Service Robots in the Domestic Environment: A Study of the Roomba Vacuum in the Home

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ABSTRACT
Domestic service robots have long been a staple of science fiction and commercial visions of the future. Until recently, we have only been able to speculate about what the experience of using such a device might be. Current domestic service robots, introduced as consumer products, allow us to make this vision a reality.

This paper presents ethnographic research on the actual use of these products, to provide a grounded understanding of how design can influence human-robot interaction in the home. We used an ecological approach to broadly explore the use of this technology in this context, and to determine how an autonomous, mobile robot might "fit" into such a space. We offer initial implications for the design of these products: first, the way the technology is introduced is critical; second, the use of the technology becomes social; and third, that ideally, homes and domestic service robots must adapt to each other.

Categories and Subject Descriptors
K.4.0 [**Computers and Society**]: General

General Terms: Design

Keywords: Human-Robot Interaction Design, Design Research, Ethnography, Domestic Robots

1. INTRODUCTION
Domestic service robots have long been a staple of science fiction and commercial visions of the future. Through novels, cartoons, and films, and the "blue-sky" projects of technology companies, we have imagined what these intelligent autonomous appliances of the future would be like. Most commonly these imaginaries take the form of humanoid assistants capable of performing multiple tasks and engaging in fairly sophisticated communication and interaction with people.

Until recently, we have only been able to speculate about what the experience of using such a device might be. Over the past five years, several domestic service robots have been introduced as consumer products. They provide an opportunity to conduct research on the actual use of consumer robotic products in order to begin to develop a grounded understanding of human-robot interaction (HRI) in the home and inform the future development of domestic robotic products.

In this paper, we report on an ethnographic design-focused research project on the use of the Roomba Discovery Vacuum (www.irobot.com) (Figure 1). The Roomba is a "robotic floor vac" capable of moving about the home and sweeping up dirt as it goes along. The Roomba is a logical merging of vacuum technology and intelligent technology. More than 15 years ago, large companies in Asia, Europe, and North America began to develop mobile robotic vacuum cleaners for industrial and commercial settings [27]. These machines move themselves autonomously across the floor, brushing or vacuuming dirt and dust into a dustbin. The home models mimic earlier industrial models, but are smaller, lighter, less functional, and less costly.

The Roomba undertakes three types of cleaning, using two rotating brushes that sweep the floor, a vacuum that sucks dust and particles off the floor, and side sweeping brushes to clean baseboards and walls. Infrared signals are used to determine the Roomba's current location in a room, and to ensure that it does not fall down stairs or off of raised floors. A set of sensors is also used to determine dirty places on the carpet that need more attention. The Roomba returns to a self charging home base after the floor is clean or when it needs to recharge. Typically, it can clean about three 14 x 16 foot rooms before doing so.

The sensor systems in the Roomba, along with most home floor

Figure 1. Roomba Discovery vacuum. Photo from http://www.irobot.com/consumer/

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cleaning robots, are not sophisticated. Inexpensive contact sensors or infrared sensors are most frequently used, along with simple heuristics to follow random motion patterns. Some newer models have additional features and are capable of navigating around furniture and returning to a charging station.

Technologically, the Roomba pales in comparison to most robots, as well as to many other products already in the home. It is not capable of planning or learning, and its sensors are relatively simple. But our intention was not to research or advance the technology *per se*, but to focus on the use and issues of human robot interaction in the home. Because the Roomba was commercially available and relatively inexpensive, it provided an appropriate platform for our research. We were specifically interested in robots that "do work," rather than the commercially available entertainment robots such as the Sony AIBO.

As robots like the Roomba become more viable in the home, for research and commercial uses, it is necessary for both technologists and designers to develop a deeper understanding of the domestic environment. The domain of the home is worlds away from the laboratory, space, or battlefield — the most common domains for human-robot interaction. Most assumptions and requirements from these domains do not readily translate to the home. In some cases, they are wholly inappropriate. In particular, we must be attentive to the material culture of the home, the everyday domestic practices of homemaking, and intimate social nature of the home where there are not "users" but rather families, couples, and individuals literally in co-habitation with technology. Our primary intention in this paper is to provide preliminary descriptions of the use of a service robot in home in order to sensitize designers and technologists to the material and social complexities that will be encountered when deploying robotics into the domestic environment.

2. BACKGROUND

2.1 Related work

There is a small but growing literature on domestic service robots in the domain of human-robot interaction but the majority of this work is technical in nature [8, 18, 20, 29]. However, relevant work for understanding the use of domestic service robots and informing their design can also be found in qualitative studies of the home outside of the domain of robotics, particularly those that relate to technology adoption, human-computer interaction, and ubiquitous computing.

