower from an application on a Google Nexus 10 tablet. The small computer will not log any information that is personally identifying (e.g., names, pictures). You will be trained on how to use both the Tango and its application.

Procedures:

If you decide to be in this research study, you will be asked to:

Pre-Use Interview

1. Complete a form to borrow experimental equipment from Deere & Company. Deere & Company will have your name as a participant in this study. However, any of your data and questions during this study will not be linked back to you. Your responses will be combined with other participants' responses.

2. Complete questionnaires on your experience with robots, and your attitudes toward your lawn
3. Answer questions about your current lawn care and knowledge of robot mowers in a group interview with a researcher and members of your household participating in this study. You will be audio recorded during the interview.
4. Observe a researcher as he or she installs the robot mower in your lawn. Installation will involve pegging a wire around the boundary of your lawn and placing a charging station on your lawn. Pictures and video will be taken of your lawn.
5. Complete training on how to use the robot mower, including safety guidelines, and its application
6. Answer questions about your thoughts and expectations of the robot mower in a group interview with a researcher and members of your household participating in this study. You will be audio recorded during the interview.
7. Complete a questionnaire on your attitudes toward the robot mower
8. You will be given written instructions and receive training from a researcher about how to get help if you have questions about the study or questions/issues with the robot mower. You can call a researcher for technical support at 919-804-2093 for any questions or issues. A researcher will record your code, the date and time of the call, what the issue or question is, and what the resolution is. No personally identifying information will be collected (e.g., names, addresses). You will also be given a manual to refer to for questions.
9. Use the robot mower in your lawn according to operating and safety instructions. You may choose not to use the robot mower.

Using the robot

1. Complete a diary once a week about your experiences and attitudes toward the robot mower
2. Take relevant or interesting pictures or videos of the robot with the tablet

Post-Use Interview

1. Complete questionnaires on your demographics, health, experience with technologies, and attitudes toward your lawn
2. Answer questions about your thoughts and experiences with the robot mower in a group interview with a researcher and members of your household participating in this study. You will be audio recorded during the interview.
3. Complete a questionnaire on your attitudes toward the robot mower
4. Give any relevant or interesting pictures or videos of the robot to the researcher

At the conclusion of the study (up to 6 weeks after the installation), a researcher will debrief you and then delete the Tango application from the tablet. Then, the tablet will be returned to your household as compensation for participating in this study. Finally, a researcher will take pictures and video of your lawn, uninstall the robot mower, and remove it from your lawn.

If anything is unclear at any time, please feel free to ask questions.

This study will last up to 6 weeks and take approximately 7 hours of your time. You may stop at any time and for any reason.

Risks or Discomforts: There is a low level of risk involved with participation in this study. A Deere Tango E5 robot mower will be installed in your lawn. You will be asked to interact with this robot mower. There are risks associated with using the robot mower. Please see the list below for the potential risks and potential outcomes of interacting with a robot. The list of potential risks and potential outcomes is not comprehensive.

Potential Risk of Using the Robot	*Potential Outcome*
Collision with participant	Contusion
Collision with object	Damage, indentation, mark
Contact with mowing blade	Laceration
Damage to property	Turf wear

You may be in close proximity to the robot mower and/or make direct physical contact with the robot mower so there is a chance that the robot mower may unintentionally collide with you. To reduce risk and potential discomfort, the robot mower operates at speeds that are usually slower than the speeds at which humans mow (approximately one mile per hour). The robot mower also uses a bumper and sensors to avoid causing damage during collisions.

In the event that the robot mower looks as though it will collide with you in an undesirable way, you can avoid the robot or immediately stop the mower by pressing the large red button on top of the mower. A researcher will review safety precautions using the mower with you, including the location and operation of the stop button.

You may a researcher at 919-804-2093 for any questions or issues.

You and/or a researcher may control the robot. The robot may perform the task with no, or only partial, human control.

Because we are audiotaping the interviews, there is a possibility that your voice will be recognized. Similarly, you or your lawn may be recognizable from pictures and/or videos of you or your lawn used in publications and presentations. You may deny permission for these materials to be used in publications and presentations (see below).

Benefits: You may benefit from this research study by having a regularly cut lawn. We also hope that other working adults as well as robot designers will benefit from what we find from conducting this study.

Compensation to You: Your household will be compensated with a Google Nexus 10 tablet for completing this research study, which will take approximately 7 hours over a maximum of 6 weeks.

U.S. Tax Law requires a mandatory withholding of 30% for nonresident alien payments of any type. Your address and citizenship/visa status may be collected for compensation purposes only. This information will be shared only with the Georgia Institute of Technology department that issues compensation, if any, for your participation.

Confidentiality: The following procedures will be followed to keep your personal information confidential in this study: The data collected about you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code rather than by your name. Your records will be kept in locked files and only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

Audio files will be transcribed; no link will be maintained that could connect your identity with your responses. The audio files will be accessible only to the research team and will be kept for archival purposes.

We may use photographs, or clips from audio or video recordings in research publications or presentations to other academics and the public. Please, select the out of the following options for use of photographs, and audio and video recordings by initialing your preference below.

Option 1: If you are willing to allow us to use photographs, video recordings, and audio recordings of any portion of your participation in this study, please initial here _______. If you have initialed here, we may use a portion of your interview in a presentation, for example, but you will never be identified by name.

Option 2: If you would prefer that we use information from your audio recording only in transcribed form (rather than as an audio clip), please initial here________.

Option 3: If you would prefer photographs or video recordings are not accessible to people outside of the research team, please initial here _________.

The Georgia Institute of Technology Office of Research Integrity Assurance may look over study records during required reviews. The Office of Human Research Protections may also look over study records during required reviews.

Costs to You: There are no costs to you, other than your time, for being in this study.

In Case of Injury/Harm: If you are injured as a result of being in this study, please contact Dr. Wendy A. Rogers at (404) 894-6775 or Dr. Tracy L. Mitzner at (404) 385-0011. Neither the Georgia Institute of Technology nor the principal investigators have made provision for payment of costs associated with any injury resulting from participation in this study.

Participant Rights:

- Your participation in this study is voluntary. You do not have to be in this study if you do not want to be.
- You have the right to change your mind and leave the study at any time without giving any reason and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You will be given a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

<u>Questions about the Study:</u> If you have any questions about the research study, you may contact Cory-Ann Smarr at (404) 894-8344 or cory-ann.smarr@gatech.edu.

<u>Questions about Your Rights as a Research Participant:</u> If you have any questions about your rights as a research participant, you may contact Ms. Kelly Winn, Georgia Institute of Technology Office of Research Integrity Assurance, at (404) 385- 2175.
If you sign below, it means that you have read (or have had read to you) the information given in this consent form, and you would like to be a volunteer in this research study.

____

Participant Name (printed)

____

Participant Signature Date

____

Name of Person Obtaining Consent (printed)

____

Signature of Person Obtaining Consent Date

Re: Experimental Use Agreement

As a condition of participating in the evaluation of our experimental consumer autonomous mower ("Mower") provided by Deere & Company ("Deere"), and in consideration of the opportunity to use such mower in the maintenance of my own property, I, _________________________ ("Tester"), acknowledge and agree to the following:

1. Deere will provide a Mower and operating and safety instructions ("Manual"). I will use the Mower in accordance with the Manual and only on my residential property. I will not allow others to use the Mower and I will take reasonable steps to protect the Mower against theft or damage while it is in my possession.

2. I will return the Mower to Deere promptly upon request. I will return the Mower in the same condition in which I am receiving it, normal wear and tear excepted.

3. I will provide Deere with information regarding my experimental use of the Mower as Deere may reasonably request. Any advice, suggestions, or improvements that I offer ("Feedback") is owned by Deere and I hereby assign any and all intellectual property rights in the Feedback to Deere, and Georgia Tech shall be licensed under any such intellectual property rights owned by Deere for educational or research purposes. If for any reason such an assignment of any Feedback to Deere is not allowed, I hereby grant to Deere a worldwide, perpetual, irrevocable, sublicensable, fully-paid-up, exclusive license under any and all intellectual property rights in the Feedback without limitation and/or any duty of accounting to me.

4. The Mower is not available for public sale as a Deere product. The Mower including the incorporated engineering, design, concept, and/or features may never be sold by Deere.

5. All information provided by Deere, including without limitation information relating to the incorporated engineering, design, concept, or features of the Mower or Manual shall not be photographed, copied, or provided on any social media or public forum or website without prior written consent of Deere.

6. Deere has neither evaluated nor made any representation to Tester regarding the Mower's suitability for use or its safety. I am receiving the mower from Deere "AS IS."

7. I agree to assume all risk and liability arising out of or relating to my possession, use, repair or maintenance of the Mower. I understand and agree that I will not assert any claim or cause of action against Deere for any damage or loss arising out of or relating to my acts, use, repair or maintenance of the Mower.

Tester Name: ____

Signature: _____________________________________

Date: ____

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 is₀	Never heard about, seen, or used this robot₁	Have only heard about or seen this robot₂	Have used or operated this robot only occasionally₃	Have used or operated this robot frequently₄
Autonomous Car	0	1	2	3	4
Deere Tango E5	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
. Unmanned Aerial Vehicle (UAV)/Drone	0	1	2	3	4

<u>Pre Lawn Questionnaire</u>

<u>INSTRUCTIONS</u>: In this section we would like to know more about your lawn <u>during this mowing season</u>. Please answer the following questions by placing a check in the appropriate box for each question or by writing your answer in the space provided. All of your answers will be treated anonymously. If there is a question you do not wish to answer, please just leave it blank and go on to the next question.

A **<u>lawn</u>** is an area of short, mown grass in a yard

1. **How big is your lawn in acres?** (If you are unsure, then please estimate.)
   - ☐1 Less than 0.10 acre
   - ☐2 0.11-0.20 acre
   - ☐3 0.21-0.30 acre
   - ☐4 0.31-0.40 acre
   - ☐5 0.41-0.50 acre
   - ☐6 0.51 acre or more
   - ☐7 Do not know for certain
   - ☐8 Do not wish to answer

2. **In general, how long (minutes) does it take to mow your lawn?** (If you are unsure, then please estimate the number of minutes.)

   ____

Please mark one answer for each of the following questions about how satisfied you are with the amount of <u>your TIME</u> it takes you to mow your lawn <u>during this mowing season</u>. If you do not mow your lawn, then mark not applicable.

1. How satisfied are you with the amount of time it takes you to <u>get ready</u> to mow your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

2. How satisfied are you with the amount of time it takes you to <u>mow</u> your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

3. How satisfied are you with the amount of time it takes you to <u>clean up after you mow</u> your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

4. Considering all these aspects, how satisfied are you with the time it takes you to mow your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

Please mark one answer for each of the following questions about how satisfied you are with the amount of EFFORT it takes you to mow your lawn during this mowing season. If you do not mow your lawn, then mark not applicable.

1. How satisfied are you with the amount of effort it takes you to get ready to mow your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

2. How satisfied are you with the amount of effort it takes you to mow your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

3. How satisfied are you with the amount of effort it takes you to clean up after you mow your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

4. Considering all these aspects, how satisfied are you with the effort it takes you to mow your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

Please mark one answer for each of the following questions about how satisfied you are with other aspects of mowing your lawn <u>during this mowing season</u>.

1. How satisfied are you with how your lawn looks?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

2. How satisfied are you with the health of your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

3. How satisfied are you with the level of sound that your current lawn mower emits while mowing your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

4. How satisfied are you with the safety of your current lawn mower?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

5. How satisfied are you with the amount of electricity your current lawn mower uses while mowing?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

6. How satisfied are you with the amount of gasoline your current lawn mower uses while mowing?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

7. How satisfied are you with your current lawn mower maintenance routine (e.g., sharpening blades)?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

8. Considering all these aspects, how satisfied are you with mowing your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

Please mark one answer for each of the following questions about how <u>important</u> your lawn is to you <u>during this mowing season</u>.

1. How important is it to you that your lawn looks acceptable?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

2. How important is it to you that your lawn is healthy?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

3. How important is it to you that current lawn mower emits acceptable levels of sound?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

4. How important is it to you that current lawn mower is safe?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

5. How important to you is the amount of electricity your current lawn mower uses while mowing?

☐1	☐2	☐3	☐4	☐5	☐6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

6. How important to you is the amount of gasoline your current lawn mower uses while mowing?

☐1	☐2	☐3	☐4	☐5	☐6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

7. How important to you is the maintenance of your current lawn mower?

☐1	☐2	☐3	☐4	☐5	☐6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

8. Considering all these aspects, how important to you is your lawn?

☐1	☐2	☐3	☐4	☐5	☐6
Very Unimportant	Unimportant	Neither Important nor Unimportant	Important	Very Important	Not Applicable

Pre-Use Interview: Part I

Today I am going to ask you about your current lawn care and about robot lawn mowers. I am interested in your opinions and what you actually think about robot mowers. Because I am interested in what *you* think, there are no right or wrong answers. If you do not understand a question, please tell me and I will try to clarify what I am asking. If you do not want to answer a question, please tell me and I will move on to the next question. Before we begin, do you have any questions? Ok, let's begin. I am turning on the audio recorder.

For the purposes of this study, the "lawn" is the area of short, mown grass in your yard. Do you have any questions?

We are going to talk about how your lawn is mowed over this mowing season.

1. Who mows your lawn the most?
2. Does anyone else mow your lawn?
3. How important is mowing your lawn? Why?
4. Why do you mow your lawn?
5. How often is your lawn mowed?
6. How do you know when to mow your lawn?
7. Is there a certain time of the week your lawn is mowed?
8. Do you have a strategy when you mow your lawn? If so, what?
9. Is there a certain pattern you mow in?
10. What type of lawnmower is currently used to mow your lawn?
    a. For example, a riding mower or walk behind mower
11. What are the positive aspects of using your current lawnmower to mow your lawn?
12. What are the negative aspects of using your current lawnmower to mow your lawn?
13. Have you ever considered hiring someone to mow your lawn?
    a. *If yes:* Why did you not hire someone to mow your lawn?

You will see and hear the phrase "use robot mower" throughout this study. "Use robot mower" can have several meanings, but for the purposes of this study "use robot mower" means that you allow the robot to mow with or without you being present. For example, if you press the arrow on the robot to make it mow right now that is "using the robot mower". Also, if you schedule the robot to mow on Saturday and you are out of town, you are "using the robot mower" to mow even though you are not at home and did not touch the robot. Please think of all these situations when you answer questions about using the robot. Do you have any questions?

14. Now we are going to talk about robot lawn mowers. That is, a robot that can mow your grass with or without you operating it.
    a. Have you used any robot mowers?
        i. *If so:* What robot mowers and describe how you used them.
    b. Have you done any research on robot mowers?
        i. *If so:* Describe the research you did.
    c. Have you used a Deere Tango?
        i. *If so:* Please describe how you used the Tango.
    d. Have you done any research on the Tango?
        i. *If so:* Describe the research you did.

I am turning off the audio recorder.

Outline of Training

Call 919-804-2093 or refer to the Operator Manual if you have any questions.

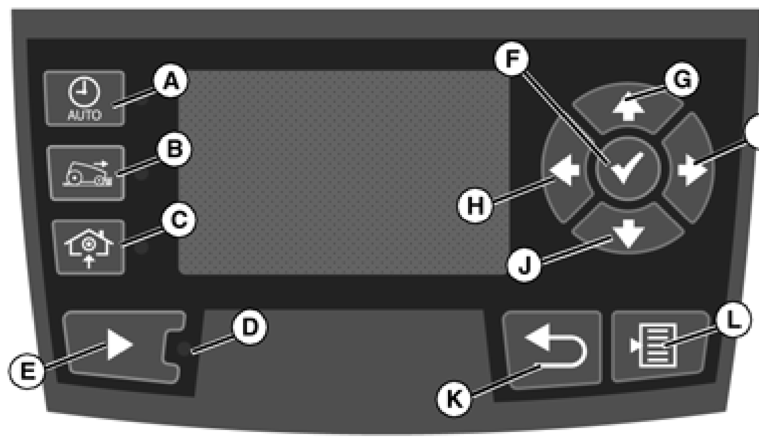
Deere Tango E5 Robot Mower

1. **Safety Features** – Explain safety features to the customer
   a. **Stop button:** Halts mower operation.
   b. **Handle sensor:** Stops mower if handle is grasped for more than 3 seconds.
   c. **Lift sensor:** Stops mower if front wheel(s) raised for more than 3 seconds.
   d. **Tilt sensor:** Stops mower if tilted more than 30 degrees in any direction for more than 3 seconds.
   e. **Bump detection**: Mower changes direction of travel if a bump is detected.
   f. **Decals**
      i. Rotating blade: Do not put hands or feet under mower
      ii. Avoid injury from rotating blade. Never allow children to ride on mower.
      iii. Avoid injury from thrown objects. Keep away from mower when it is operating.
      iv. Read operator's manual before use
      v. Press STOP button and turn off power before lifting or servicing mower
2. **Main switch**: Turns the mower power on or off.
3. **Hazard Barrier -** Explain the importance of hazard barriers.
   a. A barrier should be in place to prevent the mower from approaching any open water. If a barrier is not present, explain the risk of the mower entering the water.
   b. A barrier should be in place to prevent the mower from approaching a steep drop-off. If a barrier is not present, explain the risk to the mower from falling from a height.
4. **Set-up and typical behavior** – Explain set-up of the mower and typical behavior.
   a. **Charging station**
      i. The charging station powers the mower's battery
      ii. Charging contacts: Charge the mower by lining up with the charging contacts on the mower
      iii. Charging station power supply: The box that provides power from the house to the charging station and the boundary wire.
   b. **Boundary wire**: Defines mowing area or keep out areas. Avoid aeration, digging, or other ground-penetrating activity near installed wires. Point out boundary wire.
   c. **Guide loop**: Wire that directs mower to charging station. Avoid aeration, digging, or other ground-penetrating activity near installed wires.
   d. **Mowing Area**: The mowing area is the area contained within the installed boundary wire.
   e. **Scheduling:** Sets mower schedule.
   f. **Boundary clean-up**: The mower is scheduled to mow the edges of the lawn periodically.

5. User Interface

a. Press stop button before using the interface. If you do not press the stop button, you cannot use the interface.

b. Personal Identification Number (PIN): Input the PIN 0000 before interacting with the interface. The interface with lock after 2 hours. The PIN is to helps prevent other people from accessing your mower. Refer to the operator's manual if you have questions. Please do not change the PIN.



c. **Mowing mode (left side)**

i. You can pick a mode from the buttons on the mower's interface. You must press the stop button, then the mode button, a solid green light appears next to the selected mode, and then press start.

ii. **A - Mow on Schedule:** mower operates on schedule

iii. **B - Go Mow Now:** mows until the battery is depleted, stops after one cycle.

