Housewives or Technophiles?: Understanding Domestic Robot Owners

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ABSTRACT

Despite the growing body of Human-Robot Interaction (HRI) research focused on domestic robots, surprisingly little is known about the demographic profile of robot owners and their influence on usage patterns. In this paper, we present the results of a survey of 379 iRobot's Roomba™ owners, that identified their demographic and usage trends. The outcome of the survey suggests that Roomba users are equally likely to be men or women, and they tend to be younger with high levels of education and technical backgrounds. Their adoption and use patterns illustrate the important role that gift exchange plays in adoption, and how the robot changes cleaning routines and creates non-cleaning activities. More generally, we argue that domestic robot adoption is growing, and suggest some of the factors that lead to a positive experience.

Categories and Subject Descriptors

J.4 [**Social and Behavioral Sciences**]: *Sociology*; K.4.2 [**Computers and Society**]: *Social Issues*

General Terms

Human Factors, Experimentation

Keywords

Domestic Robot, User Study

1. INTRODUCTION

A number of researchers report that technological advances have opened up new horizons for robotic products in domestic sphere [1,5,13]. This emerging market is also reflected in the exponential growth in the sale of domestic robots that perform utilitarian tasks [28] and suggests that soon our homes will be equipped with robotic products. Yet, despite these growth trends, few have empirically identified who the users are and how they use their robots at home.

In this study, we address this gap by reporting socio-cultural trends that we identified from a survey we conducted with 379

Roomba users. Among other domestic robots that serve household tasks, such as Scooba, Robomower and Dressman, we selected Roomba for three main reasons. First, Roomba have been very successful in the United States and that gave us wide accessibility to Roomba owners making it easier to recruit a large sample size. Second, Roomba is one of the longest available domestic robots, and we hypothesize that its adoption may have gone beyond "early adopters" or leading users, allowing us to capture a broader range of experiences. Third, and most importantly, Roomba is an exemplary case for understanding how householders respond to robotic products that replace blue-collar work in the home, which some researchers believe to be the future of home robotic products [19].

This paper is organized as follows: after reviewing related scholarly work, we describe how we conducted and analyzed the survey. Then we turn to the outcome of our study and present several socio-cultural trends from two perspectives: demographic composition and their influence on usage patterns. Specifically, we discuss initial purchase, current practices in cleaning and non-cleaning activities, and projected future growth. Our findings reconfirm but also expand on what has already been reported in previous literature and provide support for more generalizable trends through our larger sample. We conclude by discussing some factors that influence adoption and use, and in particular those which lead to the best human-robot interaction experience.

2. RELATED WORK

In recent years, a body of scholarly work in Human-Robot Interaction (HRI) has emerged focused on people's robotic experiences. In this section, we discuss different methods that have been used to explore the relationship between a human and a robot including laboratory experiments and field observation. We also present research focused on domestic robots and discuss why a study with a larger sample size is helpful for acquiring broader perspectives about usage patterns.

In a discussion of empirical HRI work, Tanaka [27] argues that a large portion of HRI research has emphasized theory development based on the results from laboratory-oriented experiments. These studies generate hypotheses and evaluate them under laboratory conditions to contribute to a theoretical understanding of task-oriented interactions between a human and a robot. Examples include, but are not limited to, research exploring what direction a robot should approach a seated person [6,30], how to follow a person in the most human-like manner [11], what situations and proximity people feel most comfortable with robots [15], and what causes people to perceive a robot to be alive [1] or affective

without verbal or facial expression [3]. Another stream of work has focused on methodology development and its evaluation. This research offers technologies and empirical tools to better study the subtle yet dynamic nature of interaction between a human and a robot in future HRI studies [16,24,29]. The commonality across these various efforts is that they all strove for rich and accurate information about the interactions between humans and robots.

Following in this tradition, the latest trend in HRI has been to leverage qualitative methods and ethnography—methods and theories that have their origins in Anthropology and Sociology [25,27]. Qualitative and ethnographic approaches, in contrast with the experimental tradition, emphasize studying actual use. A trade-off in this approach is that it is difficult to control the environment of study, specific hypotheses can not easily be tested, but ethnographic research offers the ability to identify behaviors unimagined in the laboratory, and also see what people actually do with robots. That said, some qualitative approaches— sometimes known as semi-structured—offer some control over what's studied, as illustrated by research that has examined passive and active robotic interaction modes and their affects on people in a train station [17], differences in interaction when one and multiple robots are present in a museum [23], and having a robot at a front desk who embodies different emotions [10]. Entirely unstructured studies of human-robot interaction have taken place in homes and schools [8,27]. Lately, roboticists have called for more ethnographically-informed real-world studies because of the richness of the data and its grounding in reality [12,25,27]. We argue that empirical understanding in domestic robots is particularly crucial because they are likely to be the first robots applied in everyday lives, and hence influence the shaping of public's perception of robotic systems.