The domestic environment as a place for technology has received increasing attention in both qualitative and quantitative research over the past 10 years. This work has ranged from comprehensive empirical studies that describe the experience of technology use [19], to the generative work focused on the conceptual design of information appliances [9]. This work is useful for research and design methodologies, and for producing frameworks for understanding the use and impact of emergent information and communication technologies (ICTs) in the domestic environment. Of particular interest is work that has focused on the relations between material artifacts and social interaction in everyday homemaking practices such as scheduling, and work that has emphasized the need to create culturally situated technologies for the home [2-4]. Together, these two emergent bodies of research reinforce the need and value of paying close attention to the material, social, and cultural details and intricacies of the home in order to design appropriate technologies for the domestic environment.

Within the HCI community, the home is regarded as an interesting place to integrate new technology. Historically, early research on the home centered on workplace activities in the home [13, 16, 19, 26]; later, ethnography as a means of describing the experience of the home became popular [22, 30]. Recently, research labs at numerous academic institutions in the US and abroad have built real or simulated homes to conduct extensive research "in the wild" [15, 17, 21, 23, 24]. While early efforts augment existing technology in the home, later efforts assume that technological interventions will be extreme. The reality is that today's homes don't seem to be keeping up — landline telephones, home alarm systems, and digital cable services are the most cutting edge communication and information technologies that are commonly seen. Fundamental changes in the structure and infrastructure of the home will need to take place to support the ubiquitous computing and autonomous service robots of the near future.

Despite these resources, much research still needs to be conducted on service robots in the context of the home. Robots are not the same as desktop computers or other forms of ICTs. Although the research into ICTs is necessary, alone it is not sufficient to develop a grounded understanding of human-robot interaction (HRI) in the home and inform the future development of domestic robotic products. The difference of physicality, autonomy, and mobility calls for a re-thinking of the experience of technologies in the domestic environment. Furthermore, robotic products such as the Roomba are not ICTs. Instead, they are appliances designed to assist in more physical forms of household labor. This presents an opportunity for design to better match technologies to the abilities and needs of people and the contexts in which everyday life unfolds. Simply put, homes are simply not designed to accommodate autonomous robotic technology — nor should they be. Rather, if autonomous mobile robots are to be used in the domestic environment the robots need to be designed to "artfully integrate" with the structures and practices of the home [36, 37].

3. RESEARCHING THE USE OF A DOMESTIC SERVICE ROBOT

Our research focuses on the home as a domestic environment. The people, practices and products that constitute a home form a highly personal moral economy, one aspect of which is cleaning and cleanliness. The practices of cleaning and cleanliness are not just instrumental activities — to keep the home free of dirt and germs. They also reflect, structure, and are structured by value-laden beliefs about what is "proper" or "good" living. This extends to how cleaning is performed in the home and the role of various technologies, from solvents to robots. [31, 33].

We have adopted an ecological view of the home and the activities and roles within. This approach is adapted from social ecology theory and our own previous ethnographic research [7, 10]. The unifying theme in ecological approaches is the environment, the relationships of the people within the environment, and with each other within the environment. Behavior can be understood as a joint function of the person and the environment.

An ecological view is by nature multidisciplinary. It offers theoretical constructs that integrate concepts and propositions from multiple disciplines. Such a view is useful when the

approach of one discipline may not offer a well-rounded perspective on a particular problem. For example, strategies for healthcare may be grounded in clinical medicine, and ignore facets of the physical environment in which patients reside. A social ecological view of such a problem might reveal interventions at the individual, organizational, and environmental level.

In our research, we conceived of the home as an ecology (Figure 2). We were interested in all of the people that inhabit and work in the home, and their relation to practices of cleaning and cleanliness. The research focused on the following factors within the ecology:

- the home as a physical space and a place containing social norms (cleaning for company, caring for family members)
- individual roles and social relations (housekeeper, caregiver, career person, single dad, children)
- goals in cleaning and tasks related to those goals
- products used
- activities performed (cooking, cleaning, laundry, sanitizing, straightening)
- how order and cleanliness relate to the home as a sense of place and a bounding environment (an interplay of private and public spaces: relaxation, entertainment, and work, cooking and eating, and bathing areas).