1. You can pick from two types of Go Mow Now:
    a. If you Go Mow Now with a charging station, the mower will mow until the battery is low and then try to return to the charging station.
    b. If you Go Mow Now without a charging station, the mower will mow until the battery is very low and stop in the lawn.
2. Mow on Schedule must be selected after Go Mow Now command to return mower to normal schedule.

iv. **C - Go Home function:** Returns mower to charging station. Use if people who are not familiar with mower operation or children are present.

v. **E - Start:** Push this button to start mower operation in the selected mode

vi. **D – Run LED:**

1. **Solid green light:** Normal operation. The mower is mowing with the blades turning. The mower is going to the charging station and the blades are not turning. The mower is in the charging station and is not charging because it is waiting on the schedule.

2. **Flashing green light**: The stop button was pressed and the mower has paused mowing. To resume mowing, press the start button.
3. **Flashing red light:** The mower has detected a condition and stopped itself. Call 919-804-2093 if you have any questions.

d. **Right side**

i. **F - Enter button:** Push this button to save or confirm selections.

ii. **4 direction buttons:**

1. G - Up arrow button: Push this button to navigate up or increase a value.
2. H - Left Arrow Button: Push this button to navigate left.
3. I - Right Arrow Button: Push this button to navigate right.
4. J - Down Arrow Button: Push this button to navigate down or decrease a value.

iii. **K - Back button**: Push this button to go back or undo an entry.

iv. **L - Menu button:** Push this button to access the user interface menu. Can be used to set-up the mower, schedule the mower to mow, and access advanced settings. I have programmed the settings to mow efficiently in your lawn but you may want to tweak them to customize them to your preferences. Call 919-804-2093 if you have any questions or refer to the operator's manual.

e. **Screen**

i. Displays information about mower including…

ii. **Time:** Mower displays current time

iii. **Boundary sensor location indicator**: Indicates whether all 4 boundary sensors are in, out, or unknown

iv. **Battery charge icon**: Graphic representation of battery charge remaining

6. **Guidelines for Operation**

a. Stopping the mower safely

i. If mower is operating, approach from behind. Mower may change its direction as you approach. Be aware of any obstacles mower may contact and change its direction as you approach.

ii. Push down on Stop button on top of mower.

iii. Push the main switch to the OFF position.

b. Press stop button before interacting with the mower each time. For example, if you want to use the interface on the mower, press stop button and then use the interface.

c. Press stop button and turn off power at the main switch. Always check to be sure the main switch is in the OFF position:

i. Before lifting or transporting the mower

ii. Before checking, cleaning, or working on the mower

iii. After striking a foreign object

iv. If the mower starts to vibrate

d. Pick up the machine from the handle
e. Carry the machine with the blade facing away from you
f. Lifts in the front and the rear of the mower stop operations
g. Keep a safe distance from the machine when it is operating
h. Start mower operation according to instructions and with feet well away from the blades
i. Never mow while people especially children, or pets are nearby without supervision
j. Never allow children or animals to attempt to ride on the mower. Do not place objects on top of the mower during operation.
k. Schedule mowing times for when children are least likely to be in the area
l. Use Go Home Mode to send the mower home until the next scheduled day if children will be in the area
m. Never allow children, persons with reduced physical, sensory, or mental capabilities or lack of experience and knowledge, or people unfamiliar with these instructions to use the machine.
n. Do not operate sprinkler systems at the same time the mower is operating.
o. Start mower operation according to instructions and with feet well away from the blades.
p. Clear your lawn of objects that might be thrown or damaged (e.g., rocks, tools, ropes)
q. If the mower stops in water, call 919-804-2093. A trained professional may have to performance maintenance on the mower.
r. Do not put hands or feet near or under rotating parts.
s. Do not open the mower. You could damage the mower by doing so.
t. Do not adjust the blade of the mower.
u. Do not handle the battery.
v. Read, understand and follow all instructions in the manual, on the mower, and in this study before starting.
w. Do not hesitate to call 919-804-2093 if you have any issues or questions.

Nexus 10 Tablet

a. Use the tablet no more than 20 feet from the robot mower
b. Operation
    a. Turn on/off tablet
    b. How to charge tablet
    c. How to take pictures & video
    d. Wireless Internet
        i. To control the mower, the tablet must be connected to the mower's wireless network
        ii. To do anything else requiring internet, you must be connected to some other wireless network
c. Tango Application
    i. How to open/close application

ii. View mower battery charge

iii. Schedule
   1. Create a schedule: limited to 2 sessions a day
   2. Add/remove time slots
   3. Change schedules
   4. Default schedule: I have set up a default schedule for mowing your lawn based on your yard size and layout. But feel free to tweak it based on your preferences. Schedule the mower to run when children or pets will not be in the yard. Schedule the mower when sprinklers are off. Mower could be used during the day or at night.

iv. Mowing mode
   1. Mow on Schedule
   2. Go Mow Now
   3. Go Home
   4. Teleoperation: You can drive the robot with the blades turned off. This may be useful to transport it to a section of the lawn it cannot reach or does not regularly reach. Once you've transported it, you could put it in Go Mow Now mode.
      a. Direction
      b. Speed

Pre-Use Interview: Part II

Now I am going to ask you about the Tango robot mower and the Tango application on the tablet. Remember I am interested in your opinions and what you actually think about robot mowers. Because I am interested in what *you* think, there are no right or wrong answers. If you do not understand a question, please tell me and I will try to clarify what I am asking. If you do not want to answer a question, please tell me and I will move on to the next question. Before we begin, do you have any questions? Ok, let's begin. I am turning on the audio recorder.

1. What are your thoughts on the Tango?
    a. Why do you think that?

2. What are your thoughts on the positive aspects of using the Tango?
    a. Why is that a positive aspect of using the Tango?

3. What are your thoughts on the negative aspects of using the Tango?
    a. Why is that a negative aspect of using the Tango?

4. How frequently do you plan on using the Tango to mow?
    a. Do you have a schedule in mind for when the Tango mows?
        i. *If so:* what is the schedule?
    b. Do you plan on scheduling the Tango to mow when you are not at home? Why or why not?

5. What do you expect to do with the Tango?
    a. *If only say mowing:* Do you expect to use it for anything other than mowing?
    b. What are your expectations of using the Tango to mow your lawn?
    c. What do you expect of the Tango's grass cutting abilities?
    d. Do you expect the Tango will take any of your time for it to mow? Why or why not?
    e. Do you expect the Tango will take any of your effort for it to mow? Why or why not?
    f. Do you expect the Tango will take any of your time to maintain it? Why or why not?
    g. Do you expect the Tango will take any of your effort to maintain it? Why or why not?
    h. Do you expect the Tango to make errors? Why or Why not?
        i. *If so:* what kinds of errors do you expect the Tango to make?
    i. What do you think of the Tango's level of sound? Why?
    j. What are your expectations of the safety of the Tango? Why?
    k. What are your expectations of the Tango's consumption of electricity? Why?

6. Do you expect the Tango will change your lawn's health or appearance?
    a. *If yes:* How so?

7. What are your thoughts on using the Tango application on this tablet?
    a. Why do you think that?
8. What are your thoughts on the positive aspects of using the Tango application on this tablet?
    a. Why is that a positive aspect of using the tablet?
9. What are your thoughts on the negative aspects of using the Tango application on this tablet?
    a. Why is that a negative aspect of using the tablet?

10. Given what you know about the Tango right now. If it were available for purchase, would you buy it? Why or why not?

11. Is there anything else you would like to mention?

I am turning off the audio recorder.

Pre Robot Mower Opinions Questionnaire

Please answer the following questions keeping the Deere Tango E5 robot mower in mind. We are interested in your thoughts and opinions so there are no right or wrong answers. Some of these questions may seem repetitive, so it is okay if your answers overlap.

1. **Given what you know about the Tango right now and assuming that the Tango is available for purchase, please indicate your intention to buy this robot for your home by marking one number (1-5) on each scale:**

No intention	1	2	3	4	5	**Strong intention**
Unlikely	1	2	3	4	5	**Likely**
Not buy it	1	2	3	4	5	**Buy it**

2. **Assume that the Tango was available for purchase, but you did not own one yet. Would you buy it? Mark one.**

Yes	No	Unsure

3. Please indicate what your attitude is towards the robot mower by marking one number (1-5) on each scale:

Bad	1	2	3	4	5	**Good**
Unfavorable	1	2	3	4	5	**Favorable**
Negative	1	2	3	4	5	**Positive**

4. **Please indicate your level of comfort with using the robot mower. Mark <u>one</u> number.**

Comfortable	1	2	3	4	5	**Uncomfortable**

5. **Please rate your impression of the robot mower by marking one number (1-5) on each scale:**

Fake	1	2	3	4	5	**Natural**
Machine-like	1	2	3	4	5	**Human-like**
Unconscious	1	2	3	4	5	**Conscious**
Artificial	1	2	3	4	5	**Lifelike**
Moves rigidly	1	2	3	4	5	**Moves elegantly**

6. **Please indicate how likely each statement is about the robot mower. Mark <u>one</u> response for each statement.**

	Extremely Unlikely$_1$	**Quite Unlikely$_2$**	**Slightly Unlikely$_3$**	**Neither$_4$**	**Slightly Likely$_5$**	**Quite Likely$_6$**	**Extremely Likely$_7$**
1. I would find a robot useful in my daily life.	1	2	3	4	5	6	7
2. Using a robot would enhance my effectiveness in my daily life.	1	2	3	4	5	6	7
3. Using a robot in my daily life would increase my productivity.	1	2	3	4	5	6	7
4. Using a robot would make my daily life easier.	1	2	3	4	5	6	7
5. Using a robot would improve my daily life.	1	2	3	4	5	6	7
6. Using a robot in my daily life would enable me to accomplish tasks more quickly.	1	2	3	4	5	6	7
7. My interaction with a robot would be clear and understandable.	1	2	3	4	5	6	7
8. I would find a robot easy to use.	1	2	3	4	5	6	7
9. I would find a robot to be flexible for me to interact with.	1	2	3	4	5	6	7

	Extremely Unlikely$_1$	Quite Unlikely$_2$	Slightly Unlikely$_3$	Neither$_4$	Slightly Likely$_5$	Quite Likely$_6$	Extremely Likely$_7$
10. It would be easy for me to become skillful at using a robot.	1	2	3	4	5	6	7
11. I would find it easy to get a robot to do what I want it to do.	1	2	3	4	5	6	7
12. Learning to operate a robot would be easy for me.	1	2	3	4	5	6	7

7. **Please indicate to what extent you agree with each statement about the robot mower. Mark <u>one</u> response for each statement.**

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**
1. I have a bond with this robot	1	2	3	4	5	6	7
2. Robots make me feel uneasy	1	2	3	4	5	6	7
3. Robots do not scare me at all	1	2	3	4	5	6	7
4. Using this robot is not appropriate for a person with my values regarding the role of robots	1	2	3	4	5	6	7
5. I believe I could communicate to others the consequences of using the robot	1	2	3	4	5	6	7
6. I have seen what others do using their robot	1	2	3	4	5	6	7
7. I am quite certain what to expect from the robot	1	2	3	4	5	6	7
8. I find using the robot to be enjoyable	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
9. I find the robot pleasant to interact with	1	2	3	4	5	6	7
10. I think the robot is nice	1	2	3	4	5	6	7
11. Using the robot does not fit the way I view the world	1	2	3	4	5	6	7
12. Using a robot is compatible with all aspects of my lawn	1	2	3	4	5	6	7
13. I think that using a robot fits well with my lawn	1	2	3	4	5	6	7
14. Using the robot runs counter to my own values	1	2	3	4	5	6	7
15. This robot is very dear to me	1	2	3	4	5	6	7
16. The results of using the robot are apparent to me	1	2	3	4	5	6	7
17. I trust the robot	1	2	3	4	5	6	7
18. This robot has no special meaning for me	1	2	3	4	5	6	7

	Strongly Disagree1	Moderately Disagree2	Somewhat Disagree3	Neither Disagree or Agree4	Somewhat Agree5	Moderately Agree6	Strongly Agree7
19. I would have no difficulty telling others about the results of using the robot	1	2	3	4	5	6	7
20. Robots make me feel uncomfortable	1	2	3	4	5	6	7
21. This robot does not move me	1	2	3	4	5	6	7
22. I think the robot can be adaptive to what I need	1	2	3	4	5	6	7
23. I feel the robot understands me	1	2	3	4	5	6	7
24. I feel emotionally connected to this robot	1	2	3	4	5	6	7
25. Before deciding whether to use a robot, I will be able to properly try it out	1	2	3	4	5	6	7
26. Using the robot runs counter to my values about how to mow my lawn	1	2	3	4	5	6	7
27. The actual process of using the robot will be pleasant	1	2	3	4	5	6	7
28. I think the robot only does what I need at that particular moment	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
29. I think the robot helps me when I consider it to be necessary	1	2	3	4	5	6	7
30. It is easy for me to observe others using a robot at home	1	2	3	4	5	6	7
31. Even if not monitored, I'd trust the robot to mow correctly	1	2	3	4	5	6	7
32. Using the robot goes against what I believe robots should be used for	1	2	3	4	5	6	7
33. I will be permitted to use a robot on a trial basis long enough to see what it could do	1	2	3	4	5	6	7
34. Using a robot fits my lawn	1	2	3	4	5	6	7
35. I would have difficulty explaining why using the robot may or may not be beneficial	1	2	3	4	5	6	7
36. I will have fun using the robot	1	2	3	4	5	6	7
37. Robots are not very visible in my life	1	2	3	4	5	6	7

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**
38. Interacting with a robot makes me nervous	1	2	3	4	5	6	7
39. In my life, one sees robots in many yards	1	2	3	4	5	6	7

8. Please indicate to what extent you agree with each statement about the appearance of the robot mower. Mark one response for each statement.

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**
1. I think the robot's appearance fits with mowing	1	2	3	4	5	6	7
2. I like the way the robot looks	1	2	3	4	5	6	7
3. I find that the robot's appearance does not match with mowing	1	2	3	4	5	6	7
4. The robot looks useful	1	2	3	4	5	6	7
5. The robot looks capable of mowing	1	2	3	4	5	6	7
6. The robot seems easy to use by looking at it	1	2	3	4	5	6	7
7. I enjoy looking at the robot	1	2	3	4	5	6	7

9. Please indicate to what extent you agree with each statement about your expectation for using the robot mower. Mark one response for each statement.

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**	**Not Applicable$_0$**
1. The robot's screen will be a good way to control the robot	1	2	3	4	5	6	7	N/A
2. I will control the robot using its screen without making mistakes	1	2	3	4	5	6	7	N/A
3. I can use the robot to mow the lawn	1	2	3	4	5	6	7	N/A
4. I know how to let the robot know what to do through its screen	1	2	3	4	5	6	7	N/A
5. The robot's screen is a good way to control the robot when I am in the yard	1	2	3	4	5	6	7	N/A
6. The robot will make few errors	1	2	3	4	5	6	7	N/A
7. I could depend on this robot to work correctly every time.	1	2	3	4	5	6	7	N/A
8. It will be easy to correct errors when using the robot	1	2	3	4	5	6	7	N/A

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$	Not Applicable$_0$
9. The robot seems reliable.	1	2	3	4	5	6	7	N/A
10. The robot will accurately mow my lawn	1	2	3	4	5	6	7	N/A
11. I can easily learn how to use the robot	1	2	3	4	5	6	7	N/A
12. I am satisfied with the robot mowing my lawn	1	2	3	4	5	6	7	N/A
13. Each time the robot mows, it will be equally as helpful	1	2	3	4	5	6	7	N/A
14. I could rely on this robot to work whenever I might need it	1	2	3	4	5	6	7	N/A
15. I am physically capable of using the screen on the robot	1	2	3	4	5	6	7	N/A
16. The robot will be efficient in mowing my lawn	1	2	3	4	5	6	7	N/A
17. I can let the robot know what to do in multiple ways	1	2	3	4	5	6	7	N/A
18. I know how to use the robot's screen to make the robot mow	1	2	3	4	5	6	7	N/A

10. Please indicate to what extent you agree with each statement about your <u>expectation</u> for using the robot mower. Mark <u>one</u> response for each statement.

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**
1. I will not be satisfied with the way my lawn looks	1	2	3	4	5	6	7
2. The pattern of cut grass will be acceptable	1	2	3	4	5	6	7
3. Using the robot to mow will be easy for me	1	2	3	4	5	6	7
4. The robot is not compatible with mowing my lawn	1	2	3	4	5	6	7
5. The robot will damage objects or plants while mowing my lawn	1	2	3	4	5	6	7
6. My grass will not look healthy	1	2	3	4	5	6	7
7. I am not confident that the robot can mow safely	1	2	3	4	5	6	7
8. The robot will use too much electricity to mow	1	2	3	4	5	6	7
9. The robot will take an acceptable amount of time to mow my lawn	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
10. The grass in my lawn will be the appropriate height when the robot mows it.	1	2	3	4	5	6	7
11. The robot will take too much time to mow my lawn	1	2	3	4	5	6	7
12. The robot is quiet when it mows	1	2	3	4	5	6	7
13. My grass will seem healthy with the robot mowing it	1	2	3	4	5	6	7
14. It will take an appropriate amount of effort to use the robot	1	2	3	4	5	6	7
15. It will be difficult for me to use the robot to mow	1	2	3	4	5	6	7
16. It will take too much effort to use the robot	1	2	3	4	5	6	7
17. The robot will use an acceptable level of electricity when it mows	1	2	3	4	5	6	7
18. The grass will be a consistent height in my lawn with the robot mowing it	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
19. The robot will not damage objects or plants while mowing my lawn	1	2	3	4	5	6	7
20. I feel safe with the robot mowing	1	2	3	4	5	6	7
21. Using this robot to mow fits my lawn	1	2	3	4	5	6	7
22. The robot is too loud when it mows	1	2	3	4	5	6	7

11. Please indicate to what extent you agree with each statement for the using the Tango application on the tablet computer. If you did not use the Tango application on the tablet computer, then mark N/A. Mark one response for each statement.