Studies of home robots—heavily focused on vacuuming robots— have provided rich, contextual accounts of their usage patterns (as well as making use of a variety of methodological traditions) [8,9,14]. Forlizzi and DiSalvo's seminal ethnography [9] of Roomba adoption shows an increase in cleaning frequency and suggested that people developed bonds with their robots. Inspired by the latter finding, Sung et al. [26] conducted a study examining the emotional attachment of people with their Roombas. They found that emotional attachments could help overcome technical unreliability and be the basis for a long-term (life) commitment to the product (also noted by [4]). Forlizzi confirms the latter finding in her work comparing Roomba with Hoover, a lightweight upright vacuum cleaner [8]. She shows that Roomba was still used a year later, whereas the Hoover had been replaced by another vacuum cleaner. Kim [14] undertook a similar study, deploying five different vacuuming robots to homes in Korea in order to identify user trends that persisted across the robots.

However, because of the complexity of organizing an empirical study where the research must be taken place at the site of use, ethnographic studies tend to have small sample sizes (often less than 20 participants). The limited number of participants makes it harder to know whether the results can be generalized across a broader section of population or whether they reflect very particular groups. Obtaining broader comprehension of Roomba users was particularly important for us because we planned to conduct an in-depth investigation of Roomba users and hence, needed to set the correct frame of reference. Therefore, we decided to employ a survey to address this challenge. We designed our survey based on the results of our own and other previous empirical research, and sought to learn whether those findings held true for broader segments of the population.

3. STUDY DESIGN

Researchers argue that surveys are an effective medium to collect data from a large sample size, to confirm trends in existing resources (i.e., demographic information), and to set expectations (i.e.. generating hypotheses for laboratory experiments, and questions for semi-structured interviewing) before conducting costly detailed studies [7]. Finally, Bernard [2] notes that surveys offer an advantage when asking sensitive questions that people might not wish to discuss in face to face setting such as those about socially undesirable behaviors. We conducted an online survey because of the logistics associated with trying to reach a broad demographic group (region, age). However, we are aware of the sample bias associated with Internet use—leaning towards the younger and more affluent. To recruit, we posted a message on Craig's List-San Francisco (sfbay.craigslist.org) which was responsible for over 90% of our data. To correctly assess the data bias influenced by the participants of Craig's List, we wrote to Craig of Craig's List to share the demographic data of the site. A demographic analysis of Craig's List users provided by Quantcast[1] suggests that affluent men use it most, but also find that the site is in the 250 most accessed across the Internet with more than 5.4 million users monthly. We also posted the message to the Roomba review forum (roombareview.com) and distributed it through various mailing lists at our institution. Our participants came from 38 of the 50 states in the USA. Most users (40%) were from the West coast, followed by the North East (26%), the South (20%) and lastly the Midwest (14%). We also had three participants from Canada.

Depending on the answers given, a participant received a minimum of 21 questions up to the maximum of 35 questions. The survey consisted of four sections focused on ownership (i.e., Roomba model owned, length of ownership and motivation for purchase), usage patterns in cleaning (i.e., frequency of use, extra manual cleaning), usage patterns not associated with vacuuming (i.e., naming, ascribing personality) and demographic information (i.e., age, gender, household membership, technical knowledge.) Due to the space allowed, we offer an online access to the questions instead of presenting them in the paper[2]. To our great surprise, our survey collected over 400 answers in just under seven hours (we did offer a $5 Starbucks gift card to participants who completed it and are residing in the United States). After filtering out duplicated IP and mailing address and undecipherable answers (i.e., "asbsdg"), we ended up with 379 valid data sets. At the end of the survey, we provided a blank comment field, and some respondents took it as an opportunity to express their enthusiasm for Roomba, as well as thanking us for administering the survey, enjoying the questions, and volunteering for future research opportunities. This enthusiastic response is not always the case with surveys, and it may reflect the engagement that the public has for robotics.