Our research had two specific goals. The first was to broadly explore and understand the use of domestic service robots in relation to cleaning and cleanliness. We were particularly interested in how the introduction and use of a domestic service robot might influence the habits and practices of housekeeping. A secondary goal was broadly concerned with domestic robots in general. How does, or might, a mobile, autonomous robot "fit" into the home? Given that such a robot is completely foreign to the home and the everyday practices of the home, how would people make sense of it, what would be the limitations and opportunities of the physical spaces of the home, and what strategies and tactics would people make use of to domesticate or resist this new technology? Although the instantiation of robotic technology has been studied in organizational contexts, our work is a necessary first step in generating this type of knowledge about the home [32].

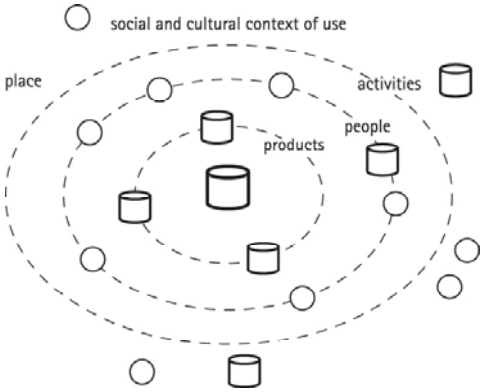

Figure 2. Schematic diagram of the home as an ecology, containing people, products, activities, and interactions within a bounded environment.

4. STUDY DESIGN

The findings reported in the paper are the result of two ethnographic studies conducted in parallel by the authors. The research took place over four months, and consisted of 14 semi-structured interviews and home tours with families, couples, and individuals aged 9 through 90. We recruited people in Pittsburgh and the surrounding metropolitan region through newspaper ads, online listservs, and word of mouth. We invited people to participate in a study about cleaning in general, to aovid any bias towards the Roomba or knowledge of robotic products in general.

4.1 Interview set one

In the first exploratory set of interviews, we conducted an introductory interview and home tour with each participant. During this time, we asked participants generally about their home and specifically about cleaning. We also asked them about their use of technological products in the home and expectations concerning robots generally and the use of the Roomba specifically. Each interview lasted approximately 1 to 1.5 hours. When possible, we interviewed all of the adult residents of the home. We then gave them a Roomba to use for a period of three to six weeks.

After three to six weeks, we interviewed the participants again. During the second interview, we asked the participants about the use of the Roomba. In particular, we were interested whether the Roomba had changed their housekeeping practices and if so, how. We were also interested in how their perceptions and expectations of the robot changed over time and with use.

In addition to giving the Roombas to "new owners," we also interviewed five current Roomba owners who had owned a Roomba for four months or more and used it at least on a bi-weekly basis. In these interviews, we asked the participants about their use of the Roomba over time. In particular, we were interested in how they came to own the Roomba, whether their use of the Roomba had changed over time, and how their habits of homemaking were different now that they owned a Roomba.

4.2 Interview set two

In the second set of interviews, we focused on the research question of how a product might change the ecology of the family. Specifically, we asserted that a new product would change the ecology of the family in several ways. To find out, we conducted introductory interviews and home tours with 3-4 family members in the context of their home. We asked about family life generally, and the activity of cleaning specifically. We asked them to show us products that were meaningful to them, along with the products they relied on to clean the home. Each interview lasted approximately 1 to 1.5 hours. In most cases, we interviewed all of the residents of the home. Interviews were augmented with visual diaries, where one member of the family logged photographs and descriptions of cleaning activities and cleaning products.

After two weeks, participants were given a Roomba Discovery vacuum. We asked them to document planned and unplanned cleaning activities, as well as their use (or lack thereof) of the new vacuum.

After four weeks, follow-up interviews were conducted by telephone. The goal was to understand the whether the new product had an influence on the ecology, from the perspective of

each member. Participants were asked to report whether they felt their new vacuum cleaned better, worse, or the same as the vacuum that the family owned.

The interviews were transcribed, and the interviews, field notes, and visual story diaries were coded and analyzed, using methods modeled after [35]. These methods involve identifying key themes in the data, for example, instances of people talking about planned vs. opportunistic cleaning. The NVIVO software program was used to code the entire set of field notes and transcriptions. To assess the validity of ethnographic data, one looks for how specific phenomena contribute to the factors under study. Strauss and Corbin suggest that a qualitative study should fit the substantive area without forcing; be comprehensible to readers and the people who were subjects, and be applicable to a variety of contexts related to the phenomena [35]. These criteria guided the development of concepts from coded constructs.