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**	**Not Applicable$_0$**
1. I am physically capable of using the tablet to control the robot	1	2	3	4	5	6	7	N/A
2. I will control the robot with the tablet without making mistakes	1	2	3	4	5	6	7	N/A
3. I know how to use the tablet to make the robot mow	1	2	3	4	5	6	7	N/A
4. I know how to let the robot know what to do with the tablet	1	2	3	4	5	6	7	N/A
5. The tablet is a good way to control the robot	1	2	3	4	5	6	7	N/A
6. The tablet is a good way to control the robot when I am in the yard	1	2	3	4	5	6	7	N/A

Important Information for Robot Mower Research Study

If you have any questions or issues about the study or mower, refer to your operator's manual or contact:

Cory-Ann Smarr 919-804-2093 (expect delays in ringing)
cory-ann.smarr@gatech.edu

Reminders:

- Complete your weekly diary
- Take pictures or videos of any challenges you have with the Tango. Also, take pictures of any relevant or interesting things the Tango does. You can email them to Cory-Ann Smarr at cory-ann.smarr@gatech.edu at any point during the study.
- A researcher may come by your lawn periodically during the study to check on the mower
- Do NOT put anything (e.g., pictures, videos, status updates) on the Internet (e.g., Twitter, Facebook, website) or email about the Tango or its application on the tablet. You can email Cory-Ann Smarr at cory-ann.smarr@gatech.edu about the Tango and its application on the tablet.

APPENDIX C: ROBOT MOWER OPINIONS QUESTIONNAIRE ITEMS

Table C.1

Pre and Post Robot Mower Opinions Questionnaires Factors, Items, and Adaptation Sources

Dimension	Factor	Item	Source Item Adapted From
Attitudinal Acceptance	Attitudinal acceptance	Bad - good	Ezer, 2008
		Favorable - unfavorable	Ezer, 2008
		Negative - positive	Ezer, 2008
		Comfortable - uncomfortable	Locally developed
Intentional Acceptance	Intentional acceptance	No intention - Strong intention	Ezer, 2008
		Unlikely - Likely	Ezer, 2008
		Not buy it - Buy it	Ezer, 2008
		Assume that the Tango was available for purchase, but you did not own one yet. Would you buy it?	Ezer, 2008
Robot	Anthropo-morphism	Fake - Natural	Bartneck, Kulić, Croft, & Zoghbi, 2009
		Machinelike - Humanlike	Bartneck, Kulić, Croft, & Zoghbi, 2009
		Unconscious - Conscious	Bartneck, Kulić, Croft, & Zoghbi, 2009
		Artificial - Lifelike	Bartneck, Kulić, Croft, & Zoghbi, 2009
		Moving rigidly - Moving elegantly	Bartneck, Kulić, Croft, & Zoghbi, 2009
Human	Perceived usefulness	I would find a robot useful in my daily life.	Davis, 1989 (TAM)
		Using a robot would enhance my effectiveness in my daily life.	Davis, 1989 (TAM)
		Using a robot in my daily life would increase my productivity.	Davis, 1989 (TAM)
		Using a robot would make my daily life easier.	Davis, 1989 (TAM)
		Using a robot would improve my daily life.	Davis, 1989 (TAM)

Dimension	Factor	Item	Source Item Adapted From
	Perceived usefulness continued	Using a robot in my daily life would enable me to accomplish tasks more quickly.	Davis, 1989 (TAM)
Human	Perceived ease of use	My interaction with a robot would be clear and understandable.	Davis, 1989 (TAM)
		I would find a robot easy to use.	Davis, 1989 (TAM)
		I would find a robot to be flexible for me to interact with.	Davis, 1989 (TAM)
		It would be easy for me to become skillful at using a robot.	Davis, 1989 (TAM)
		I would find it easy to get a robot to do what I want it to do.	Davis, 1989 (TAM)
		Learning to operate a robot would be easy for me.	Davis, 1989 (TAM)
Human	Robot anxiety	Robots do not scare me at all	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		Interacting with a robot makes me nervous	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		Robots make me feel uncomfortable	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		Robots make me feel uneasy	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
Human	Trialability	*Pre:* Before deciding whether to use a robot, I will be able to properly try it out *Post:* Before deciding whether to use a robot, I was able to properly try it out	Moore & Benbasat, 1991
		Pre: I will be permitted to use a robot on a trial basis long enough to see what it could do *Post:* I was permitted to use a robot on a trial basis long enough to see what it could do	Moore & Benbasat, 1991
Human	Perceived sociability	I find the robot pleasant to interact with	Heerink, Kröse, Evers, & Wielinga, 2010a (Almere Model)

Dimension	Factor	Item	Source Item Adapted From
	Perceived sociability continued	I feel the robot understands me	Heerink, Kröse, Evers, & Wielinga, 2010a (Almere Model)
		I think the robot is nice	Heerink, Kröse, Evers, & Wielinga, 2010a (Almere Model)
Human	Perceived enjoyment	I find using the robot to be enjoyable	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		Pre: The actual process of using the robot will be pleasant. *Post:* The actual process of using the robot is pleasant	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		Pre: I will have fun using the robot *Post:* I have fun using the robot	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
Human	Visibility	In my life, one sees robots in many yards	Moore & Benbasat, 1991
		Robots are not very visible in my life	Moore & Benbasat, 1991
		I have seen what others do using their robot	Moore & Benbasat, 1991
		It is easy for me to observe others using a robot at home	Moore & Benbasat, 1991
Human	Robot trust	*Pre:* Even if not monitored, I'd trust the robot to mow correctly *Post:* Even if not monitored, I'd trust the robot to do the job right	Gefen, Karahanna, & Straub, 2003
		I trust the robot	Gefen, Karahanna, & Straub, 2003
		I am quite certain what to expect from the robot	Gefen, Karahanna, & Straub, 2003
Human	Result demon-strability	*Pre:* I would have no difficulty telling others about the results of using the robot *Post:* I have no difficulty telling others about the results of using the robot	Venkatesh & Bala, 2008 (TAM3); Venkatesh & Davis, 2000 (TAM2)
		I believe I could communicate to others the consequences of using the robot	Venkatesh & Bala, 2008 (TAM3)
		The results of using the robot are apparent to me	Venkatesh & Bala, 2008 (TAM3)
		I would have difficulty explaining why using the robot may or may not be beneficial	Venkatesh & Bala, 2008 (TAM3)

Dimension	Factor	Item	Source Item Adapted From
Context	Compat-ibility with values	Using the robot runs counter to my own values	Karahanna, Agarwal, & Angst, 2006
		Using the robot does not fit the way I view the world	Karahanna, Agarwal, & Angst, 2006
		Using the robot goes against what I believe robots should be used for	Karahanna, Agarwal, & Angst, 2006
		Using this robot is not appropriate for a person with my values regarding the role of robots	Karahanna, Agarwal, & Angst, 2006
		Using the robot runs counter to my values about how to mow my lawn	Karahanna, Agarwal, & Angst, 2006
Context	Compat-ibility with physical environment	I think that using a robot fits well with my lawn	Locally developed
		Using a robot is compatible with all aspects of my lawn	Locally developed
		Using a robot fits my lawn	Locally developed
Human	Emotional attachment	I feel emotionally connected to this robot	Schifferstein & Zwartkruis-Pelgrim, 2008
		This robot is very dear to me	Schifferstein & Zwartkruis-Pelgrim, 2008
		I have a bond with this robot	Schifferstein & Zwartkruis-Pelgrim, 2008
		This robot has no special meaning for me	Schifferstein & Zwartkruis-Pelgrim, 2008
		This robot does not move me	Schifferstein & Zwartkruis-Pelgrim, 2008
Robot	Perceived Adaptivity	I think the robot can be adaptive to what I need	Heerink, Kröse, Evers, & Wielinga, 2010a (Almere Model)
		Pre: I think the robot only does what I need at that particular moment *Post:* I think the robot will only do what I need at that particular moment	Heerink, Kröse, Evers, & Wielinga, 2010a (Almere Model)
		Pre: I think the robot helps me when I consider it to be necessary *Post:* I think the robot will help me when I consider it to be necessary	Heerink, Kröse, Evers, & Wielinga, 2010a (Almere Model)

Dimension	Factor	Item	Source Item Adapted From
Robot	Appearance	I think the robot's appearance fits with mowing	Locally developed
		The robot looks capable of mowing	Locally developed
		I find that the robot's appearance does not match with mowing	Locally developed
		The robot looks useful	Locally developed; Inspired by findings from Eimler et al., 2011; Hegel et al., 2009
		The robot seems easy to use by looking at it	Locally developed; Inspired by findings from Eimler et al., 2011; Hegel et al., 2009
		I like the way the robot looks	Locally developed; Inspired by findings from Eimler et al., 2011; Hegel et al., 2009
		I enjoy looking at the robot	Locally developed; Inspired by findings from Eimler et al., 2011; Hegel et al., 2009
Robot	Method of Control (mower UI)	I am physically capable of using the screen on the robot	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		Pre: I will control the robot using its screen without making mistakes *Post:* I can control the robot using its screen without making mistakes	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		I know how to use the robot's screen to make the robot mow	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		I know how to let the robot know what to do through its screen	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		Pre: The robot's screen will be a good way to control the robot *Post:* The robot's screen is a good way to control the robot	Locally developed; Inspired from Smarr, Fisk, & Rogers, 2013
		The robot's screen is a good way to control the robot when I am in the yard	Locally developed; Inspired from Smarr, Fisk, & Rogers, 2013

Dimension	Factor	Item	Source Item Adapted From
Robot	Usability	*Pre:* The robot will make few errors *Post:* The robot makes few errors	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
		Pre: The robot will accurately mow my lawn *Post:* The robot accurately mows my lawn	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
		Pre: The robot will be efficient in mowing my lawn *Post:* The robot is efficient in mowing my lawn	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
		I am satisfied with the robot mowing my lawn	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
		I can easily learn how to use the robot	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
		I can let the robot know what to do in multiple ways	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
		Pre: It will be easy to correct errors when using the robot *Post:* It is easy to correct errors when using the robot	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
		I can use the robot to mow the lawn	Locally developed; Inspired by Weiss, Bernhaupt, Lankes, & Tscheligi, 2009
Robot	Perceived Reliability	I could depend on this robot to work correctly every time.	Kidd, 2003
		The robot seems reliable.	Kidd, 2003
		I could rely on this robot to work whenever I might need it.	Kidd, 2003
		Each time the robot mows, it is equally as helpful	Kidd, 2003
Task-technology fit	Time / Efficiency	*Pre:* The robot will take an acceptable amount of time to mow my lawn *Post:* It takes an acceptable amount of time to mow my lawn	Locally developed from people's mowing goals and Goodhue, 1995
		Pre: The robot will take too much time to mow my lawn *Post:* It takes too much time to mow my lawn	Locally developed from people's mowing goals and Goodhue, 1995
	Damage prevention	*Pre:* The robot will damage objects or plants while mowing my lawn *Post:* The robot has damaged objects or plants while mowing my lawn	Locally developed from people's mowing goals and Goodhue, 1995

Dimension	Factor	Item	Source Item Adapted From
	Damage prevention continued	*Pre:* The robot will not damage objects or plants while mowing my lawn *Post:* The robot has not damaged objects or plants while mowing my lawn	Locally developed from people's mowing goals and Goodhue, 1995
	Effort of use	*Pre:* It will take too much effort to use the robot *Post:* It takes too much effort to use the robot	Locally developed from people's mowing goals and Goodhue, 1995
		Pre: It will take an appropriate amount of effort to use the robot *Post:* It takes an appropriate amount of effort to use the robot	Locally developed from people's mowing goals and Goodhue, 1995
	Compat-ibility	Using this robot to mow fits my lawn	Locally developed
		The robot is not compatible with mowing my lawn	Locally developed
	Ease of use	*Pre:* It will be difficult for me to use the robot to mow *Post:* It is difficult for me to use the robot to mow	Locally developed from people's mowing goals and Goodhue, 1995
		Pre: Using the robot to mow will be easy for me *Post:* Using the robot to mow is easy for me	Locally developed from people's mowing goals and Goodhue, 1995
	Appearance of lawn	*Pre:* The grass in my lawn will be the appropriate height when the robot mows it. *Post:* The grass in my lawn is the appropriate height	Locally developed from people's mowing goals and Goodhue, 1995
		The grass is a consistent height in my lawn	Locally developed from people's mowing goals and Goodhue, 1995
		Pre: The pattern of cut grass will be acceptable *Post:* The pattern of the cut grass is acceptable	Locally developed from people's mowing goals and Goodhue, 1995
		Pre: I will not be satisfied with the way my lawn looks *Post:* I am not satisfied with the way my lawn looks	Locally developed from people's mowing goals and Goodhue, 1995
	Health of lawn	*Pre:* My grass will seem healthy with the robot mowing it *Post:* My grass seems healthy	Locally developed from people's mowing goals and Goodhue, 1995
		Pre: My grass will not look healthy *Post:* My grass does not look healthy	Locally developed from people's mowing goals and Goodhue, 1995

Dimension	Factor	Item	Source Item Adapted From
	Level of sound	The robot is too loud when it mows	Locally developed from people's mowing goals and Goodhue, 1995
		The robot is quiet when it mows	Locally developed from people's mowing goals and Goodhue, 1995
	Safety	I feel safe with the robot mowing	Locally developed from people's mowing goals and Goodhue, 1995
		I am not confident that the robot can mow safely	Locally developed from people's mowing goals and Goodhue, 1995
	Energy Consump-tion	*Pre:* The robot will use an acceptable level of electricity when it mows *Post:* The robot uses an acceptable level of electricity when it mows	Locally developed from people's mowing goals and Goodhue, 1995
		Pre: The robot will use too much electricity to mow *Post:* The robot uses too much electricity to mow	Locally developed from people's mowing goals and Goodhue, 1995
Robot	Method of control (remote UI)	I am physically capable of using the tablet to control the robot	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		Pre: I will control the robot with the tablet without making mistakes *Post:* I can control the robot with the tablet without making mistakes	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		I know how to use the tablet to make the robot mow	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		I know how to let the robot know what to do with the tablet	Locally developed; Inspired by findings from Beer, Prakash, et al., 2012
		The tablet is a good way to control the robot	Locally developed; Inspired from Smarr, Fisk, & Rogers, 2013
		The tablet is a good way to control the robot when I am in the yard	Locally developed; Inspired from Smarr, Fisk, & Rogers, 2013

APPENDIX D: WEEKLY DIARY

Diary Entry

You have been given a weekly diary to record your experiences interacting with the Deere Tango E5 robot mower. This diary includes spaces for you to record your experiences and any difficulties you had with the robotic mower.

Remember there are no right or wrong answers.

Please email Cory-Ann Smarr at cory-ann.smarr@gatech.edu with any relevant pictures that are interesting or would help us understand your responses to these questions.

If you have any questions or if anything is unclear, please contact Cory-Ann Smarr at cory-ann.smarr@gatech.edu or 919-804-2093.

* Required

1. **1. Did you use the robot mower this week?** *
   Keep in mind "using" the robot mower means any time you allow the robot to mow with or without you being present.
   Mark only one oval.
   - ( ) Yes
   - ( ) No. Please skip to Question 1d.

2. **1a. If yes, why did you use the robot mower this week?**
   Please describe.

   ____
   ____
   ____
   ____
   ____

3. **1b. What were the positive aspects of using the robot mower this week?** *
   Please describe.

   ____
   ____
   ____
   ____
   ____

4. **1c. What were the negative aspects of using the robot mower this week?** *
Please describe.

5. **1d. If no, why did you NOT use the robot mower this week?**
Please describe.

6. **2. Did you watch the robot mower this week?** *
Mark only one oval.

- Yes
- No. Please skip to Question 2e.

7. **2a. If yes, why did you watch the robot mower this week?**
Please describe.

8. **2b. If yes, which days of the week did you watch the robot mower?**
Check all that apply.

- [ ] Monday
- [ ] Tuesday
- [ ] Wednesday
- [ ] Thursday
- [ ] Friday
- [ ] Saturday
- [ ] Sunday

9. **2c. If yes, how many minutes did you watch the robot mower this week in total?**
If you do not know, then please estimate.

____

10. **2d. If yes, who did you watch the robot mower with this week?**
Check all that apply.

- [ ] I watched the mower by myself.
- [ ] I watched the mower with another member of my household.
- [ ] I watched the mower with my neighbor.
- [ ] I watched the mower with a visitor who lives outside my neighborhood.
- [ ] Other: _______________________________

11. **2e. If no, why did you NOT watch the robot mower this week?**
Please describe.

____
____
____
____
____

12. **3. Were there any difficulties using the robot mower this week?** *
Mark only one oval.

- ( ) Yes
- ( ) No

13. **3a. If yes, what were the difficulties and how did you overcome those difficulties?**
Please describe.

____
____
____
____
____

14. **4. Please indicate what your attitude is towards the robot mower.** *
Mark only one oval.

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Good

15. **5. Please indicate what your attitude is towards the robot mower.** *
Mark only one oval.

	1	2	3	4	5	
Unfavorable	◯	◯	◯	◯	◯	Favorable

16. **6. Please indicate what your attitude is towards the robot mower.** *
Mark only one oval.

	1	2	3	4	5	
Negative	◯	◯	◯	◯	◯	Positive

17. **7. Please indicate your level of comfort with using the robot mower.** *
Mark only one oval.

	1	2	3	4	5	
Uncomfortable	◯	◯	◯	◯	◯	Comfortable

18. **8. Please indicate how likely each statement is.** *

Mark only one oval per row.

	Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely
a. I would find a robot useful in my daily life.							
b. Using a robot would enhance my effectiveness in my daily life.							
c. Using a robot in my daily life would increase my productivity.							
d. Using a robot would make my daily life easier.							
e. Using a robot would improve my daily life.							
f. Using a robot in my daily life would enable me to accomplish tasks more quickly.							

19. **9. Please indicate how likely each statement is.** *

Mark only one oval per row.

	Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely
a. My interaction with a robot would be clear and understandable.							
b. I would find a robot easy to use.							
c. I would find a robot to be flexible for me to interact with.							
d. It would be easy for me to become skillful at using a robot.							
e. I would find it easy to get a robot to do what I want it to do.							
f. Learning to operate a robot would be easy for me.							

20. **10. Did you use the Tango application on the Nexus 10 tablet this week?** *

Mark only one oval.

- Yes
- No. Please skip to Question 10d.

21. **10a. If yes, why did you use the Tango application this week?**

Please describe.

22. **10b. What were the positive aspects of using the Tango application on the tablet this week?**
Please describe.

____
____
____
____
____

23. **10c. What were the negative aspects of using the Tango application on the tablet this week?**
Please describe.

____
____
____
____
____

24. **10d. If no, why did you NOT use the Tango application this week?**
Please describe.