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[1] www.quantcast.com/sfbay.craigslist.org

[2] http://www.surveymonkey.com/s.aspx?sm=fgGQHWh5ngec0Td Ct3t1qg_3d_3d

For data analysis, we took more of a qualitative approach than quantitative measures. When we designed our study, we sought to obtain insights about qualitative characteristics and broad categories of users. This focus led us to collect more behavioral and qualitative data than scale-based numbers. For instance, based on the findings reported in previous studies, we asked our participants to check the activities that they had done with Roombas such as experimenting, watching for fun, conversing with it and more. The majority of our questions consists of what users have done with Roomba and why. This does not mean that we overlooked the effectiveness of statistical analysis with scale-based data. We also collected numerical data, where necessary, including Roomba satisfaction and cleaning frequency. They became helpful to confirm findings from the previous reports, such as the increase of regular and opportunistic cleaning, and the holding of symbolic and aesthetic value of Roomba [9]. We also sought to determine whether responses to our questions varied by demographics. Taking Roomba's naming practice as an example, we ran statistical analyses (T-tests or analysis of variance—ANOVA) to see whether naming was correlated to gender, age group, technical knowledge or household composition.

4. FINDINGS

In this section, we first discuss the demographic characteristics of Roomba owners. Then we review purchasing, cleaning, and non-cleaning patterns. We conclude by examining an apparent growth in the adoption of Roomba and other domestic robots.

4.1 Demography: Away From Stereotypes

Rogers [22] argues that determining the actual audience for a product is central—because the lead users play a critical role in fueling the adoption by others, thus ensuring the product's overall success in the marketplace. So, our first question was, who is a typical Roomba user? Vacuuming has long been largely women's work [20,21] (and indeed, within HRI some studies have followed this assumption by recruiting women subjects for vacuuming research [14]) while technological innovation has been associated with men we wondered which audience Roomba would attract: homemakers or technophiles? However, our data suggests that more user profiles may exist than these two stereotypes. Figure 1 shows that our respondents were largely younger and consisted of slightly more women than men.
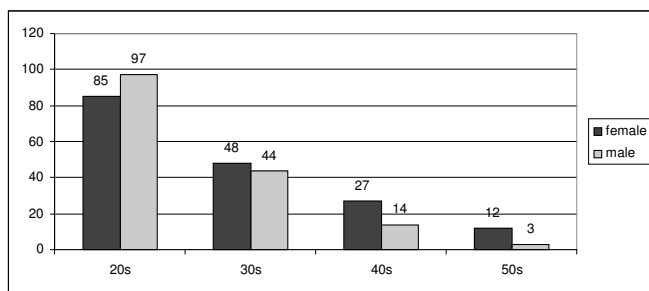

Figure 1. Age and Gender Distribution

Our respondent profile is somewhat similar in age distribution of Craig's List users, but our participants are younger. Specifically, our Roomba users are mainly people between 18 and 29, with more than half of the people in this group (N=95) being between

the ages of 18 and 24. Surprisingly we did not find any significant differences in cleaning/non-cleaning use patterns related to age.

Our participants were almost equally divided across gender: 194 women and 181 men in total. Further, upon asking whether or not they were the primary users of Roomba, 139 women and 132 men reported that they were, which shows even less distinction between genders. Breaking gender by age (Figure 1), there were more men in their 20's while we saw the opposite in older groups. Given the large portion of men who said that they were responsible for vacuuming with Roomba (the primary user), we wanted to know whether they had been responsible for cleaning prior to Roomba. Of the 89 men who lived with at least one other person, only 27 had been responsible for vacuuming prior to Roomba. We suggest then that Roomba may trigger some swapping of vacuuming practices across genders. Here, we excluded men who lived alone because we assumed that they had to clean by themselves with or without the aid of Roomba.

More than age and gender, the household composition seems to influence Roomba usage patterns. We had 85 participants (23%) who lived alone, 164 participants (43%) who lived with other adults but not children, and 128 households (34%) that included adults and children. Moreover, irrespective of whether they lived with another person or not, half (49.6%, N=188) of our participants owned one or more pets including cats, dogs, parrots, and rabbits. Households with children expressed greater satisfaction with Roomba's performance. We asked each participant to rate their satisfaction with Roomba on a scale from one to seven where one meant "Horrible. I prefer traditional vacuuming" and seven meant "Heavenly. I cannot live without it". The independent variable T-test shows that the participants with children (M=4.93) rated their satisfaction significantly higher than those without children (M=4.53, t(374)=2.63, p<0.01). This was supported by the open-ended accounts participants provided, where those with children (and pets) described a variety of activities that their children (and pets) could do with Roomba. We learned that Roomba was used to help children crawl by following it, and that the robot chased pets and also gave them rides (particularly parrots).