5. FINDINGS

Following an ecological approach, we have organized our findings into three domains: people and products: people's expectations of robots and of the Roomba; people and activities: how the Roomba changed the practice of housekeeping, and product and space: the fit of the Roomba to the environment. Each of these domains constitutes one aspect of the ecology of the home. Although not exhaustive of the ecology of the home, they present rich description of the use of a service robot in the domestic environment and the material and social complexities encountered when deploying robotics into the domestic environment.

5.1 People and Products: Expectations and evaluations of robots and the Roomba

Expectations of a technology are often quite powerful in shaping the initial experience with a technology. While people had high expectations of robots, they had low expectations of the practical functionality of the Roomba. Although participants acknowledged that the Roomba was a robot, they made a distinction between it and "other robots." This distinction seemed to be based on the fact that the Roomba was a consumer product — thus implicitly in contrast with other robots that were either fictional or tools in used in science (one given example was the Mars Rover).

For example, although ET, a woman in her early 30s, was not in a technology-related field, she described herself as having "some familiarity" with robots through her brother who had been a computer science major and from visiting a local university where robots are frequently demonstrated or on display. When asked about her expectations of the Roomba, she referenced her anecdotal knowledge about robots in general and projected it onto the functionality of the Roomba, assuming that the Roomba would perform less well than other robots.

"…I've seen how difficult even the simplest operation is when you're dealing with sensing and those kinds of mechanisms, so like it [the Roomba] *might do a kind of 'ok' job, but that it might miss certain parts of the room, or get confused or get stuck or something like that."*

The most common expectation of robots given by the participants in the study was that a robot would be "intelligent." Closely coupled to the expectations of intelligence was the ability to learn. Participants expected that a robot would gain knowledge of the environment over time, and adapt its behavior accordingly.

Interestingly, many of the expectations of intelligence and learning of the Roomba were not based on science fiction or visions of the future, but on the capabilities of existing products. For example when JH, a middle-aged architect, realized that the Roomba would not learn, he expressed disappointment. He went on to relay how "even cars now learned" "how you like to sit" and "how you drive" and "about the road" and then "adjust themselves." His expectation was that a consumer robot would be at least as advanced as other existing consumer technologies.

The fact that the Roomba does not learn its environment quickly became apparent to participants though understanding how it navigated and maneuvered through the space. The lack of intelligence limited the attributions of intelligence to the Roomba. For example, when TO was asked how smart the Roomba was, she responded;

"Not very, because it has no capacity to learn. I can't tell it, you know, that this is the kitchen and it remembers approximate dimensions and obstacles or anything and it'll ram itself into a wall a dozen times before it decides 'oh, there's a wall there'."

Similarly, after using the Roomba for a month, ET stated:

"I was kind of surprised at how dumb it seemed... it used a very simple system of bumping into things, rather than any kind of other visioning system that I could tell…."I made me think it was a little bit pathetic, because it would sorta near-miss all the time, you know, slam into things by a quarter to an eighth of an inch."

However, all of the participants were pleasantly surprised when actually using the Roomba. Although nearly universally the Roomba did not match the general expectations of "a robot," this seemed to have little effect on the actual use of the Roomba. Even those participants who expressed disappointment that the Roomba was not more intelligent, particularly that it did not seem to ever "figure its way around," did not report using the Roomba less because of this. Thirteen of the fourteen households were surprised by how well the Roomba actually worked.

5.2 People and Activities: How using the Roomba influenced the practice of housekeeping

The use of the Roomba affected how people cleaned — specifically, both males and females of a variety of ages used it. Additionally, it affected the activity of cleaning, by supporting opportunistic cleaning and multi-tasking as well as planned cleaning.

5.2.1 Cleaning is a concern for both men and women

Both males and females interacted with the Roomba, making cleaning a concern for everyone in the home, not just the female homemaker and caregiver. This is deviation from the historical role that technology has played in the home [5, 11]. In three of the families, males introduced the technology to the family. Two fathers and one son took the lead in taking the Roomba out of its box, charging it, setting it up, reading the manual, and sometimes learning how to use the barriers and the remote control:

WJ, female aged 57: "Well, my nephew got it out of the box. He is very interested in robotics. He got it out of the box, and he set it up, and then we used it, I think on the dining room floor. And I

was very skeptical as I said in my notes. But then when I went to wet mop the floor, which I usually do after I dry mop, I noticed that I was not getting nearly as much dirt on the sponge mop that I usually did, even after I have done the other cleaning first and so we just think it is terrific."

PL, male aged 44: "Oh my dad (age 81) opened it, read the instructions, and set it up, and my mom used it a great deal. At first, she was believing that it's going to get stuck under the chair, or it's going to get stuck somewhere, but it did not get stuck anywhere."