____
____
____
____
____

25. **11. Were there any difficulties using the Tango application on the Nexus 10 tablet this week?** *
Mark only one oval.

- ( ) Yes
- ( ) No

26. **11a. If yes, what were the difficulties and how did you overcome those difficulties?**
Please describe.

____
____
____
____
____

27. **12. Please write any other comments, thoughts, or experiences about using the robot mower this week.** *

____

____

____

____

____

28. **13. What is your nickname for this study? Please do NOT write your real name.** *
Hint: The 1st part of your nickname is your favorite color. The 2nd part of your nickname is your favorite season (e.g., spring, winter).

____

29. **14. Email any relevant or interesting pictures from this week to Cory Smarr at cory-ann.smarr@gatech.edu** *
Mark only one oval.

- ( ) I plan to email pictures
- ( ) I do not plan to email pictures

APPENDIX E: POST-USE INTERVIEW MATERIALS

Demographics & Health Questionnaire

INSTRUCTIONS: In this section we would like to know more about you. Please answer the following questions by placing a check in the appropriate box for each question or by writing your answer in the space provided. All of your answers will be treated anonymously. If there is a question you do not wish to answer, please just leave it blank and go on to the next question.

1. Gender: Male ☐$_1$ Female ☐$_2$

2. Age: __________

3. What is the highest level of education that you have completed?

☐$_1$ No formal education

☐$_2$ Less than high school graduate

☐$_3$ High school graduate/GED

☐$_4$ Vocational training

☐$_5$ Some 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.)

4. Do you consider yourself Hispanic or Latino?

☐$_1$ Yes

☐$_2$ No

4a. If "Yes", would you describe yourself:

☐$_1$ Cuban

☐$_2$ Mexican

☐$_3$ Puerto Rican

☐$_4$ Other (please specify) _______________

5. How would you describe your primary racial group? (Check one)

- ☐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) ___________________

6. Do you live by yourself?

- ☐1 Yes
- ☐2 No

6a. If No, how many people beside you live in your home? ________________

7. Who do you live with in your home? (Check all that apply)

- ☐1 Significant other
- ☐2 Friends
- ☐3 Parents
- ☐4 Grandparents
- ☐5 Siblings
- ☐6 Children
- ☐7 Grandchildren
- ☐8 Other_______________

7. 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) ___________________

8. What is your primary occupation? ___________________

If retired:

8a. What was your primary occupation? __________________

8b. What year did you retire? ____________________

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

☐1 Less than $25,000

☐2 $25,000-$49,999

☐3 $50,000-$74,999

☐4 $75,000-$99,999

☐5 $100,000-$124,999

☐6 $125,000-$149,999

☐7 $150,000-$174,999

☐8 $175,000-$199,999

☐9 $200,000 or more

☐10 Do not know for certain

☐11 Do not wish to answer

Health Information

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

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

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

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

3. The following items are activities you might do during a typical day. Does your health currently limit you in these activities? Check <u>one</u> box for each type of activity.

	Not limited at all$_1$	**Limited a little**$_2$	**Limited a lot**$_3$
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 household activities, such as pushing vacuum cleaner, scrubbing tiles, or washing windows			
g. Vigorous activities, such as running, pushing lawn mower, or participating in strenuous sports (e.g., swimming laps)			
h. Walking **more than a mile**			
i. Walking **one block**			
j. Walking **several blocks**			

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						
g.	Desktop/Laptop Computer					
h.	Email (e.g., Gmail, Yahoo)					
i.	Photo/Video Software (e.g., editing, organizing; iPhoto, Picture Manager, Photoshop)					
j.	Productivity Software (e.g., Excel, PowerPoint, Quicken, TurboTax, Word)					
k.	Social Networking (e.g., Facebook, MySpace)					
l.	Tablet Computer (e.g., iPad, Touchpad, Zoom)					
Everyday Technology						
m.	Automatic Teller Machine (ATM)					
n.	Photocopier (e.g., Lexmark, Xerox)					
o.	Home Security System (e.g., Ackerman Security System, ADT)					
p.	In-Store Kiosk (e.g., grocery self-checkout, price checker)					
q.	Microwave Oven					
r.	Programmable Device (e.g., coffee maker, thermostat)					

		Not sure what it is$_1$	Not used$_2$	Used once$_3$	Used occasionally$_4$	Used frequently$_5$
Health Technology						
s.	Blood Pressure Monitor (e.g., measure blood pressure)					
t.	Digital Thermometer (e.g., measure temperature)					
u.	Health Management Software (e.g., diet, exercise, keep track of weight)					
v.	Heart Rate Monitor (e.g., measure heart rate, pulse)					
w.	Medication Reminder Device (e.g., schedule electronic alerts)					
x.	Pedometer (e.g., measure walking distance)					
Recreational Technology						
y.	Digital Music Player (e.g., iPod, MP3 player, Zune)					
z.	Digital Photography (e.g., camcorder, camera)					
aa.	Electronic Book Reader (e.g., Kindle, Nook)					
bb.	Gaming Console (e.g., Playstation, Wii, XBox)					
cc.	Online Coupons/ Shopping (e.g., Amazon, Groupon, retail stores)					
dd.	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						
ee.	Airline Kiosk (e.g., check in, print boarding pass)					
ff.	Bus Tracker (e.g., check location of buses, estimate time of arrival)					
gg.	Map Software (e.g., get directions, plan routes; Google Maps, MapQuest)					
hh.	Navigation System (e.g., GPS, OnStar)					
ii.	Online Travel Reservation (e.g., airline website, Expedia, Travelocity)					
jj.	Parking Payment System (e.g., exiting lot, paying for space)					

		Not sure what it is1	Not used2	Used once3	Used occasionally4	Used frequently5
Other technology						
kk.	Google Nexus tablet (e.g., Nexus 7, Nexus 10)					
ll.	Other Android tablet (e.g., Samsung Galaxy Tab)					
mm.	Non-Android tablet (e.g., Apple iPad, Microsoft Surface)					
nn.	Android smart phone (e.g., HTC One, Samsung Galaxy S4)					
oo.	Non-Android smart phone (e.g., Apple iPhone, Nokia Lumia)					

Post Lawn Questionnaire

INSTRUCTIONS: In this section we would like to know more about your lawn when the Tango mows your lawn. Please answer the following questions by placing a check in the appropriate box for each question or by writing your answer in the space provided. All of your answers will be treated anonymously. If there is a question you do not wish to answer, please just leave it blank and go on to the next question.

A **lawn** is an area of short, mown grass in a yard

Please mark one answer for each of the following questions about how satisfied you are with the amount of your TIME it takes you to have the Tango mow your lawn. If you did not have the Tango mow your lawn, then mark not applicable.

1. How satisfied are you with the amount of time it takes you to get the Tango ready to mow your lawn?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

2. How satisfied are you with the amount of time it takes you to let the Tango know to mow your lawn?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

3. How satisfied are you with the amount of time it takes you to clean up after the Tango mows your lawn?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

4. Considering all these aspects, how satisfied are you with the time it takes you to have the Tango mow your lawn?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

Please mark one answer for each of the following questions about how satisfied you are with the amount of EFFORT it takes you to have the Tango mow your lawn. If you did not have the Tango mow your lawn, then mark not applicable.

1. **How satisfied are you with the amount of effort it takes you to get the Tango ready to mow your lawn (e.g., pull out mower, put gasoline in it)?**

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

2. **How satisfied are you with the amount of effort it takes you to let the Tango know to mow your lawn?**

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

3. **How satisfied are you with the amount of effort it takes you to clean up after the Tango mows your lawn?**

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

4. **Considering all these aspects, how satisfied are you with the effort it takes you to have the Tango mow your lawn?**

☐1	☐2	☐3	☐4	☐5	☐6
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

Please mark one answer for each of the following questions about how satisfied you are <u>when the Tango mows your lawn</u>.

1. How satisfied are you with how your lawn looks when the Tango mows your lawn?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

2. How satisfied are you with the health of your lawn when the Tango mows it?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

3. How satisfied are you with the level of sound that the Tango emits while mowing your lawn?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

4. How satisfied are you with the safety of the Tango?

☐$_1$	☐$_2$	☐$_3$	☐$_4$	☐$_5$	☐$_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

5. How satisfied are you with the amount of electricity the Tango uses while mowing?

☐ $_1$	☐ $_2$	☐ $_3$	☐ $_4$	☐ $_5$	☐ $_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

6. How satisfied are you with the Tango's maintenance routine?

☐ $_1$	☐ $_2$	☐ $_3$	☐ $_4$	☐ $_5$	☐ $_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

7. Considering all these aspects, how satisfied are you with the Tango mowing your lawn?

☐ $_1$	☐ $_2$	☐ $_3$	☐ $_4$	☐ $_5$	☐ $_6$
Very Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Very Satisfied	Not Applicable

Post-Use Interview

Today I am going to ask you about your attitudes toward and experiences with the Deere Tango E5 robot mower. I am interested in your opinions and what you actually think about robot mowers. Because I am interested in what *you* think, there are no right or wrong answers. If you do not understand a question, please tell me and I will try to clarify what I am asking. If you do not want to answer a question, please tell me and I will move on to the next question. Before we begin, do you have any questions? Ok, let's begin. I am turning on the audio recorder.

For the purposes of this study, the "lawn" is the area of short, mown grass in your yard. Do you have any questions?

Remember "use robot mower" can have several meanings, but for the purposes of this study "use robot mower" means that you allow the robot to mow with or without you being present. For example, if you press the arrow on the robot to make it mow right now that is "using the robot mower". Also, if you schedule the robot to mow on Saturday and you are out of town, you are "using the robot mower" to mow even though you are not at home and did not touch the robot. Please think of all these situations when you answer questions about using the robot. Do you have any questions?

15. What did you use the Tango to do?
    a. *If only say mowing:* Did you use it for anything other than mowing?
16. Was there anything you wanted the Tango to do that it could not do?
17. Did you watch the Tango when it was mowing your lawn? Every time?

We are going to talk about how you used the Tango to mow your lawn.

18. Who used the Tango the most to mow your lawn? Why?
19. Did anyone else use the Tango to mow your lawn?
20. How often did you use the Tango to mow your lawn? Why?
21. Did you adjust how often you used the Tango since I installed the Tango?
    a. *If yes:* What adjustments did you make? How did you know to make the adjustments?
22. How did you know when to use the Tango to mow your lawn?
23. Is there a certain time of the week you used the Tango to mow your lawn? Why?
24. Did you have a strategy when you use the Tango to mow your lawn? If so, what?
25. Did you hire someone to mow your lawn during the study?
    a. *If yes:* Why?
26. Did you also use your regular lawn mower to cut grass?
    a. *If yes*: How did you use your regular lawn mower during this study?
27. Did you do anything else to cut your grass during this study?
    a. *If yes:* What? Why?

28. What are your thoughts on the Tango?
    a. Why do you think that?

29. What are your thoughts on the positive aspects of using the Tango?
    a. Why is that a positive aspect of using the Tango?
    b. What is your favorite aspect of using the Tango?

30. What are your thoughts on the negative aspects of using the Tango?
    c. Why is that a negative aspect of using the Tango?
    d. What is your least favorite aspect of using the Tango?

31. Did you use the Tango how you planned to from the first interview? Why or why not?
    b. Did you use it more or less frequently than you planned?
        i. *If yes:* Why?
    c. Did you use the same schedule you started out with? Why or why not?
    d. Did you use the Tango when you were not home? Why or why not?

32. Did you use the Tango how you expected to? Why or why not?
    a. Did the Tango mow your lawn how you expected it to? Why or why not?
    b. Did the Tango's grass cutting abilities meet your expectations? Why or why not?
    c. Did the Tango take as much of your time for it to mow as you expected? Why or why not?
    d. Did the Tango take as much of your effort for it to mow as you expected? Why or why not?
    e. Did the Tango take as much of your time to maintain it as you expected? Why or why not?
    f. Did the Tango take as much of your effort to maintain it as you expected? Why or why not?
    g. Did the Tango meet your expectations for making errors? Why or Why not?
        i. *If not:* What kind of errors did the Tango make?
    h. Did the Tango meet your expectations for level of sound? Why or Why not?
    i. Did the Tango meet your expectations for the safety of the Tango? Why or Why not?
    j. Did the Tango meet your expectations for consumption of electricity? Why or Why not?

33. Did use of the Tango change your lawn's health or appearance?
    a. *If yes:* How so?

34. Was there anything you wanted to do with the Tango that it could not do?

35. What are your thoughts on using the Tango application on this tablet?
    a. Why do you think that?

36. What are your thoughts on the positive aspects of using the Tango application on this tablet?
    a. Why is that a positive aspect of using the tablet?

37. What are your thoughts on the negative aspects of using the Tango application on this tablet?
    a. Why is that a negative aspect of using the tablet?

38. Was there anything you wanted to do with the Tango application that it could not do?

39. Given what you know about the Tango right now. If it were available for purchase, would you buy it? Why or why not?

40. Do you show the robot mower to anyone?
    a. *If yes:* Please describe (*who, what, why, when, where*).
    b. *If no:* Why not?

41. Do you talk about the Tango with anyone?
    a. *If yes:* Please describe (*who, what, why, when, where*).
    b. *If no:* Why not?

42. Would you want to personalize or customize your Tango?

43. Did you name the Tango?
    a. *If yes:* What was the name?

44. Did you put an outfit or costume on the Tango?
    a. *If yes:* Please describe it.

45. Is there anything else you would like to mention?

I am turning off the audio recorder.

<u>Post Robot Mower Opinions Questionnaire</u>

Please answer the following questions keeping the Deere Tango E5 robot mower in mind. We are interested in your thoughts and opinions so there are no right or wrong answers. Some of these questions may seem repetitive, so it is okay if your answers overlap.

1. **Given what you know about the Tango right now and assuming that the Tango is available for purchase, please indicate your intention to buy this robot for your home by marking one number (1-5) on each scale:**

No intention	1	2	3	4	5	**Strong intention**
Unlikely	1	2	3	4	5	**Likely**
Not buy it	1	2	3	4	5	**Buy it**

2. **Assume that the Tango was available for purchase, but you did not own one yet. Would you buy it? Mark <u>one</u>.**

Yes	No	Unsure

3. Please indicate what your attitude is towards the robot mower by marking one number (1-5) on each scale:

Bad	1	2	3	4	5	**Good**
Unfavorable	1	2	3	4	5	**Favorable**
Negative	1	2	3	4	5	**Positive**

4. **Please indicate your level of comfort with using the robot mower. Mark one number.**

Comfortable	1	2	3	4	5	**Uncomfortable**

5. **Please rate your impression of the robot mower by marking one number (1-5) on each scale:**

Fake	1	2	3	4	5	**Natural**
Machine-like	1	2	3	4	5	**Human-like**
Unconscious	1	2	3	4	5	**Conscious**
Artificial	1	2	3	4	5	**Lifelike**
Moves rigidly	1	2	3	4	5	**Moves elegantly**

6. Please indicate how likely each statement is about the robot mower. Mark one response for each statement.

	Extremely Unlikely₁	**Quite Unlikely₂**	**Slightly Unlikely₃**	**Neither₄**	**Slightly Likely₅**	**Quite Likely₆**	**Extremely Likely₇**
1. I would find a robot useful in my daily life.	1	2	3	4	5	6	7
2. Using a robot would enhance my effectiveness in my daily life.	1	2	3	4	5	6	7
3. Using a robot in my daily life would increase my productivity.	1	2	3	4	5	6	7
4. Using a robot would make my daily life easier.	1	2	3	4	5	6	7
5. Using a robot would improve my daily life.	1	2	3	4	5	6	7
6. Using a robot in my daily life would enable me to accomplish tasks more quickly.	1	2	3	4	5	6	7
7. My interaction with a robot would be clear and understandable.	1	2	3	4	5	6	7
8. I would find a robot easy to use.	1	2	3	4	5	6	7
9. I would find a robot to be flexible for me to interact with.	1	2	3	4	5	6	7

	Extremely Unlikely$_1$	Quite Unlikely$_2$	Slightly Unlikely$_3$	Neither$_4$	Slightly Likely$_5$	Quite Likely$_6$	Extremely Likely$_7$
10. It would be easy for me to become skillful at using a robot.	1	2	3	4	5	6	7
11. I would find it easy to get a robot to do what I want it to do.	1	2	3	4	5	6	7
12. Learning to operate a robot would be easy for me.	1	2	3	4	5	6	7

7. Please indicate to what extent you agree with each statement about the robot mower. Mark <u>one</u> response for each statement.