Collectively, our Roomba owners had attained high levels of education, with most having an undergraduate degree (N=229) and many having a graduate degree (N=112). Only 35 people have left education after high school. Moreover, many of those with college degrees had their academic training in technical fields. Among the 341 people with college level education, 153 had engineering-related degrees. However, we recognize that not everyone who acquires technical knowledge does so through formal school education. So, in addition to asking about education, we also asked whether people worked in a technical profession, or whether they were a "recreational engineer" with technical hobbies (i.e. amateur radio). Based on answers to these three questions 48% of participants identified as technical (N=182), indicating that a big portion of Roomba users were familiar with technology, and perhaps more so than average. While a large portion of our participants had technical knowledge, about half (43%, N=158) self-identified as being attracted to new technology and gadgets. A smaller number of people (18%, N=66) said they normally did not get attracted to technology but Roomba excited them. Given robots' position in science-fiction narrative, we asked

whether our respondents enjoyed sci-fi, but very few (20%, N=73) claimed to be fans.

While we had some participants that might fit the demographic profiles of technology enthusiastic and homemaker, we suggest that it would be overly simplistic to reduce Roomba owners to these two profiles. Instead, younger and more technically inclined (which includes more than just technophiles), and living with other people appeared to be more stable demographic profiles. We also think that further work would be needed in exploring these profiles in more detail—including off-Internet sampling.

4.2 Why They Buy and Give: Purchase

When we asked what motivated people to purchase their first Roomba, we anticipated two responses: people hating vacuuming and wanting to own new technology. While these answers did prevail, we found other explanations (Table 1). Notably, most people responded that they decided to buy after having seen it demonstrated, heard about it, or were given it.

Table 1. Motivation for first Roomba ownership

Purchase motivation for First Roomba (N=379)	responses
Through my or other's experience (demonstrated, recommended, gifted)	188
Interested in new technology	173
Hate vacuuming	171
Curiosity	152
Always wanted to own robots (childhood dream)	79
Overwhelming amount of cleaning. Need assistance	63
To workaround physical difficulties	44

One person noted that he decided to purchase Roomba based on the positive comments he read online. Being interested in new technology or curiosity was another large motivator of purchase. Although less popular, some purchased Roomba out of necessity including physical conditions that made cleaning difficult or feeling overwhelmed by the amount of vacuuming. For example, one person told us that she was pregnant and needed help vacuuming. Another person bought it to reduce her asthma by both keeping the house dust free and reducing manual effort. Additionally, several people left comments that price and sales were big factor in their purchase.

Acknowledging the power of social influence (recommendations) in purchase decisions, we wanted to see if that trend continued in subsequent Roomba purchases. We had 71 participants who had multiple Roombas, and Table 2 shows that gifts constituted a popular reason for owning multiple robots. Also, the bond between people and Roomba led to additional purchases.

Table 2. Motivation for the subsequent Roomba purchase

Purchase motivation for subsequent Roomba (N=71)	# of responses
It was a gift	24
Loved the first one very much and wanted more.	24
Need to clean different parts of the home.	20
Wanted one for cleaning and the other for hacking.	16
My first one broke so purchase another. Then, I fixed my first one and hence owned multiple.	13

In addition to understanding the motivation for acquiring subsequent Roombas, we also identified how long it took for people to decide on additional units. Among the 71 multiple Roomba owners, 54 participants acquired additional unit(s) within a year of the first purchase. Among them, 11 people had added the robot just in a month. In contrast, only 17 participants reported that they purchased additional ones a year later, including just one person who acquired one after three years.

This data suggests that initial impressions of robots have a strong role in determining further adoption, because people will either buy more for themselves or give it to someone else as a gift. Indeed, 87 people in our survey gave Roomba to someone else as a gift, popularly for winter holidays (Christmas, Hannakah) (N=55), birthdays (N=37), and housewarmings (N=33). Other responses included Valentine's Day, Mother's Day (but not Father's Day), anniversaries, weddings and to our surprise, even a funeral. We also inquired as to the gender of the recipient of their gifts: 41 participants have given Roombas just to women while 39 people have given it to both genders, and just 7 people have gifted it to just men. This data suggests despite the balance of responsibility, as a gift it is perceived to be more useful to women than men. This finding held irrespective of the gender of the giver, both men and women tend to give Roombas to women.

4.3 Cleaning: When, How and With What

We asked three questions to get at changes in cleaning. Participants recorded how often and what time they cleaned before and with Roomba, and whether they did any extra manual vacuuming. The results show that the cleaning frequency increased with Roomba (Table 3). The number of households that cleaned on a daily basis increased (from 22 to 37 households), while those that cleaned monthly or less decreased (from 46 to 22 households). A one-way ANOVA test also supports that there is a change in vacuuming frequency between before and after the use of Roomba ($F(4,350)=19.537$, $p<0.001$).

Table 3. Frequency of cleaning before/after Roomba usage

	Before Roomba	With Roomba
Cleaning frequency	*# of responses*	*# of responses*
Every day	22	37
Every other day	54	75
Weekly	159	168
Bi-weekly	70	46
Monthly or less	46	22

We also wanted to know whether Roomba influenced what time people vacuumed, particularly because some units had a scheduling function. Although we did not identify any statistical relationship between the scheduling function and the time of cleaning, participants did describe shifts in vacuuming time due to the use of Roomba in the open-ended question. Before Roomba, cleaning routines focused on the days that people could spend time at home: weekends, Friday night, and work-at-home days. With Roomba, however, participants began to utilize times they were not at home or they were occupied by other tasks including while they were at work, children at school, putting children to bed, or while they or their pets slept.

Although Roomba vacuumed without requiring the presence of householders, many still manually vacuumed. In fact, the majority

of our participants (N=243) reported doing this extra cleaning (Table 4).

Table 4. Frequency of extra manual vacuuming

Extra manual vacuuming?	# of responses
Yes, always.	45
Yes, occasionally.	136
Yes, but rarely.	58
No, never.	135

When asked why they did extra cleaning and how they did it, our respondents explained that they did it when they wanted a quick or spot-oriented clean, or when they wanted a thorough, deep clean. Quick cleaning involved vacuums, sweepers or hand, and often coincided with guests coming to visit or when a small mess had been made. Deep cleaning involved upright vacuum cleaners in most cases. One participant pointed out that Roomba left fine dust on the carpet, which caused allergies and hence they manually vacuumed on a weekly basis. Homes with pets tended to go through this process more often because they found Roomba suction was insufficient to clear up pet hair and waste. Corners, edges, stairs and cobwebs were cited as other reasons for manual vacuuming. Unfortunately it seems that the more that people have to follow up with manual vacuuming, the less satisfied they are with Roomba. The T-Test result shows that those who did not perform extra cleaning rated their satisfaction with Roomba higher (M=4.96) than those who did additional cleaning (M=4.51, t(376)=2.998, p<0.004). However, within the group who did extra cleaning, the satisfaction varied depending on how frequently they had to do it. People who rarely did manual cleaning had the highest satisfaction (M=5.13) followed by those who occasionally cleaned manually (M=4.54), while those who always did it recorded lowest satisfaction (M=3.63).

To help Roomba clean, householders made physical modifications to their homes, a process referred to as *roombarization*. Common types of roombarization included clearing up wires, changing furniture layout, and tucking in rug tassel [26]. Our survey data shows that approximately half of our participants (48%, N=180) modified their homes, and most of them (N=127) changed it after they adopted Roomba. Although less reported, we had participants who changed their home before using Roomba for the first time (10%, N=38), or changed their home both before and after adopting Roomba (4%, N=16). Interestingly enough, technical knowledge seemed to pose impact on roombarization. Among the 180 people who roombarized, 101 users self-identified as technical. Changing parts of the home likely existed when technological objects were introduced, but we were surprised that people did this before even knowing what Roomba might need based on seeing it operate in their own home. Also we are unaware of any other technology that has a specific name for this type of work, however, the creation of roombarization is one of the many unique aspects of Roomba adoption that we discuss next.