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
1. I have a bond with this robot	1	2	3	4	5	6	7
2. Robots make me feel uneasy	1	2	3	4	5	6	7
3. Robots do not scare me at all	1	2	3	4	5	6	7
4. Using the robot is not appropriate for a person with my values regarding the role of robots	1	2	3	4	5	6	7
5. I believe I could communicate to others the consequences of using the robot	1	2	3	4	5	6	7
6. I have seen what others do using their robot	1	2	3	4	5	6	7
7. I am quite certain what to expect from the robot	1	2	3	4	5	6	7
8. I find using the robot to be enjoyable	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
9. I find the robot pleasant to interact with	1	2	3	4	5	6	7
10. I think the robot is nice	1	2	3	4	5	6	7
11. Using the robot does not fit the way I view the world	1	2	3	4	5	6	7
12. Using a robot is compatible with all aspects of my lawn	1	2	3	4	5	6	7
13. I think that using a robot fits well with my lawn	1	2	3	4	5	6	7
14. Using the robot runs counter to my own values	1	2	3	4	5	6	7
15. This robot is very dear to me	1	2	3	4	5	6	7
16. The results of using the robot are apparent to me	1	2	3	4	5	6	7
17. I trust the robot	1	2	3	4	5	6	7
18. This robot has no special meaning for me	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
19. I have no difficulty telling others about the results of using the robot	1	2	3	4	5	6	7
20. Robots make me feel uncomfortable	1	2	3	4	5	6	7
21. This robot does not move me	1	2	3	4	5	6	7
22. I think the robot can be adaptive to what I need	1	2	3	4	5	6	7
23. I feel the robot understands me	1	2	3	4	5	6	7
24. I feel emotionally connected to this robot	1	2	3	4	5	6	7
25. Before deciding whether to use a robot, I was able to properly try it out	1	2	3	4	5	6	7
26. Using the robot runs counter to my values about how to mow my lawn	1	2	3	4	5	6	7
27. The actual process of using the robot is pleasant	1	2	3	4	5	6	7
28. I think the robot will only do what I need at that particular moment	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
29. I think the robot will help me when I consider it to be necessary	1	2	3	4	5	6	7
30. It is easy for me to observe others using a robot at home	1	2	3	4	5	6	7
31. Even if not monitored, I'd trust the robot to do the job right	1	2	3	4	5	6	7
32. Using the robot goes against what I believe robots should be used for	1	2	3	4	5	6	7
33. I was permitted to use a robot on a trial basis long enough to see what it could do	1	2	3	4	5	6	7
34. Using a robot fits my lawn	1	2	3	4	5	6	7
35. I would have difficulty explaining why using the robot may or may not be beneficial	1	2	3	4	5	6	7
36. I have fun using the robot	1	2	3	4	5	6	7
37. Robots are not very visible in my life	1	2	3	4	5	6	7

	Strongly Disagree$_1$	**Moderately Disagree**$_2$	**Somewhat Disagree**$_3$	**Neither Disagree or Agree**$_4$	**Somewhat Agree**$_5$	**Moderately Agree**$_6$	**Strongly Agree**$_7$
38. Interacting with a robot makes me nervous	1	2	3	4	5	6	7
39. In my life, one sees robots in many yards	1	2	3	4	5	6	7

8. **Please indicate to what extent you agree with each statement about the appearance of the robot mower. Mark <u>one</u> response for each statement.**

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**
1. I think the robot's appearance fits with mowing	1	2	3	4	5	6	7
2. I like the way the robot looks	1	2	3	4	5	6	7
3. I find that the robot's appearance does not match with mowing	1	2	3	4	5	6	7
4. The robot looks useful	1	2	3	4	5	6	7
5. The robot looks capable of mowing	1	2	3	4	5	6	7
6. The robot seems easy to use by looking at it	1	2	3	4	5	6	7
7. I enjoy looking at the robot	1	2	3	4	5	6	7

9. **Please indicate to what extent you agree with each statement for using the robot mower. Mark <u>one</u> response for each statement.**

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**	**Not Applicable$_0$**
1. The robot's screen is a good way to control the robot	1	2	3	4	5	6	7	N/A
2. I can control the robot using its screen without making mistakes	1	2	3	4	5	6	7	N/A
3. I can use the robot to mow the lawn	1	2	3	4	5	6	7	N/A
4. I know how to let the robot know what to do through its screen	1	2	3	4	5	6	7	N/A
5. The robot's screen is a good way to control the robot when I am in the yard	1	2	3	4	5	6	7	N/A
6. The robot makes few errors	1	2	3	4	5	6	7	N/A
7. I could depend on this robot to work correctly every time.	1	2	3	4	5	6	7	N/A
8. It is easy to correct errors when using the robot	1	2	3	4	5	6	7	N/A
9. The robot seems reliable.	1	2	3	4	5	6	7	N/A

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$	Not Applicable$_0$
10. The robot accurately mows my lawn	1	2	3	4	5	6	7	N/A
11. I can easily learn how to use the robot	1	2	3	4	5	6	7	N/A
12. I am satisfied with the robot mowing my lawn	1	2	3	4	5	6	7	N/A
13. Each time the robot mows, it is equally as helpful	1	2	3	4	5	6	7	N/A
14. I could rely on this robot to work whenever I might need it.	1	2	3	4	5	6	7	N/A
15. I am physically capable of using the screen on the robot	1	2	3	4	5	6	7	N/A
16. The robot is efficient in mowing my lawn	1	2	3	4	5	6	7	N/A
17. I can let the robot know what to do in multiple ways	1	2	3	4	5	6	7	N/A
18. I know how to use the robot's screen to make the robot mow	1	2	3	4	5	6	7	N/A

10. Please indicate to what extent you agree with each statement for the using the robot mower. Mark one response for each statement.

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
1. I am not satisfied with the way my lawn looks	1	2	3	4	5	6	7
2. The pattern of the cut grass is acceptable	1	2	3	4	5	6	7
3. Using the robot to mow is easy for me	1	2	3	4	5	6	7
4. The robot is not compatible with mowing my lawn	1	2	3	4	5	6	7
5. The robot has damaged objects or plants while mowing my lawn	1	2	3	4	5	6	7
6. My grass does not look healthy	1	2	3	4	5	6	7
7. I am not confident that the robot can mow safely	1	2	3	4	5	6	7
8. The robot uses too much electricity to mow	1	2	3	4	5	6	7
9. It takes an acceptable amount of time to mow my lawn	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
10. The grass in my lawn is the appropriate height	1	2	3	4	5	6	7
11. It takes too much time to mow my lawn	1	2	3	4	5	6	7
12. The robot is quiet when it mows	1	2	3	4	5	6	7
13. My grass seems healthy	1	2	3	4	5	6	7
14. It takes an appropriate amount of effort to use the robot	1	2	3	4	5	6	7
15. It is difficult for me to use the robot to mow	1	2	3	4	5	6	7
16. It takes too much effort to use the robot	1	2	3	4	5	6	7
17. The robot uses an acceptable level of electricity when it mows	1	2	3	4	5	6	7
18. The grass is a consistent height in my lawn	1	2	3	4	5	6	7
19. The robot has not damaged objects or plants while mowing my lawn	1	2	3	4	5	6	7

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**
20. I feel safe with the robot mowing	1	2	3	4	5	6	7
21. Using this robot to mow fits my lawn	1	2	3	4	5	6	7
22. The robot is too loud when it mows	1	2	3	4	5	6	7

11. Please indicate to what extent you agree with each statement for the using the Tango application on the tablet computer. If you did not use the Tango application on the tablet computer, then mark N/A. Mark one response for each statement.

	Strongly Disagree1	Moderately Disagree2	Somewhat Disagree3	Neither Disagree or Agree4	Somewhat Agree5	Moderately Agree6	Strongly Agree7	Not Applicable0
1. I am physically capable of using the tablet to control the robot	1	2	3	4	5	6	7	N/A
2. I can control the robot with the tablet without making mistakes	1	2	3	4	5	6	7	N/A
3. I know how to use the tablet to make the robot mow	1	2	3	4	5	6	7	N/A
4. I know how to let the robot know what to do with the tablet	1	2	3	4	5	6	7	N/A
5. The tablet is a good way to control the robot	1	2	3	4	5	6	7	N/A
6. The tablet is a good way to control the robot when I am in the yard	1	2	3	4	5	6	7	N/A

12. Please indicate to what extent you agree with each statement about the appearance of the robot mower. Mark <u>one</u> response for each statement.

	Strongly Disagree₁	Moderately Disagree₂	Somewhat Disagree₃	Neither Disagree or Agree₄	Somewhat Agree₅	Moderately Agree₆	Strongly Agree₇
1. I think the robot's appearance fits with mowing	1	2	3	4	5	6	7
2. I like the way the robot looks	1	2	3	4	5	6	7
3. I find that the robot's appearance does not match with mowing	1	2	3	4	5	6	7
4. The robot looks useful	1	2	3	4	5	6	7
5. The robot looks capable of mowing	1	2	3	4	5	6	7
6. The robot seems easy to use by looking at it	1	2	3	4	5	6	7
7. I enjoy looking at the robot	1	2	3	4	5	6	7

13. Please indicate to what extent you agree with each statement for using the robot mower. Mark one response for each statement.

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$	Not Applicable$_0$
1. The robot's screen is a good way to control the robot	1	2	3	4	5	6	7	N/A
2. I can control the robot using its screen without making mistakes	1	2	3	4	5	6	7	N/A
3. I can use the robot to mow the lawn	1	2	3	4	5	6	7	N/A
4. I know how to let the robot know what to do through its screen	1	2	3	4	5	6	7	N/A
5. The robot's screen is a good way to control the robot when I am in the yard	1	2	3	4	5	6	7	N/A
6. The robot makes few errors	1	2	3	4	5	6	7	N/A
7. I could depend on this robot to work correctly every time.	1	2	3	4	5	6	7	N/A
8. It is easy to correct errors when using the robot	1	2	3	4	5	6	7	N/A
9. The robot seems reliable.	1	2	3	4	5	6	7	N/A

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$	Not Applicable$_0$
10. The robot accurately mows my lawn	1	2	3	4	5	6	7	N/A
11. I can easily learn how to use the robot	1	2	3	4	5	6	7	N/A
12. I am satisfied with the robot mowing my lawn	1	2	3	4	5	6	7	N/A
13. Each time the robot mows, it is equally as helpful	1	2	3	4	5	6	7	N/A
14. I could rely on this robot to work whenever I might need it.	1	2	3	4	5	6	7	N/A
15. I am physically capable of using the screen on the robot	1	2	3	4	5	6	7	N/A
16. The robot is efficient in mowing my lawn	1	2	3	4	5	6	7	N/A
17. I can let the robot know what to do in multiple ways	1	2	3	4	5	6	7	N/A
18. I know how to use the robot's screen to make the robot mow	1	2	3	4	5	6	7	N/A

14. Please indicate to what extent you agree with each statement for the using the robot mower. Mark <u>one</u> response for each statement.

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
1. I am not satisfied with the way my lawn looks	1	2	3	4	5	6	7
2. The pattern of the cut grass is acceptable	1	2	3	4	5	6	7
3. Using the robot to mow is easy for me	1	2	3	4	5	6	7
4. The robot is not compatible with mowing my lawn	1	2	3	4	5	6	7
5. The robot has damaged objects or plants while mowing my lawn	1	2	3	4	5	6	7
6. My grass does not look healthy	1	2	3	4	5	6	7
7. I am not confident that the robot can mow safely	1	2	3	4	5	6	7
8. The robot uses too much electricity to mow	1	2	3	4	5	6	7
9. It takes an acceptable amount of time to mow my lawn	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
10. The grass in my lawn is the appropriate height	1	2	3	4	5	6	7
11. It takes too much time to mow my lawn	1	2	3	4	5	6	7
12. The robot is quiet when it mows	1	2	3	4	5	6	7
13. My grass seems healthy	1	2	3	4	5	6	7
14. It takes an appropriate amount of effort to use the robot	1	2	3	4	5	6	7
15. It is difficult for me to use the robot to mow	1	2	3	4	5	6	7
16. It takes too much effort to use the robot	1	2	3	4	5	6	7
17. The robot uses an acceptable level of electricity when it mows	1	2	3	4	5	6	7
18. The grass is a consistent height in my lawn	1	2	3	4	5	6	7
19. The robot has not damaged objects or plants while mowing my lawn	1	2	3	4	5	6	7

	Strongly Disagree$_1$	Moderately Disagree$_2$	Somewhat Disagree$_3$	Neither Disagree or Agree$_4$	Somewhat Agree$_5$	Moderately Agree$_6$	Strongly Agree$_7$
20. I feel safe with the robot mowing	1	2	3	4	5	6	7
21. Using this robot to mow fits my lawn	1	2	3	4	5	6	7
22. The robot is too loud when it mows	1	2	3	4	5	6	7

15. Please indicate to what extent you agree with each statement for the using the Tango application on the tablet computer. If you did not use the Tango application on the tablet computer, then mark N/A. Mark <u>one</u> response for each statement.

	Strongly Disagree$_1$	**Moderately Disagree$_2$**	**Somewhat Disagree$_3$**	**Neither Disagree or Agree$_4$**	**Somewhat Agree$_5$**	**Moderately Agree$_6$**	**Strongly Agree$_7$**	**Not Applicable$_0$**
1. I am physically capable of using the tablet to control the robot	1	2	3	4	5	6	7	N/A
2. I can control the robot with the tablet without making mistakes	1	2	3	4	5	6	7	N/A
3. I know how to use the tablet to make the robot mow	1	2	3	4	5	6	7	N/A
4. I know how to let the robot know what to do with the tablet	1	2	3	4	5	6	7	N/A
5. The tablet is a good way to control the robot	1	2	3	4	5	6	7	N/A
6. The tablet is a good way to control the robot when I am in the yard	1	2	3	4	5	6	7	N/A

Debriefing: Human-Robot Interaction for Robot Mowers

Thank you for participating in this research study. This research could not be conducted without your help.

A robot is a system that can perceive and act upon its environment. For example, you may be familiar with the robot vacuum cleaner made by iRobot called the Roomba. Robots have the potential to make our lives easier, safer, and more efficient. However, the benefits of using a robot can only be realized if people accept, or use, the robot. People's attitudes (e.g., likes, dislikes) and intentions (e.g., plan to purchase) can influence how people accept (e.g., use) a robot. This study was designed to learn about individual's attitudes, intentions, and use of robot mowers at their homes.

Our goal is to assess people's attitudes, intentions, and interactions with robot mowers at their homes. More specifically, we want to understand your acceptance of a Deere Tango E5 robot mower and what characteristics of the human, robot, and context are important for acceptance of robot mowers. In the end, we want to use our findings from this research study to help design future robots and to inform acceptance theories.

You were asked to interact with a Deere Tango E5 robot mower. The Tango is currently for sale in parts of Europe and meets the latest European *draft* standard for autonomous mowers (FprEN 60335-2-107:201X). The Tango is not currently for sale in the United States and may never be. The Tango you used was different from the European version by adding a small computer that logged your usage of the robot mower and its settings. The small computer also allowed you to control the robot mower from an application on a Google Nexus 10 tablet. The small computer did not log any information that is personally identifying (e.g., names, pictures). You were trained on how to use both the Tango (including safety guidelines) and its application.

We are interested in what people who may potentially use the robot mower in the future think about robot mowers as well as how they use them. Therefore, we purposefully selected households that may be likely to purchase a robot mower in the future. For example, working adults, who do not have the time to mow their lawns, may be likely to use a robot mower in the future. We also purposefully selected lawns that would allow the Tango to mow more efficiently and effectively (i.e., flat lawns smaller than or equal to 0.25 acres). The Tango can mow lawns that have a maximum incline of 20 degrees and are up to 0.4 acres.

In this research study, you were asked to:

Pre-Use Interview

1. Complete a form to borrow experimental equipment from Deere & Company.
2. Complete questionnaires on your experience with robots, and your attitudes toward your lawn
3. Answer questions about your current lawn care and knowledge of robot mowers in a group interview with a researcher and members of your household participating in this study. You were audio recorded during the interview.
4. Observe a researcher as he or she installs the robot mower in your lawn. Pictures and video were taken of your lawn.
5. Complete training on how to use the robot mower, including safety guidelines, and its application
6. Answer questions about your thoughts and expectations of the robot mower in a group interview with a researcher and members of your household participating in this study. You were audio recorded during the interview.
7. Complete a questionnaire on your attitudes toward the robot mower
8. You were given written instructions and receive training from a researcher about how to get help if you have questions about the study or questions/issues with the robot mower. You could call technical support for any questions. Technical support recorded the date and time of the call, what the issue or question was, and what the resolution was. You were also given a manual to refer to for questions.

9. Use the robot mower in your lawn according to operating and safety instructions. You may have chosen not to use the robot mower.

Using the robot

1. Complete a diary once a week about your experiences and attitudes toward the robot mower
2. Take relevant or interesting pictures or videos of the robot with the tablet

Post-Use Interview

1. Complete questionnaires on your demographics, health, experience with technologies, and attitudes toward your lawn
2. Answer questions about your thoughts and experiences with the robot mower in a group interview with a researcher and members of your household participating in this study. You were audio recorded during the interview.
3. Complete a questionnaire on your attitudes toward the robot mower
4. Give any relevant or interesting pictures or videos of the robot to the researcher

Now that you have completed the study, a researcher will delete the Tango application from the tablet. Then, the tablet will be returned to your household as compensation for participating in this study. Finally, a researcher will take pictures and video of your lawn and uninstall the robot mower and remove it from your lawn.

Remember there were no right or wrong answers to any of the questions. Your individual information and answers will be kept confidential and any presentation or publication resulting from this study will not directly identify you.

The findings from this study will provide insight into people's attitudes, intentions, and use of robot mowers. Ultimately, findings from this study will be used to help design future robot mowers and to inform acceptance theories. Thank you for your time and involvement in this study!

If you have any questions or ways to improve our research, then please feel free to contact:

Principal Investigator:	Dr. Wendy A. Rogers	(404) 894-6775 wendy@gatech.edu
Support Staff:	Dr. Tracy L. Mitzner	(404) 385-0011 tracy@gatech.edu
Student Investigator:	Cory-Ann Smarr	(404) 894-8344 cory-ann.smarr@gatech.edu

APPENDIX F: EXPERIENCE USING ROBOT MOWER CODING SCHEME

Table F.1

Experience Using Robot Mower Coding Scheme for Negative Aspects

Code	Definition	Examples
Environment segments	**Any comment about a negative aspect of the physical or social environment in which the human-robot interaction takes place**	
Compatibility with physical environment	The degree to which using a robot is perceived as congruent with the physical structures of its surroundings and weather. Includes the robot influencing the environment or vice versa. Does not include the user between the robot and environment. The actual performance of an activity to make the environment more compatible (e.g., raking leaves) would also be coded under tasks.	Robot can't mow as well with the leaves; it's not good to mow when the grass is wet
Compatibility with values	The degree to which a robot promotes or detracts from a participant's cultural values or beliefs.	Robot could help me maintain my independence as I age
Result demon-strability	The degree to which an individual can measure, observe, or communicate the results of using the robot. It is not the actual usage of the robot but is the user's discernment or communication of the tangible results of using the robot.	I can see where the robot mowed the grass; the grass was cut evenly
Trialability	The degree to which a robot may be experimented with on a limited basis	I got to try out the robot
Visibility	The degree to which a participant sees the Tango being used by other people	Seeing a Tango mowing in a neighbor's yard

Code	Definition	Examples
Person segments	**Any comment about a negative aspect of the person**	
Anxiety toward robot	The degree to which an individual is apprehensive when he or she is faced with the possibility of using robots	I'm nervous about using the robot
Perceived enjoyment	The degree to which using a robot is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated.	The robot is fun to watch
Perceived ease of use	The degree to which a person believes that using a particular robot would be free of effort.	Figuring out how to do something; did not need manual; intuitive; easy; little effort; no effort; no preparation
Perceived usefulness	The degree to which a person believes that using a personal robot would enhance his or her completion of a task (benefits)	Saves time; we can perform other activities; mowing while I'm away from home; don't have to think about mowing; I don't have to mow
Physical capabilities	A participant's current or future physical abilities related to mowing lawn	Fatigue; walking
Robot trust	The attitude that the robot will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability	Get comfortable with it; increase confidence; robot proves itself over time; unsure about robot mowing
Robot segments	**Any comment about a negative aspect of the robot**	
Adaptivity	A robot's accumulation of experience through learning	The robot learned to go back to its station better after the first few days
Appearance	What a robot looks like or an evaluation of what robot looks like	The robot looks like a turtle; it looks dinky
Intelligence	Participant comments on the level of intelligence the robot possesses	Logic; memory; no pattern