4.4 Why They Name…: Roomba Culture

Previous studies of Roomba [8,9,26] report a variety of intriguing non-cleaning activities associated with Roomba including, but not limited to, naming, ascribing personality and gender. Questions remain though about how common these activities are across Roomba owners. Our survey took 9 of those activities (table 5) and asked people to check the ones they had done. Table 5 shows

each activity, and the number of people who had done it. Based on the result, we hypothesize that more popular activities require less work. For hacking Roomba as an example, which required sufficient effort to be successful, only 6% had undertaken this activity even though half of our participants had technical knowledge and interest. In the open-ended section of the survey, participants described hacking as including mounting cameras and TV screens, and adding height sensors to stop Roomba from getting stuck in low spaces. However, more people (40%) reported to have played or casually experimented with their robot including kicking it, placing dirt in front of it, and chasing pets with it. Some experiments required more creativity and work, such as creating mirror wall to interrupt Roomba's sensing ability and building a race track to compete with neighbor's Roomba.

Table 5. Non-Cleaning Roomba Activities

Activity Type	# of responses
Watch Roomba running for fun	276
Give a demonstration to others	217
Play and experiment	141
Ascribe a gender to Roomba	135
Name Roomba	87
Ascribe a personality to Roomba	44
Talk to Roomba (praise, greet)	42
Buy costume (dress up)	43
Hack the internal system	21

Additionally, we looked at how many people treated Roomba as a living social being, which included activities such as buying costumes, naming, and ascribing gender and personality. Overall, respondents had relatively low rates of treating Roomba as a living entity. Giving Roomba gender was most common, and in contrast to our previous study where all participants referred to Roomba as male [26], the survey showed that people were equally likely to refer to it as he (N=50) or she (N=49) and some used both genders (N=33). Our statistical analysis returns no significant relation between the gender of the owner and the gender that they ascribe to their Roomba.

In our survey, 46 men and 41 women reported naming their Roombas. And 34 of them were multiple Roomba owners, to whom we asked if they named all or some of their robots, to learn whether it was an established practice within their home. Except for two owners, the multiple Roomba households named all of their robots. We also asked for the names respondents gave to their Roombas. Most commonly, the robots were given a human name such as Sarah, Alex, Joe, and Veronica. Other names were wordplays on the word "Roomba": Roomie, Roomby and Ruby. We saw these names across multiple households. We also saw names related to cleaning activities including hydro-and-oxy, cleaner winner, Super Downy (a laundry product in U.S.), Floorence, and dirt demon. Additionally, we had robot-centered names such as Darth Roomba, bot, and robotina. Finally, some drew inspiration from the physical shape of Roomba, such as trilobite (also happens to be the name of Electrolux's vacuuming robot), petite, and pancakes. We asked our participants when they named their Roomba, before or after purchasing it.

Overwhelmingly, 83% (N=65) named their robot after they acquired it.

Ascribing personality was interesting because not everyone described it positively. Indeed, personalities included silly, temperamental, flirty, and stubborn. Also people compared Roomba's personality to humans or animals, saying for example "doesn't listen to me... like a man.", "it's just a little crazy thing. It is kind of like me", and "naughty two year old". Furthermore, we learned that people theorized about Roomba's intentions based on its behavior, for example saying that it favored a particular spot in the home. Occasionally, participants reported that Roomba tried to communicate to people or to other Roombas. One interesting question we wanted to know more was whether these users who perceived Roomba in such an animate way would also talk to and dress their vacuum. However, we could not identify any statistical relationship between ascribing personality, and talking with or purchasing costumes for Roomba. Indeed, among the 42 people who reported talking to or greeting their Roomba, only 18 said that the ascribed personality to Roomba. Further, of the 43 people who bought costumes for Roomba, only eight thought it had personality. Also, naming and ascribing gender do not correlate with whether someone thinks Roomba has a personality. However, the personality does seem to be correlated to pet ownerships. Participants with pets tended to ascribe personalities (33 among 188 pet owners) more frequently than those who didn't (11 among 185 non-pet owners) according to the T-test result (t(373)=3.54, p<0.001).

Although the people who engaged in non-cleaning Roomba activities were the minority (around 20%), they had significantly higher rates of satisfaction with the product than those who did not. For example, people who named their Roomba showed higher satisfaction (M=4.99) than who didn't (M=4.57, t(371)=2.476, p<.015). Similar trends appeared on those who ascribed gender and personality. Roomba owners who ascribed gender showed higher satisfaction (M=4.91) than who did not (M=4.53, t(376)=2.579, p<.011). Finally, those who ascribed personality to Roomba expressed more satisfaction (M=5.16) than those who did not (M=4.60, t(375)=2.538, p<.013). It was not possible within our study to explain whether people showed higher satisfaction because of these activities, or vice versa. Yet, we suggest that non-cleaning activities, probably those perceived as least important in the design of a domestic robot, appear to make a vast difference to the human-robot experience.

4.5 Why they Keep Buying: More Robots

Positive experiences reported by Roomba users [8,9,26] accompanied by encouraging projections from industry organizations [28] collectively suggest that there is a market for domestic robots, and that it will continue to grow. Our survey data also suggests that this optimistic growth trend is plausible, but adds two additional points. First, we saw that many of our participants had become Roomba owners in the last year, and second, that adoption of a robot led to the adoption of others.

As shown in Figure 2, the majority of our participants have become Roomba users recently: owners for less than a year. Looking at the data closely, more respondents reported purchasing their Roomba less than a month ago than those who had owned their robot for 1-2 years. Given that Roomba has only been

manufactured and sold since 2002, our data suggests that more users are buying them each year, and suggests a growth curve.
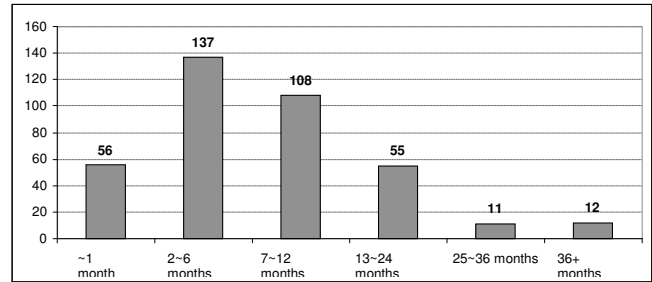

Figure 2. Length of ownership since the first Roomba

Our Roomba owners also tended to own other types of robots which they purchased for both utilitarian and entertainment purposes. Table 6 shows that approximately half (44%, N=165) of our participants owned at least one additional robot they used in home. We were surprised to find 11 people who owned Dressman™, the ironing robot that has just become available in the United States and has a retail price of over $1000 US (also sold for over 900€), and 13 people who owned Paro, a baby seal robot that was originally designed for nursing environment [18].

Table 6. Additional robots owned by Roomba users

Types of Robots	# of Units
Scooba™ (mopping)	37
Robomower™ (lawn mowing)	47
Dirt Dog™ (garage cleaning)	27
AIBO™ (toy dog)	25
Dressman™ (ironing)	11
Paro™ (nursing)	13
Other robotic vacuum cleaners	3
Humanoid robot toys (i.e., Robosapien)	62

Table 7. Total number of other robots owned beside Roomba

# of robots	1 robot	2 robot	3 robot	4 robot	5 robot	6 robot	7 robot
# of owner	132	20	6	3	2	1	1

Some of our participants owned multiple types of robots beside Roomba as indicated by Table 7. Most people (N=132) owned one additional type of robot beside Roomba. However, some recorded that they owned more than five types of robots as listed in Table 6. One person in particular, who was only 19-year-old, reported owning every robot in Table 6 except for other robotic vacuum cleaner. We followed up with him via email to confirm that he had typed the correct data in. He explained to us that he had purchased Scooba on his own, but received all the other robots as gifts for his birthday, graduation and other occasions. While he represented the very extreme, generally our data suggest that adoption of domestic robots is on the rise, which in turn implies that it is timely to understand who the adopters are, and what draws them to the product, and their experiences with it.

In summary, our survey findings show a variety of usage patterns that Roomba owners appear to exhibit. We learned that the

demographics of Roomba owners may extend well beyond homemakers and technophiles, unpacking these profiles may help us to understand the lure of domestic robots. One aspect of the Roomba owner that seems important, because it was common, is the fact that most people valued their own and others' experiences with Roomba when making their purchase. Again, we think that this merits more attention, such as "does word of mouth recommendations apply to other robots as well?" We also learned that once Roomba entered the home, it changed the dynamics of owners' cleaning cultures by increasing the frequency, shifting the routine time, and causing physical modifications of the home environment. Roomba also inspired non-cleaning patterns in some of our respondents. Coincidently, they were most pleased with their human-robot experience and tended to be name, give gender and personality to their robotic floor vacuum cleaners. Finally, ownership appeared to be rising, and once one type of robotic product was owned, others seemed to follow.