Code	Definition	Examples
Method of control	Use of an interface is a negative aspect independent of problems with interface.	The screen on the robot lacks color
Reliability	The degree a robot makes errors in performing tasks it was designed to perform. Includes good or bad reliability.	Lack of errors; makes mistakes; issues; getting stuck; battery died
Sociability of robot	Robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact. Participant assigning social characteristics to Tango.	Name Tango; dress up Tango in outfit
Usability	The extent to which a robot can be used by intended users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use	
Task Segments	**Any comment about a negative aspect of the task related to lawn mowing**	
Criticality of task	The importance of getting the task done correctly	It is critical to mow the lawn
Frequency of interaction	The frequency of human-robot interaction in a specified time frame. It is not how much a robot is used overall.	I didn't interact with the robot much
Type of interaction	When participant specifies a form or type of interaction with the Tango.	
Other	**Any comment about a negative aspect that did not fit in the other codes**	

Table F.2

Experience Using Robot Mower Coding Scheme for Positive Aspects

Code	Definition	Examples
Environment segments	**Any comment about a positive aspect of the physical or social environment in which the human-robot interaction takes place**	
Compatibility with physical environment	The degree to which using a robot is perceived as congruent with the physical structures of its surroundings and weather. Includes the robot influencing the environment or vice versa.	The robot could cut our grass; the robot was able to mulch the leaves
Compatibility with values	The degree to which a robot promotes a participant's cultural values or beliefs.	Robot could help me if I couldn't physically mow in the future
Result demonstrability	The degree to which an individual can measure, observe, or communicate the results of using the robot. It is not the actual usage of the robot, but it is the user's discernment or communication of the tangible results of using the robot.	I can see where the robot mowed the grass; the grass was cut evenly
Trialability	The degree to which a robot may be experimented with on a limited basis	I tried out the robot
Visibility	The degree to which a participant sees the Tango being used by other people	Seeing a Tango mowing in a neighbor's yard
Person segments	**Any comment about a positive aspect of the person**	
Anxiety toward robot	The degree to which an individual is apprehensive when he or she is faced with the possibility of using robots	I'm not nervous about using the robot
Perceived enjoyment	The degree to which using a robot is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated.	I enjoy watching the robot

Code	Definition	Examples
Perceived ease of use	The degree to which a person believes that using a particular robot would be free of effort.	Did not need manual; intuitive; easy; no preparation
Perceived usefulness	The degree to which a person believes that using a personal robot would enhance his or her completion of a task (benefits)	Saves time; we can perform other activities; mowing while I'm away from home; don't have to think about mowing; I don't have to mow
Robot trust	The attitude that the robot will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability	Get comfortable with it; increase confidence; robot proves itself over time
Robot segments	**Any comment about a positive aspect of the robot**	
Adaptivity	A robot's accumulation of experience through learning	The robot learned to go back to its station better after the first few days
Appearance	What a robot looks like or an evaluation of what robot looks like	I like the way the robot looks
Method of control	Ways in which a human can interface with a robot to provide input.	The robot ran on a schedule; I pressed the mow now button
Mow anytime	The mower is capable of mowing at all times of the day	Robot can mow in dark
Performance expectations	A participant's expectation of the mower's performance	
Reliability	The degree to which a robot makes errors in performing tasks it was designed to perform	Lack of errors
Sociability of robot	Robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact. Participant assigning social characteristics to Tango.	Name Tango; dress up Tango in outfit

Code	Definition	Examples
Usability	The extent to which a robot can be used by intended users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use	
Task Segments	**Any comment about a positive aspect of the task related to lawn mowing**	
Criticality of task	The importance of getting the task done correctly	It is critical to mow the lawn
Frequency of interaction	The frequency of human-robot interaction in a specified time frame. It is not how much a robot is used overall.	I didn't interact with the robot much
Type of interaction	When participant specifies a form or type of interaction with the Tango.	
Other	**Any comment about a positive aspect that did not fit in the other codes**	

APPENDIX G: CONCEPTUAL VALIDATION OF FRAMEWORK CODING SCHEME

Table G.1

Conceptual Validation of Framework Coding Scheme

Code	Definition	Examples
Environment segments	**Any comment about the physical or social environment in which the human-robot interaction takes place that participants mention in a discussion of robot acceptance**	
Compatibility with physical environment	The degree to which using a robot is perceived as congruent with the physical structures of its surroundings and weather. Includes the robot influencing the environment or vice versa. Does not include the user. The actual performance of an activity to make the environment more compatible (e.g., person raking leaves) would be coded under tasks.	Robot can't mow as well with the leaves; it's not good to mow when the grass is wet
Compatibility with values	The degree to which a robot promotes or detracts from a participant's cultural values or beliefs.	Robot could help me maintain my independence as I age
Result demonstrability	The degree to which an individual can measure, observe, or communicate the results of using the robot. It is not the actual usage of the robot but is the user's discernment or communication of the tangible results of using the robot.	I can see where the robot mowed the grass; the grass was cut evenly
Trialability	The degree to which a robot may be experimented with on a limited basis	I got to try out the robot
Visibility	The degree to which a participant sees the Tango being used by other people	Seeing a Tango mowing in a neighbor's yard

Code	Definition	Examples
Person segments	**Any comment about the person that participants mention in a discussion of robot acceptance**	
Anxiety toward robot	The degree to which an individual is apprehensive when he or she is faced with the possibility of using robots	I'm nervous about using the robot
Perceived enjoyment	The degree to which using a robot is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated.	The robot is fun to watch
Experience using robot	Participant wants to use the robot more	Wants to see robot in action; we'll see in 6 weeks
Perceived ease of use	The degree to which a person believes that using a particular robot would be free of effort.	Figuring out how to do something; did not need manual; intuitive; easy; little effort; no effort; no preparation
Perceived usefulness	The degree to which a person believes that using a personal robot would enhance his or her completion of a task (benefits)	Saves time; we can perform other activities; mowing while I'm away from home; don't have to think about mowing; I don't have to mow
Person-Person Sociability	The Tango moderates or plays a role in interactions between people	Showing Tango to a friend; talking about Tango with co-worker
Physical capabilities	A participant's current or future physical abilities related to mowing lawn	Fatigue; walking
Robot trust	The attitude that the robot will help achieve an individual’s goals in a situation characterized by uncertainty and vulnerability	Get comfortable with it; increase confidence; robot proves itself over time; unsure about robot mowing
Robot segments	**Any comment about the robot that participants mention in a discussion of robot acceptance**	
Adaptivity	A robot's accumulation of experience through learning	The robot learned …
Appearance	What a robot looks like or an evaluation of what robot looks like	The robot looks like a ...; it looks dinky

Code	**Definition**	**Examples**
Cost	The expense of purchasing the Tango or an evaluation of the expense	It costs $3,000; costs too much
Efficiency	The time it takes for the Tango to mow the lawn or an evaluation of the time it takes	The robot's mowing is not as efficient as I am
Energy consumption	The degree to which the Tango consumes electricity and not other energy sources (e.g., gasoline)	The robot didn't use much electricity; I didn't smell gas when the robot mowed
Intelligence	Participant comments on the level of intelligence the robot possesses	Logic; memory; no pattern
Maintenance	Something physically done to maintain the robot and keep it in working order	Sharpening the blades; storing for the winter
Method of control	Ways in which a human can interface with a robot to provide input.	It was easy to set the schedule; the robot ran on a schedule; I pressed the mow now button
Reliability	The degree a robot makes errors in performing tasks it was designed to perform. Includes good or bad reliability.	Lack of errors; makes mistakes; issues; getting stuck; battery died
Safety	The level of safety of using or interacting with Tango	The blades tucked up under the robot seem safe
Security of robot	Participant wants to keep the robot from being stolen or vandalized.	It would be easy for someone to steal the robot
Sociability of robot	Participant assigning social characteristics to Tango.	Name Tango; dress up Tango in outfit
Sound	Level of noise or sound emitted by robot	The robot is quiet
Speed	Participant mentions the Tango's speed. Does not include speed of mower blades.	Speed of mowing; ground speed
Usability	The extent to which a robot can be used by intended users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use	

Code	Definition	Examples
Task Segments	**Any comment about the task related to lawn mowing that participants mention in a discussion of robot acceptance**	
Criticality of task	The importance of getting the task done correctly	It is critical to mow the lawn
Frequency of interaction	The frequency of human-robot interaction in a specified time frame. It is not how much a robot is used overall.	I didn't interact with the robot much
Type of interaction	When participant specifies a form or type of interaction with the Tango.	
New mower task	Participant suggests additional tasks for the Tango to do outside its current capabilities. Mowing grass and mulching leaves are NOT coded here, because those are tasks that the Tango is designed to perform.	Deliver drinks; pull weeds; detect weeds
New person task	Task that participant did not do before using the mower	Checking on mower; put mower into charging station
Task of mowing	Conditions surrounding using the Tango to mow. The condition impacts how, how often, when, or where using Tango to mow. This code can involve the user whereas compatibility with physical environment does not.	If summertime, then cut the grass higher than in the fall. If grass is growing quickly, then mow the grass more often. If friends coming over, then use Tango to make the grass look nice. If we're not home, then only use Tango in back yard.
Task of mulching leaves	Activities performed related to leaf disposal. The user or Tango disposes of leaves.	Tango mulches leaves; participant rakes leaves

APPENDIX H: INTENTIONAL ACCEPTANCE CODING SCHEME

Table H.1

Intentional Acceptance Coding Scheme

Code	Definition and Examples
Reasons for Intention	Any reason participants mention as impacting their intention to purchase a Tango
Age	Current age or future age (e.g., we're young; as we age; when we're older)
Compatibility with physical environment	The degree to which the Tango is congruent with its physical surroundings (e.g., yard layout, grass, fences, sections of yard). Can be good or bad compatibility. Mentions an aspect of the environment.
Cost of Tango	The initial purchase price of the Tango is too high or is acceptable.
Ease of use	The degree to which a person believes that using Tango would be free of effort (e.g., convenient). Can be easy or difficult to use.
Hire a person instead of buy Tango	Participant can hire a person to mow their grass because a person is cheaper and/or can do all lawn maintenance (e.g., mowing, edging, cover whole yard)
Lack of physical exercise	The Tango takes away from the participant's physical exertion that s/he gets from mowing the grass with their regular lawn mower. Their actual exertion in mowing.
Like/Dislike mowing	Participant likes (e.g., enjoys, wants to mow) or dislikes (e.g., doesn't want to mow) mowing in general or a specific aspect of mowing (e.g., being outside)
Likes/Dislikes Tango	Participants likes or dislikes Tango - usually don't specify a reason why. For example, the Tango is nice, slick, cool, neat, bad.
Lower priority purchase	Other purchases have a higher priority than a Tango
Maintenance	Participant mentions upkeep or maintaining Tango. Also, mentions cost of upkeep.
Mowing is a habit	I'm used to mowing. It's a habit. It's something I do.

Code	Definition and Examples
Mowing isn't that hard/bad	Mowing is easy to do. It's not hard or difficult. It's not that inconvenient. Mowing isn't that bad. I don't hate mowing.
Mow lawn myself instead of Tango	Participants say they'll just mow the lawn instead of the Tango
New mower task or feature	The participant wants the Tango to perform a task that is not currently designed to perform. The Tango is currently designed to mower grass and mulch leaves on a schedule or on demand (i.e., pressed mow now button)
Not have to hire someone to mow	The Tango mows so that participant doesn't have to hire someone to mow the lawn
Physically capable of mowing	Participants are physically able or not able to mow. Does not relate to the amount of exercise a participant gets.
Recommendation - individual	Participant communicates with someone who has used the Tango already (e.g., coworker, neighbor).
Recommendation - mass media	Testimonial or endorsement of person in advertisement or mass media (e.g., celebrity, a person paid to provide their opinion). Not an interpersonal connection.
Remote user interface	Participant mentions remote user interface (e.g., tablet application, Nexus) as impacting intentional acceptance
Tango appearance	Participant likes or dislikes what the Tango looks like, or some aspect of its appearance (e.g., color)
Tango cuts more at a time	e.g., bigger blade, more blades
Tango performance	Tango's quality of performing tasks it was designed to perform (e.g., mowing grass, mulching leaves). Can be good or bad performance (e.g., make sure it does a good job).
Tango security	Tango is not secure enough or has a good level of security (e.g., steal, vandalize, reprogram Tango)
Time available to mow	No time to mow. We're busy. Can also be we have the time to mow.
Trust	Participants do or do not trust the Tango

Code	Definition and Examples
Unsure of Tango's capabilities	Participant is unsure of Tango's capabilities. The Tango has not proven itself.
Want to use Tango more	Participant wants to use the Tango more (e.g., gain experience and/or knowledge of Tango)

APPENDIX I: PARTICIPANTS' ROBOT EXPERIENCE

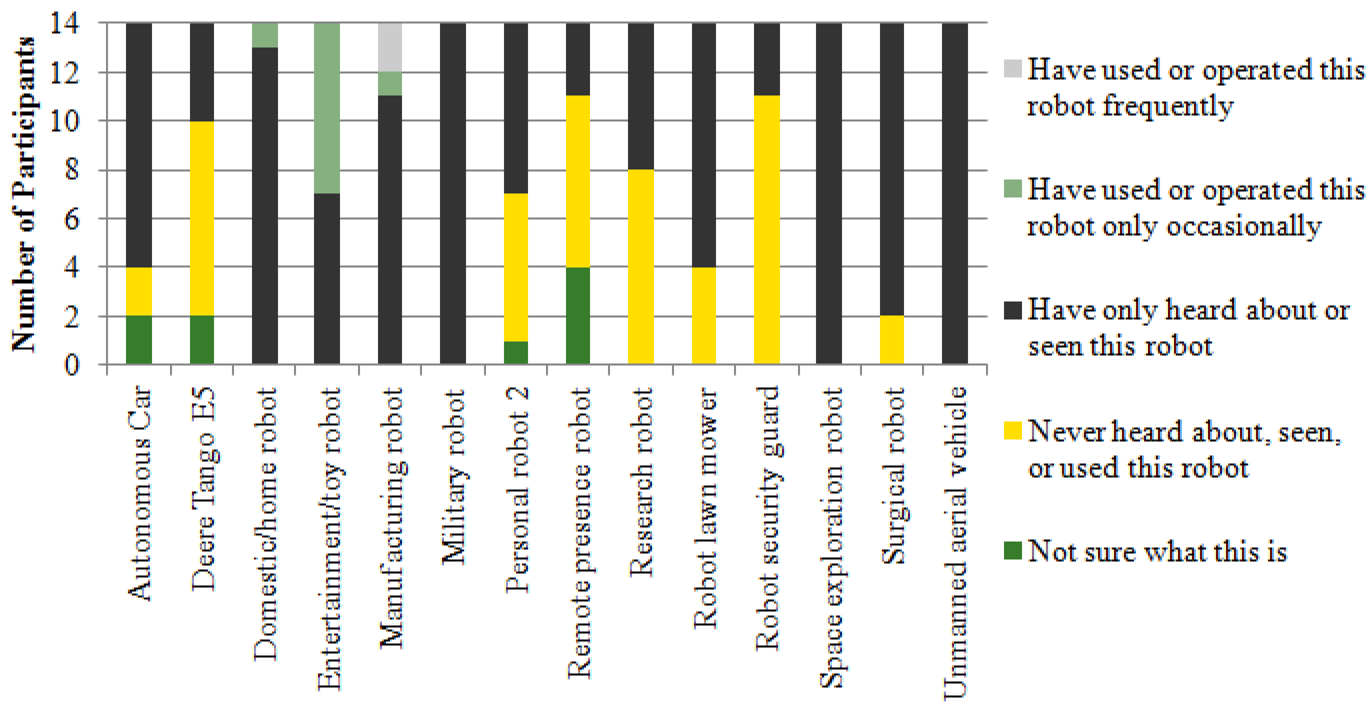


Figure I.1 Usage study participants' robot experience.

APPENDIX J: PARTICIPANTS' TECHNOLOGY EXPERIENCE

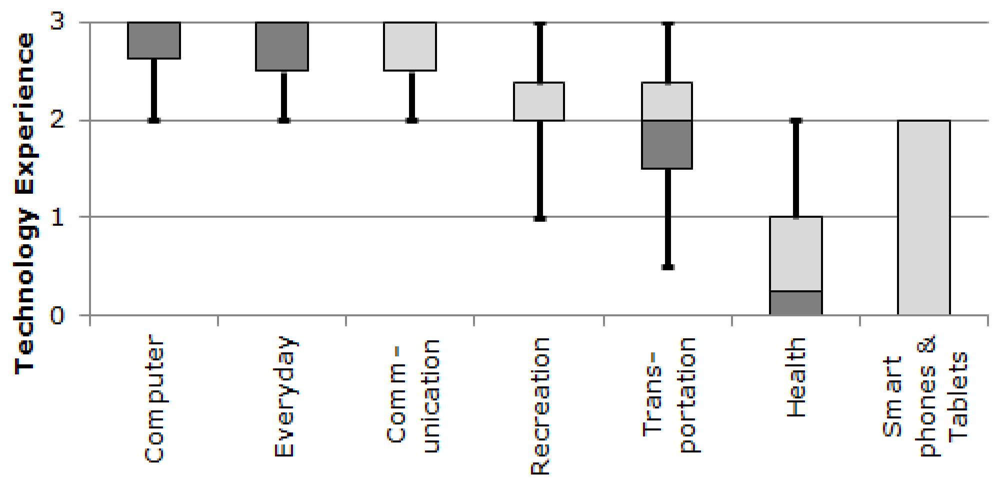


Figure J.1 Usage study participants' technology experience.

APPENDIX K: USAGE STUDY – RELIABILITY OF ROBOT MOWER OPINIONS QUESTIONNAIRE

Table K.1

Internal Reliability of Factors Assessed by the Robot Mower Opinions Questionnaire

			Test-Retest (Mdn of items)		Cronbach's Alpha						
Factor	# Items	n	Spearman's rho	*p*	Pre	Post	Week 1	Week 2	Week 3	Week 4	Week 5
Adaptivity	3	7	1.00	<0.01	-0.15	-0.85					
Appearance	2	7	0.54	0.22	0.87	0.60					
Attitudinal acceptance	3	7	0.33	0.47	0.99	0.97	0.99	0.95	1.00	0.99	1.00
Compatibility with physical environment	3	7	0.00	1.00	0.96	0.86					
Compatibility with values	5	7	0.76	0.05	0.70	0.83					
Intentional acceptance	3	7	0.78	0.04	1.00	1.00					
Method of control - mower	6	7	0.41	0.37	0.82	0.86					
Perceived ease of use	6	7	-0.24	0.60	0.85	0.96	0.96	0.81	0.97	0.97	0.95
Perceived enjoyment	3	7	0.17	0.72	0.82	0.88					
Perceived sociability	3	7	0.31	0.50	0.29	0.18					
Perceived usefulness	6	7	-0.20	0.66	0.94	0.94	0.95	0.95	0.98	0.97	0.96
Reliability	4	7	0.76	0.05	0.92	0.91					
Result demonstrability	4	7	0.97	<0.01	-0.17	0.78					
Robot anxiety	4	7	0.63	0.13	0.55	-1.10					
Robot trust	3	7	0.73	0.06	0.22	0.87					

			Test-Retest (Mdn of items)		Cronbach's Alpha						
Factor	# Items	n	Spearman's rho	*p*	Pre	Post	Week 1	Week 2	Week 3	Week 4	Week 5
Task-technology fit	22	7	0.75	0.05	0.93	0.92					
Trialability	2	7	0.65	0.11	0.65	0.22					
Usability	8	7	0.90	0.01	0.93	0.84					
Visibility	4	7	0.32	0.49	0.18	0.75					

APPENDIX L: SURVEY STUDY MATERIALS

Note: All materials from the survey study are presented here except for the text descriptions and video of the robot mower. The text descriptions are presented on pages 99-101. The video is available upon request from the author.

Study Listing on Socialsci.com participants' accounts

The following words that are not bolded will be shown to participants.

Title: Opinions about lawn mowers

Description: The goal of this research study is to better understand people's opinions of lawn mowers after reading a text description of a mower and watching it mow in a video. To take part in this research study, participants must be 18 years of age or older; living in the United States; fluent in reading English; and living in a home with a lawn. Also, someone in the participant's household – or the participant himself or herself – must be responsible for mowing the lawn by either mowing it themselves or having someone else mow the lawn. Please complete this study in one session. If you do not complete this study in one session, your answers will not be saved and you will not be compensated.

Reward: 50 points

Estimated time to complete: 30 minutes

Participants left before data collection closes (This number will decrease as each participant completes the study): 350 left

Georgia Institute of Technology
Protocol and Consent Title: Opinions about lawn mowers

Dear Subject,

You are being asked to be a volunteer in a research study. If you complete the online survey, it means that you have read (or have had read to you) the information contained in this letter, and would like to be a volunteer in this research study.

Purpose: The purpose of this study is to understand individuals' thoughts on a lawn mower. We expect to enroll 350 adults in this research study.

Exclusion/Inclusion Criteria: To take part in this research study, participants must be 18 years of age or older; living in the United States; fluent in reading English; and living in a home with a lawn. Also, someone in the participant's household – or the participant himself or herself – must be responsible for mowing the lawn by either mowing it themselves or having someone else mow the lawn. A lawn is an area of short, mown grass on the property where you live.

Procedures: If you decide to be in this research study, you will be asked to: answer questions about yourself, read a brief description about the mower, watch a short video about the mower, and answer questions about your thoughts on the mower. Finally, you will be debriefed and compensated. You will be asked to complete this research study in one session, which should take about 30 minutes to complete.

Risks or Discomforts: The risks involved are no greater than those involved in using a computer.

Benefits: You are not likely to benefit directly from this study. We hope that lawn mower designers as well as others will benefit from what we find from conducting this study with respect to improving lawn mowers.

Compensation to You: You will be compensated with 50 SocialSci.com points for completing this research study. If you do not complete this survey in one session, your answers will not be saved and you will not be compensated.

Confidentiality: The following procedures will be followed to keep your personal information anonymous this study: The data collected about you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code rather than by your name. Your records will be kept in locked files and only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

Although this survey will be run from a 'secure' https server typical of those used to handle credit card transactions, there is a small possibility that responses could be viewed by unauthorized third parties, such as computer hackers. Key SocialSci.com personnel

(Director of Operation, Chief Technology Officer) will have access to your logged data. The IP address of the computer you use to access this page will not be stored on any log files on SocialSci.com's system. SocialSci.com does store one-way, non-reversible encryption hashes of participant IP addresses during key activities on the website (account creation, login, and trading in earned points for monetary rewards). No other potentially identifiable information will be stored unless you explicitly enter it. Note that we will not ask for your name, address, or any other identifiable information.

To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB may review study records. The Office of Human Research Protections may also look over study records during required reviews.

Costs to You: There are no costs to you, other than your time, for being in this study.

In Case of Injury/Harm: If you are injured as a result of being in this study, please contact Dr. Wendy A. Rogers at (404) 894-6775 or Dr. Tracy L. Mitzner at (404) 385-0011. Neither the Georgia Institute of Technology nor the principal investigators have made provision for payment of costs associated with any injury resulting from participation in this study.

Participant Rights:

- Your participation in this study is voluntary. You do not have to be in this study if you do not want to be.
- You have the right to change your mind and leave the study at any time without giving any reason and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You may print out a copy of this consent form to keep.
- You do not waive any of your legal rights by participating in this survey.

Questions about the Study: If you have any questions about the research study, you may contact Cory-Ann Smarr at (404) 894-8344 or cory-ann.smarr@gatech.edu.

Questions about Your Rights as a Research Participant: If you have any questions about your rights as a research participant, you may contact Ms. Kelly Winn, Georgia Institute of Technology, Office of Research Integrity Assurance, at (404) 385-2175.

If you complete the online survey, it means that you have read (or have had read to you) the information contained in this letter, and would like to be a volunteer in this research study.

Thank you,
Cory-Ann Smarr, MS
Tracy L. Mitzner, PhD
Wendy A. Rogers, PhD

Qualification Questions

Are you 18-69 years old?

- **Yes**
- **No**

Do you currently live in the United States?

- Yes
- No

Are you fluent in reading English?

- Yes
- No

Do you currently live at a home that has a lawn? A lawn is an area of short, mown grass on the property where you live.

- Yes
- No

Are you, or someone you live with, responsible for making sure your grass is mowed? Select "Yes" if you or someone you live with mows the grass. Also, select "Yes" if you – or someone you live with – pays a lawn service or someone else to mow your grass. Otherwise, check "No".

- Yes
- No

Perceptions of Robot Mower

1. **What percentage of the time does the robot mower complete all of its tasks correctly?**

o 60%
o 70%
o 80%
o 90%
o 100%

2. **How can you schedule the times that the robot mower mows?** *Select all that apply.*

□ The robot mower is not capable of mowing on a schedule
□ The robot mower has a preset schedule that you cannot change
□ You can use a screen on the robot mower
□ You can use an application on your smart phone
□ You can verbally tell the robot mower when it needs to mow

3. **What tasks did the robot mower perform in the video?** *Select all that apply.*

□ Drove into its charging station
□ Left its charging station
□ Mowed the boundary of the lawn
□ Mowed the lawn in a pattern of parallel lines
□ Mowed the lawn randomly (no pattern)

Robot Acceptance Questionnaire

Note: Black text in gray boxes was not seen by participants.

INSTRUCTIONS: In the following section, please answer the following questions keeping the robot mower in mind.
We are interested in your thoughts and opinions so there are no right or wrong answers.
Some of these questions may seem repetitive, so it is okay if your answers overlap.

Int_int

Given what you know about the robot mower right now and assuming that the mower is available for purchase, please indicate your intention to buy this robot mower for your home by selecting one number (1-5). *

	1	2	3	4	5	
No Intention	○	○	○	○	○	Strong Intention

Int_like

Given what you know about the robot mower right now and assuming that the mower is available for purchase, please indicate your intention to buy this robot mower for your home by selecting one number (1-5). *

Please pay attention to the response scale as it has changed.

	1	2	3	4	5	
Unlikely	○	○	○	○	○	Likely

Int_buy

Given what you know about the robot mower right now and assuming that the mower is available for purchase, please indicate your intention to buy this robot mower for your home by selecting one number (1-5). *

Please pay attention to the response scale as it has changed.

	1	2	3	4	5	
Not buy it	○	○	○	○	○	Buy it

Int_ynu

Assume that the robot mower was available for purchase, but you did not own one yet. Would you buy it? *

- Yes
- No
- Unsure

att_bad

Please indicate what your attitude is towards the robot mower by selecting one number (1-5). *

	1	2	3	4	5	
Bad	○	○	○	○	○	Good

att_fav

Please indicate what your attitude is towards the robot mower by selecting one number (1-5). *

Please pay attention to the response scale as it has changed.

	1	2	3	4	5	
Unfavorable	○	○	○	○	○	Favorable

att_pos

Please indicate what your attitude is towards the robot mower by selecting one number (1-5). *

Please pay attention to the response scale as it has changed.

	1	2	3	4	5	
Negative	○	○	○	○	○	Positive

TAM

Please indicate how likely each statement is about the robot mower *

Select one response for each row.

	Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely
PU1 Using the robot mower in my daily life would enable me to accomplish tasks more quickly.	○	○	○	○	○	○	○
PEOU1 I would find the robot mower to be flexible for me to interact with.	○	○	○	○	○	○	○
PEOU2 I would find it easy to get the robot mower to do what I want it to do.	○	○	○	○	○	○	○
PU2 I would find the robot mower useful in my daily life.	○	○	○	○	○	○	○

TAM_1

Please indicate how likely each statement is about the robot mower *

Select one response for each row.

	Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely
PU3 Using the robot mower in my daily life would increase my productivity.	○	○	○	○	○	○	○
PU4 Using the robot mower would improve my daily life.	○	○	○	○	○	○	○
PU5 Using the robot mower would make my daily life easier.	○	○	○	○	○	○	○
PEOU3 It would be easy for me to become skillful at using the robot mower.	○	○	○	○	○	○	○

TAM_2

Please indicate how likely each statement is about the robot mower *

Select one response for each row.

	Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely
PU6 Using the robot mower would enhance my effectiveness in my daily life.							
PEOU4 I would find the robot mower easy to use.							
PEOU5 My interaction with the robot mower would be clear and understandable.							
PEOU6 Learning to operate the robot mower would be easy for me.							

Please indicate to what extent you agree with each statement about the robot mower and using it to mow your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
CompatP1 Using the robot mower would not require significant changes to my existing lawn							
CompatP2 Using the robot mower would fit my lawn							
Appear1 I do not like the way the robot mower looks							
CompatP3 Using the robot mower would be completely compatible with my lawn							
Anx1 I would hesitate to use the robot for fear of making mistakes I cannot correct							

BotOp2

Please indicate to what extent you agree with each statement about the robot mower and using it to mow your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
Anx2 Robot mowers would not scare me at all	○	○	○	○	○	○	○
CompatV1 Using the robot mower would be consistent with the way I think mowing my lawn should be conducted	○	○	○	○	○	○	○
Appear2 I would enjoy looking at the robot mower	○	○	○	○	○	○	○
Anx3 It would scare me to think I could get into problems when using the robot mower	○	○	○	○	○	○	○
Anx4 Robot mowers would make me feel uneasy	○	○	○	○	○	○	○

Please indicate to what extent you agree with each statement about the robot mower and using it to mow your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
Anx5 I would feel apprehensive about using the robot mower	○	○	○	○	○	○	○
Appear3 I like the way the robot mower looks	○	○	○	○	○	○	○
CompatP4 Using the robot mower would be compatible with all aspects of my lawn	○	○	○	○	○	○	○
Anx6 Interacting with the robot mower would make me nervous	○	○	○	○	○	○	○
Anx7 The robot mower would be somewhat intimidating to me	○	○	○	○	○	○	○

BotOp4

Please indicate to what extent you agree with each statement about the robot mower and using it to mow your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
CompatV2 Using the robot mower would not fit the way I view the world	○	○	○	○	○	○	○
CompatP5 To use the robot mower, I would not have to change any aspect of my lawn	○	○	○	○	○	○	○
CompatP6 I think that using the robot mower would fit well with my lawn	○	○	○	○	○	○	○
CompatV3 Using the robot mower would run counter to my own values	○	○	○	○	○	○	○
CompatV4 Using the robot mower would run counter to my values about how to mow my lawn	○	○	○	○	○	○	○

BotOp5

Please indicate to what extent you agree with each statement about the robot mower and using it to mow your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
CompatV5 Using the robot mower would go against what I believe robots should be used for	○	○	○	○	○	○	○
CompatV6 Using the robot mower would not be appropriate for a person with my values regarding the role of robots	○	○	○	○	○	○	○
Appear4 The robot mower is nice looking	○	○	○	○	○	○	○
Anx8 Robot mowers would make me feel uncomfortable	○	○	○	○	○	○	○
Appear5 The robot mower looks appealing	○	○	○	○	○	○	○

SocEzer1

How much does each of the following words match what you imagine the robot mower would be like mowing your lawn? *

Select one response for each row.

	Not at all	To a limited extent	To a moderate extent	To a large extent	To a great extent
Social1 Playful					
Social2 Dull					
Social3 Unimaginative					
Social4 Compassionate					
Social5 Motivated					
Social6 Lifelike					
Social7 Friendly					

SocEzer2

How much does each of the following words match what you imagine the robot mower would be like mowing your lawn? *

Select one response for each row.

	Not at all	To a limited extent	To a moderate extent	To a large extent	To a great extent
Social8 Talkative					
Social9 Boring					
Social10 Artificial					
Social11 Creative					
Social12 Unfeeling					
Social13 Expressive					
Social14 Unsocial					

BotOp6

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
TTF1 I would feel safe with the robot mower mowing							
TTF2 I would not be confident that the robot mower can mow safely							
Enjoy1 I would enjoy doing things with the robot mower							
Soc1 The robot mower would understand me							
rDemo1 The results of using the robot mower would be apparent to me							

BotOp7

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
TTF3 My grass would seem healthy when the robot mower mows it							
Soc2 I think the robot mower would be nice							
TTF4 Using the robot to mow would be easy for me							
TTF5 My grass would not look healthy when the robot mower mows it							
Enjoy2 I would find the robot mower boring							

BotOp8

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
Trust1 I would trust the robot mower	○	○	○	○	○	○	○
TTF6 The robot mower would take too much time to mow my lawn	○	○	○	○	○	○	○
TTF7 The robot mower would damage objects or plants while mowing my lawn	○	○	○	○	○	○	○
rDemo2 I would have no difficulty telling others about the results of using the robot mower	○	○	○	○	○	○	○
rDemo3 The consequences of using the robot mower would be clear to me	○	○	○	○	○	○	○

BotOp9

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
TTF8 It would take an appropriate amount of effort to use the robot mower	○	○	○	○	○	○	○
Enjoy3 The actual process of using the robot mower would be pleasant	○	○	○	○	○	○	○
TTF9 The robot mower would take an acceptable amount of time to mow my lawn	○	○	○	○	○	○	○
Enjoy4 I would enjoy using the robot mower	○	○	○	○	○	○	○
Soc3 I would find the robot mower pleasant to interact with	○	○	○	○	○	○	○

BotOp10

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
TTF10 The grass in my lawn would be at the appropriate height when the robot mower mows it	○	○	○	○	○	○	○
rDemo4 I would have difficulty explaining why using the robot mower may or may not be beneficial	○	○	○	○	○	○	○
Soc4 I feel the robot mower would understand me	○	○	○	○	○	○	○
TTF11 The grass would be a consistent height in my lawn when the robot mower mows it	○	○	○	○	○	○	○
TTF12 The robot mower would not compatible with mowing my lawn	○	○	○	○	○	○	○

BotOp11

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
Trust2 I would trust the robot mower to mow my lawn	○	○	○	○	○	○	○
Enjoy5 I would find the robot mower enjoyable	○	○	○	○	○	○	○
Enjoy6 I would find using the robot mower to be enjoyable	○	○	○	○	○	○	○
TTF13 It would be difficult for me to use the robot to mow	○	○	○	○	○	○	○
TTF14 The pattern of cut grass would look acceptable when the robot mower mows it	○	○	○	○	○	○	○

BotOp12

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
Trust3 I would be quite certain what to expect from the robot mower	○	○	○	○	○	○	○
Trust4 Even if not monitored, I would trust the robot mower to mow correctly	○	○	○	○	○	○	○
TTF15 The robot mower would use an acceptable level of electricity when it mows	○	○	○	○	○	○	○
TTF16 It would take too much effort to use the robot mower	○	○	○	○	○	○	○
Enjoy7 I would have fun using the robot mower	○	○	○	○	○	○	○

BotOp13

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
rDemo5 I believe I could communicate to others the consequences of using the robot mower	○	○	○	○	○	○	○
TTF17 I would not be satisfied with the way my lawn would look when the robot mower mows it	○	○	○	○	○	○	○
TTF18 The robot mower would use too much electricity to mow	○	○	○	○	○	○	○
TTF19 Using the robot mower to mow would fit my lawn	○	○	○	○	○	○	○
TTF20 The robot mower would not damage objects or plants while mowing my lawn	○	○	○	○	○	○	○

BotOp14

Please indicate to what extent you agree with each statement about your EXPECTATION for using the robot mower in your lawn *

Select one response for each row.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Moderately Agree	Strongly Agree
Soc5 I would consider the robot mower pleasant	○	○	○	○	○	○	○
Trust5 I would allow the robot mower to mow my lawn even if I do not watch it	○	○	○	○	○	○	○
Enjoy8 I would find the robot mower fascinating	○	○	○	○	○	○	○

TrustOlson1

How much does each of the following words match what you imagine the robot mower would be like at your home? *

	Not at all	To a limited extent	To a moderate extent	To a large extent	To a great extent
TrustWord1 Unpredictable	○	○	○	○	○
TrustWord2 Hostile	○	○	○	○	○
TrustWord3 Unreliable	○	○	○	○	○
TrustWord4 Precise	○	○	○	○	○
TrustWord5 Efficient	○	○	○	○	○

TrustOlson2

How much does each of the following words match what you imagine the robot mower would be like at your home? *

	Not at all	To a limited extent	To a moderate extent	To a large extent	To a great extent
TrustWord6 Reliable	○	○	○	○	○
TrustWord7 Misleading	○	○	○	○	○
TrustWord8 Safe	○	○	○	○	○
TrustWord9 Risky	○	○	○	○	○
TrustWord10 Predictable	○	○	○	○	○

<u>**ROBOT FAMILIARITY AND USE QUESTIONNAIRE**</u>

For the following types of robots, please indicate your familiarity in terms of hearing about them, using them, or operating them. Circle one number per row.