5. DISCUSSIONS AND FUTURE WORK

Five years have passed since Roomba was first introduced to the market and anecdotal reports state more than two million users have adopted it worldwide. As Norman emphasizes that the user experience, appearance and quality of the product gets increasingly important as it matures [19], we argue that it is a timely subject to take a closer look at who the robot users are and how they employ it in their domestic space. Our survey specifically addressed the following three issues: unveiling demographic profile, reporting generalizable trends of Roomba usage and confirming the growth of domestic robots.

First of all, we took a step toward revealing demographic characteristics of Roomba users. Within the extent of our survey data, we identified that Roomba users were younger (largely in their 20's) with higher education and technical knowledge. This description could suggest that they were technophiles and dominantly men, but we found many women owners were primary users too. Our participants also told us that many of them were not technophiles, or interested in science fiction, which leads us to speculate that they are not as enthusiastic as stereotypes about robotic ownership might suggest. Usage patterns among our respondents seemed to be somewhat influenced by who they live with (i.e., children and pets) rather who they are (i.e., their gender or interest in technology). Homes with children and pets reported more engaged with robot, including having it play with children or chase their pets. We even identified that having pets seemed to be related with the tendency to ascribe personalities to robots.

Second of all, we re-confirmed and expanded on the findings reported from other ethnographic studies of Roomba usage. Forlizzi and DiSalvo [9] identified that the use of Roomba increased cleaning frequency. Our survey mirrors this increase by presenting that more people cleaned on a daily basis after adopting Roomba. They also found that people valued Roomba for freeing them to perform other tasks [9], which we saw in our data through the descriptions of what people did while Roomba is vacuuming, such as working in their office and putting children to bed. Like other studies [8,9,26], we saw that people not only utilize the robot for its intended purpose of cleaning, but also they adopt it in other ways through naming it, playing with it, giving it a personality and gender. However, our survey additionally indicates that these activities do not appear uniformly across all

users. Nevertheless, our data begins to shed some light on how these non-cleaning activities help to build the bond between a Roomba and their owners. They showed significantly higher satisfaction than those users who did not engage in such activities. This implicates that researchers should consider a holistic user experience even when designing task-oriented appliances because it can make a powerful and positive impact on the human-robot experience.

Finally, our study suggests that the number of people who own a robot has grown rapidly in recent years, having purchased numerous types of domestic robots for vacuuming, mopping, entertaining and other household activities. About half of our study participants have owned at least one robot in the home, in addition to Roomba. We argue that those who engender positive user experience with their first robot tend to employ more in the future. We support this argument by presenting how Roomba owners acquired additional robot. They either bought more units based on their first experience, or received it as a gift based on someone else's positive experience. This implies how robots get introduced to our home is critical (as also noted by [9]) in determining the future adoption of robotic products. Also, we suggest that perhaps the best way to migrate robotic technologies into the home is to find people who already have domestic robots and then encouraging them to take up new types of systems and recommend the robots to their friends and family.

While our survey revealed some aspects about robot users and their usage patterns, much more remain unknown. Firstly, further work is needed to understand precise portrayal of domestic robot users because our data may be biased by the users of the Internet and Craig's List. To minimize the bias, we first turned to Craig of Craig's List for sharing the demographic profile of the site. Also, we carefully examined if any of our data is influenced by a specific age group by running variance analysis. Within our analysis, we did not identify any user characteristic such as giving Roomba as a gift and using it on a daily basis be impacted by a specific age group. Yet, to make these findings more credible, it is critical to enlarge the range of survey by employing offline users with broader age groups. Continuing this effort, we propose an in-depth interview with people who adopted various types of domestic robots (like those who own more than five types of robots in the home) to further investigate what led them to own multiple robots and how they interact with them. This study will help expand our knowledge on domestic use of robots beyond cleaning practices. Lastly and critically, we need to learn from people who have abandoned using Roomba. By hearing from both users who have successfully adopted and who have given up, we will be able to complete our understanding of how householders truly respond to the robots in their home.

6. CONCLUSIONS

In this paper, we presented findings from an online survey of 379 Roomba users. Our survey focused on demographics and use patterns (cleaning and non-cleaning), and allowed us to learn whether results from previous research were more broadly applicable across the Roomba owner community. Additionally, we identified some promising directions for future research. Although our study results may have been influenced by our recruitment strategy, we remain positive that the survey has value

for thinking about who Roomba users are, and what their human-robot interaction experiences have been.

7. ACKNOWLEDGMENTS

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