Types of Robots	Not sure what this is	Never heard about, seen, or used this robot	Have only heard about or seen this robot	Have used or operated this robot ONLY OCCASIONALLY	Have used or operated this robot FREQUENTLY
1. Autonomous car	0	1	2	3	4
2. Deere Tango E5	0	1	2	3	4
3. Domestic/home robot (e.g., Roomba)	0	1	2	3	4
4. Entertainment/toy robot (e.g., Aibo, Furby)	0	1	2	3	4
5. Manufacturing robot (e.g., robotic arm in factory)	0	1	2	3	4
6. Military robot (e.g., search and rescue)	0	1	2	3	4
7. Personal Robot 2 (PR2)	0	1	2	3	4
8. Remote presence robot (e.g., Texai, Anybot)	0	1	2	3	4
9. Research robot (e.g., at a university or company)	0	1	2	3	4
10. Robot lawn mower	0	1	2	3	4
11. Robot security guard	0	1	2	3	4
12. Space exploration robot (e.g., Mars Rover)	0	1	2	3	4

13. Surgical robot (e.g., da Vinci Surgical System)	**0**	**1**	**2**	**3**	**4**
14. Unmanned aerial vehicle (UAV) /Drone	**0**	**1**	**2**	**3**	**4**

<u>Technology Experience Questionnaire</u>

INSTRUCTIONS: Within the LAST YEAR, please indicate how much you have used any of the technologies listed below. (Select one box per row)

		Not sure what it is$_1$	Not used$_2$	Used once$_3$	Used occasionally$_4$	Used frequently$_5$
1.	Desktop/ laptop computer					
2.	Tablet computer (e.g., Apple iPad, Google Nexus 7, Microsoft Surface)					
3.	Smart phone (e.g., Apple iPhone, Nokia Lumia, Samsung Galaxy S4)					
4.	Email (e.g., Gmail, Yahoo, Outlook)					

Demographics Questions

INSTRUCTIONS: In this section we would like to know more about you.

1. How old are you in years? ______

2. Gender: Male ☐1 Female ☐2

2. What region of the United States do you currently live in? (Check one)

- ☐1 Central (IL, IN, KY, MO, OH, TN, WV)
- ☐2 East North Central (IA, MI, MN, WI)
- ☐3 Northeast (CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT)
- ☐4 Northwest (AK, ID, OR, WA)
- ☐5 South (AR, KS, LA, MS, OK, TX)
- ☐6 Southeast (AL, FL, GA, NC, SC, VA)
- ☐7 Southwest (AZ, CO, NM, UT)
- ☐8 West (HI, CA, NV)
- ☐9 West North Central (MT, NE, ND, SD, WY)

3. What is the highest level of education that you have COMPLETED? For example, if you have completed at least one semester of college but have not graduated with a Bachelor's degree, then check "Some college/Associate's degree". (Check one)

- ☐1 No formal education
- ☐2 Less than high school graduate
- ☐3 High school graduate/GED
- ☐4 Vocational training
- ☐5 Some 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.)

4. How would you describe your primary racial group? (Check one)

- ☐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. Do you consider yourself Hispanic or Latino? (Check one)

- ☐1 Yes
- ☐2 No

5 a. If you consider yourself Hispanic or Latino, how would you describe yourself? (Check one)

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

6. Is English your primary language? (Check one)

- ☐1 Yes
- ☐2 No

6 a. If "No", what is your primary language? _______________________

7. What is your current marital status? (check one)

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

8. Which category best describes your yearly HOUSEHOLD income in US dollars?
Do not give the dollar amount, just select one category:

- ☐1 Less than $25,000
- ☐2 $25,000-$49,999
- ☐3 $50,000-$74,999
- ☐4 $75,000-$99,999
- ☐5 $100,000-$124,999
- ☐6 $125,000-$149,999
- ☐7 $150,000-$174,999
- ☐8 $175,000-$199,999
- ☐9 $200,000 or more
- ☐10 Do not know for certain
- ☐11 Do not wish to answer

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. In general, would you say your health is: (Check one)

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

Lawn Mowing Questionnaire

INSTRUCTIONS: In this section we would like to know more about your experiences mowing lawns.

1. Have you ever mowed grass? (Check one)

- ☐1 Yes
- ☐2 No

1 a. If "Yes", for how many years have you mowed grass? If you do not know for certain, please estimate. (Check one)

- ☐1 Less than 1 year
- ☐2 1-2 years
- ☐3 3-5 years
- ☐4 6-10 years
- ☐5 More than 10 years
- ☐6 I have only mown grass a few times ever

2. Within the last year, who mowed your lawn the most? If multiple people mowed your lawn equal amounts, then select all that apply.

- ☐1 Myself
- ☐2 Someone else that I live with
- ☐3 A friend or neighbor
- ☐4 A relative that I do not live with
- ☐5 A lawn service
- ☐6 Other (please specify): ____________________

3. In general, how <u>satisfied</u> are you with how your grass is mowed? (Select one)

- ☐1 Very dissatisfied
- ☐2 Dissatisfied
- ☐3 Neither dissatisfied nor satisfied
- ☐4 Satisfied
- ☐5 Very satisfied

4. What types of lawn mowers are currently used to mow your lawn? (Select all that apply)

- ☐1 Walk behind gas mower
- ☐2 Walk behind electric mower
- ☐3 Walk behind reel mower
- ☐4 Riding gas mower or lawn tractor
- ☐5 Riding electric mower or lawn tractor
- ☐6 Robot lawn mower
- ☐7 Do not know for certain
- ☐8 Other (Please specify): ______________________________

5. What is the size of the property that you live on? An acre is approximately 75% of an American football field. If you do not know for certain, please estimate. (Check one)

- ☐1 Less than 0.5 acre
- ☐2 0.5-0.9 acre
- ☐3 1-2 acres
- ☐4 3-5 acres
- ☐5 More than 5 acres
- ☐6 Do not know for certain

6. In general, how important is it to you that your lawn is mowed? (Check one)

- ☐1 Very unimportant
- ☐2 Unimportant
- ☐3 Neither unimportant nor important
- ☐4 Important
- ☐5 Very important

<u>Debriefing:</u> Opinions about lawn mowers

Thank you for participating in this research study. This research could not be conducted without your help.

A robot is a system that can perceive and act upon its environment. For example, you may be familiar with the robot vacuum cleaner made by iRobot called the Roomba. Robots have the potential to make our lives easier, safer, and more efficient. However, the benefits of using a robot can only be realized if people accept, or use, the robot. People's attitudes (e.g., likes, dislikes) and intentions (e.g., plan to purchase) can influence how people accept (e.g., use) a robot. This study was designed to learn about individuals' attitudes towards and intentions of buying robot mowers to use at their homes.

Our goal is to understand your acceptance of a robot lawn mower at your home. More specifically, we want to assess what characteristics of the human, robot, and context are important for acceptance of robot mowers. In the end, we want to use our findings from this research study to help design future robots and to inform acceptance theories.

You were asked to read a description and watch a video of a Deere Tango E5 robot mower. We want to understand the effects of different reliabilities of the robot mower (i.e., percentages of time the mower correctly performed a task) and its communication abilities (e.g., email) on your acceptance. The percentages and abilities presented in this research study are hypothetical examples of how a robot mower might function. The actual percentage of time that the robot correctly completes its tasks is unknown at this time. Currently, the robot mower moves at speeds up to one mile per hour, and it does not email.

The Tango is currently for sale in parts of Europe. The Tango is not currently for sale in the United States and may never be.

Remember there were no right or wrong answers to any of the questions. Your individual information and answers will be kept confidential and any presentation or publication resulting from this study will not directly identify you.

Thank you for your time and involvement in this study!

If you have any questions or ways to improve our research, then please feel free to contact:

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APPENDIX M: SURVEY STUDY – ROBOT ACCEPTANCE QUESTIONNAIRE ITEMS

Table M.1

Robot Acceptance Questionnaire Factors, Items, and Adaptation Sources

Dimension	Factor	Item	Item Adapted From
Attitudinal Acceptance	Attitudinal acceptance	Bad - good	Ezer, 2008
		Unfavorable - Favorable	Ezer, 2008
		Negative - positive	Ezer, 2008
Intentional Acceptance	Intentional acceptance	No intention - Strong intention	Ezer, 2008
		Unlikely - Likely	Ezer, 2008
		Not buy it - Buy it	Ezer, 2008
		Assume that the Tango was available for purchase, but you did not own one yet. Would you buy it?	Ezer, 2008
Human	Perceived usefulness	Using the robot mower in my daily life would enable me to accomplish tasks more quickly.	Davis, 1989 (TAM)
		I would find the robot mower useful in my daily life.	Davis, 1989 (TAM)
		Using the robot mower in my daily life would increase my productivity.	Davis, 1989 (TAM)
		Using the robot mower would improve my daily life.	Davis, 1989 (TAM)
		Using the robot mower would make my daily life easier.	Davis, 1989 (TAM)
		Using the robot mower would enhance my effectiveness in my daily life.	Davis, 1989 (TAM)
Human	Perceived ease of use	I would find the robot mower to be flexible for me to interact with.	Davis, 1989 (TAM)
		I would find it easy to get the robot mower to do what I want it to do.	Davis, 1989 (TAM)
		It would be easy for me to become skillful at using the robot mower.	Davis, 1989 (TAM)
		I would find the robot mower easy to use.	Davis, 1989 (TAM)
		My interaction with the robot mower would be clear and understandable.	Davis, 1989 (TAM)

Dimension	Factor	Item	Item Adapted From
	Perceived ease of use continued	Learning to operate the robot mower would be easy for me.	Davis, 1989 (TAM)
Human	Robot anxiety	I would hesitate to use the robot for fear of making mistakes I cannot correct	Venkatesh et al., 2003
		Robot mowers would not scare me at all	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		It would scare me to think I could get into problems when using the robot mower	Venkatesh et al., 2003
		Robot mowers would make me feel uneasy	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		I would feel apprehensive about using the robot mower	Venkatesh et al., 2003
		Interacting with the robot mower would make me nervous	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		The robot mower would be somewhat intimidating to me	Venkatesh et al., 2003
		Robot mowers would make me feel uncomfortable	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
Human	Perceived sociability	The robot mower would understand me	Locally developed
		I think the robot mower would be nice	Heerink et al., 2010a (Almere Model)
		I would find the robot mower pleasant to interact with	Heerink et al., 2010a (Almere Model)
		I feel the robot mower would understand me	Heerink et al., 2010a (Almere Model)
		I would consider the robot mower pleasant	Heerink et al., 2010a (Almere Model)
Human	Perceived enjoyment	I would enjoy doing things with the robot mower	Heerink et al., 2010a (Almere Model)
		I would find the robot mower boring	Heerink et al., 2010a (Almere Model)

Dimension	Factor	Item	Item Adapted From
	Perceived enjoyment continued	The actual process of using the robot mower would be pleasant	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		I would enjoy using the robot mower	Heerink et al., 2010a (Almere Model)
		I would find the robot mower enjoyable	Heerink et al., 2010a (Almere Model)
		I would find using the robot mower to be enjoyable	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		I would have fun using the robot mower	Venkatesh, 2000; Venkatesh & Bala, 2008 (TAM3)
		I would find the robot mower fascinating	Heerink et al., 2010a (Almere Model)
Human	Robot trust	I would trust the robot mower	Gefen, Karahanna, & Straub, 2003
		I would trust the robot mower to mow my lawn	Heerink et al., 2010a (Almere Model)
		I would be quite certain what to expect from the robot mower	Gefen et al., 2003
		Even if not monitored, I would trust the robot mower to mow correctly	Gefen et al., 2003
		I would allow the robot mower to mow my lawn even if I do not watch it	Heerink et al., 2010a (Almere Model)
Human	Result demon-strability	The results of using the robot mower would be apparent to me	Venkatesh & Bala, 2008 (TAM3)
		I would have no difficulty telling others about the results of using the robot mower	Venkatesh & Bala, 2008 (TAM3); Venkatesh & Davis, 2000 (TAM2)
		The consequences of using the robot mower would be clear to me	Locally developed
		I would have difficulty explaining why using the robot mower may or may not be beneficial	Venkatesh & Bala, 2008 (TAM3)

Dimension	Factor	Item	Item Adapted From
	Result demon-strability continued	I believe I could communicate to others the consequences of using the robot mower	Venkatesh & Bala, 2008 (TAM3)
Context	Compat-ibility with values	Using the robot mower would be consistent with the way I think mowing my lawn should be conducted	Karahanna, Agarwal, & Angst, 2006
		Using the robot mower would not fit the way I view the world	Karahanna et al., 2006
		Using the robot mower would run counter to my own values	Karahanna et al., 2006
		Using the robot mower would run counter to my values about how to mow my lawn	Karahanna et al., 2006
		Using the robot mower would go against what I believe robots should be used for	Karahanna et al., 2006
		Using the robot mower would not be appropriate for a person with my values regarding the role of robots	Karahanna et al., 2006
Context	Compat-ibility with physical environment	Using the robot mower would not require significant changes to my existing lawn	Karahanna et al., 2006
		Using the robot mower would fit my lawn	Moore & Benbasat, 1991
		Using the robot mower would be completely compatible with my lawn	Moore & Benbasat, 1991
		Using the robot mower would be compatible with all aspects of my lawn	Moore & Benbasat, 1991
		To use the robot mower, I would not have to change any aspect of my lawn	Karahanna et al., 2006
		I think that using the robot mower would fit well with my lawn	Moore & Benbasat, 1991
Robot	Appearance	I do not like the way the robot mower looks	McCroskey, McCroskey, & Richmond, 2006
		I would enjoy looking at the robot mower	Inspired by findings from Eimler et al., 2011; Hegel et al., 2009

Dimension	Factor	Item	Item Adapted From
	Appearance continued	I like the way the robot mower looks	Inspired by findings from Eimler et al., 2011; Hegel et al., 2009
		The robot mower is nice looking	McCroskey et al., 2006
		The robot mower looks appealing	McCroskey et al., 2006
Task-technology fit	Time / Efficiency	The robot mower would take too much time to mow my lawn	Locally developed from people's mowing goals and Goodhue, 1995
		The robot mower would take an acceptable amount of time to mow my lawn	Locally developed from people's mowing goals and Goodhue, 1995
	Damage prevention	The robot mower would damage objects or plants while mowing my lawn	Locally developed from people's mowing goals and Goodhue, 1995
		The robot mower would not damage objects or plants while mowing my lawn	Locally developed from people's mowing goals and Goodhue, 1995
	Effort of use	It would take an appropriate amount of effort to use the robot mower	Locally developed from people's mowing goals and Goodhue, 1995
		It would take too much effort to use the robot mower	Locally developed from people's mowing goals and Goodhue, 1995
	Compat-ibility	The robot mower would not compatible with mowing my lawn	Locally developed
		Using the robot mower to mow would fit my lawn	Locally developed
	Ease of use	Using the robot to mow would be easy for me	Locally developed from people's mowing goals and Davis, 1989
		It would be difficult for me to use the robot to mow	Locally developed from people's mowing goals and Davis, 1989

Dimension	Factor	Item	Item Adapted From
Task-technology fit	Appearance of lawn	The grass in my lawn would be at the appropriate height when the robot mower mows it	Locally developed from people's mowing goals and Goodhue, 1995
		The grass would be a consistent height in my lawn when the robot mower mows it	Locally developed from people's mowing goals and Goodhue, 1995
		The pattern of cut grass would look acceptable when the robot mower mows it	Locally developed from people's mowing goals and Goodhue, 1995
		I would not be satisfied with the way my lawn would look when the robot mower mows it	Locally developed from people's mowing goals and Goodhue, 1995
	Health of lawn	My grass would seem healthy when the robot mower mows it	Locally developed from people's mowing goals and Goodhue, 1995
		My grass would not look healthy when the robot mower mows it	Locally developed from people's mowing goals and Goodhue, 1995
	Safety	I would feel safe with the robot mower mowing	Locally developed from people's mowing goals and Goodhue, 1995
		I would not be confident that the robot mower can mow safely	Locally developed from people's mowing goals and Goodhue, 1995
	Energy Consump-tion	The robot mower would use an acceptable level of electricity when it mows	Locally developed from people's mowing goals and Goodhue, 1995
		The robot mower would use too much electricity to mow	Locally developed from people's mowing goals and Goodhue, 1995

APPENDIX N: SURVEY STUDY – PARTICIPANTS' LAWN MOWING BACKGROUND

Table N.1

Survey Study Participants' Lawn Mowing Background by Condition and in Total

	Experimental Condition (Reliability/Communication)									
Lawn Mowing	**90%,/ 1-way**	**90%/ 2-way**	**90%/ no info**	**70%/ 1-way**	**70%/ 2-way**	**70%/ no info**	**No info/ 1-way**	**No info/ 2-way**	**No info/ no info**	**Total**
% Ever mowed	96.67	90.00	96.55	84.38	96.67	100.00	93.94	84.38	80.65	91.43
% Mow >10 years†	26.67	30.00	58.62	28.13	40.00	36.36	45.45	28.13	19.35	34.64
% Property size was less than 0.5 acre†	43.33	43.33	41.38	43.75	53.33	36.36	48.48	50.00	45.16	45.00
% Mower types used were walk behind gas	57.14	47.22	62.16	52.63	57.14	63.16	60.53	48.89	48.72	55.13
M Number of types of mowers used†	1.17 (0.35)	1.20 (0.35)	1.28 (0.41)	1.19 (0.71)	1.17 (0.51)	1.15 (0.42)	1.15 (0.38)	1.41 (0.38)	1.26 (0.77)	1.22 (0.50)
M Satisfaction with mowing lawn*† (SD)	3.80 (0.81)	3.97 (0.72)	3.83 (0.81)	4.19 (1.00)	3.83 (1.02)	3.91 (0.64)	3.73 (1.07)	4.06 (0.96)	3.97 (0.72)	3.92 (0.87)
M Importance of mowing lawn**† (SD)	3.83 (1.07)	4.03 (0.85)	3.48 (1.02)	3.69 (0.87)	3.60 (0.82)	3.73 (0.83)	3.52 (1.19)	3.78 (0.94)	3.55 (0.93)	3.69 (0.93)

Note. † No statistically significant differences among the conditions were found from a 3 (reliability) x 3 (communication) MANOVA after Bonferroni correction ($\alpha = .004$).
*Response scale satisfaction: 1-Very dissatisfied; 2-Dissatisfied; 3-Neither satisfied nor dissatisfied; 4-Satisfied; 5-Very satisfied.
**Response scale importance: 1-Very unimportant; 2-Unimportant; 3-Neither important nor unimportant; 4-Important; 5-Very important.

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