In both these cases, the skepticism of the females was mediated by the excitement of the males, and the functionality of the Roomba exceeded people's expectations.

Unlike other vacuums already used by the families, the Roomba also appealed to children and elders, beyond primary homemakers. Although some of this is due the novelty and autonomy of the product, it could also be due to the fact that robotic technology is accessible, and when well designed, easy to use. Many people talked about being able to vacuum "at the push of a button;" the 90-year old woman in the study laughingly described the Roomba as "the epitome of laziness," and children created messes on the carpet to see how well the Roomba would do. Two of the families realized that the Roomba provided an opportunity for children to learn directly about robotic technology, while engaging in cleaning activities:

PL: "N (age 9) was very interested in the Roomba. I had to keep him from driving it around the house. He was learning how to use the remote control."

WJ: "I would say that my sister and my nephew were maybe a little more inclined to clean the floors than they would have been before. So it doesn't end up being my job quite as much."

Others realized that the Roomba's autonomy and ease of use would make it accessible for elders and those who have problems with mobility:

PL: "But for my parents, who probably run it sitting down, it allowed them to get the floor cleaned without even getting out of the chair. So for them, you know, from elderly point of view, it definitely changed that part of cleaning."

WJ: "And for people like my mom who are elderly, it's one thing where they have to struggle to figure out how they are going to vacuum, instead they could just a press a button."

5.2.2 The Roomba changes how people clean and how often people clean

In all cases, using the Roomba vacuum changed the activity of floor cleaning. The autonomy of the Roomba allowed for multitasking, meaning that participants could do something else while the floor was being vacuumed. In addition, because cleaning using the Roomba could be done with minimal physical effort, both opportunistic and planned cleaning activities increased. Finally, participants found creative ways to use the Roomba, as is often found with previously unexperienced technology products.

The promise of technology in the home reducing labor is one that has been promised time and time over history [5,6,34]. During the course of our interviews the Roomba seemed to reduced labor, by allowing people to do something else while it cleaned:

PL: "There again, I had the convenience of being able to go for a walk and back here it is vacuuming."

WJ: "It's cutting my time in half in terms of cleaning the floors. And I can do something else when that's happening. So, it's really great."

In addition, the Roomba changed the kinds of cleaning activities. In the study, we defined two types of cleaning activities: planned cleaning, such as a weekly housecleaning, and opportunistic cleaning, which was filling a gap of unscheduled time with the most pressing cleaning tasks. Most families engaged in primarily opportunistic cleaning, engaging in cleaning activities when time in their weekly schedule permitted. Many set a deadline of the weekend, noting that as long as cleaning tasks got done by Friday, it did not matter precisely when they were done. A few others planned cleaning activities at specific times during the week. The Roomba proved to be helpful for both types of cleaning. It shortened planned cleaning time, because other activities on the list could be undertaken while vacuuming was taking place. It was also easy to simply run the Roomba to clean up a spill or an unanticipated mess. One family even noted that they could undertake more opportunistic cleaning, and keep the basic cleanliness of the house at a higher level:

WJ: "Well, there is really no reason for us not to just turn it on. It takes no effort. So we might just as well have it going you know like every other day or something, instead of using it just once a week."

The Roomba required that floors were relatively clutter-free, which caused some participants to undertake pre-cleaning activities. This effort seemed to be worth the benefit of having the work done automatically:

JS, female aged 47: "Yes, I think I find I have to put more stuff up. If I'm just vacuuming with a regular vacuum, I will sort of go under and around, and you know move stuff a little bit to to get around the furniture legs, but then I will put it back. Whereas if I using the Roomba, well I take everything up and put it on the bed."

Finally, people devised creative ways to use the Roomba, as is common in the experimentation period with new technology:

Mrs. S: "Another thing I like about the Roomba: if it is NOT dirt you vacuumed up, you can search it again… we lost E's earring back and it was easy to find… unlike a regular vac when you have to rip open the big bag full of nasty dust and dirt and dig through it."

"I 'pre-cleaned' by doing the baseboards and sweeping all the dirt away from the wall. I took the extra stuff off the floor and then the Roomba could do the cleaning unattended."

5.3 Products and Environments: The physical environment of the home influences how the Roomba is used

The physical environment of the home played a significant factor in the use and subsequent perceptions of the Roomba. Multi-level homes with stairs, area rugs with fringes, and curtains that touched the floor created obstacles for using the product. Consequently, participants had to decide if and when to intervene in the operation of the Roomba. This created an unusual dynamic between the product, the physical environment, and participant.

For example, one participant had a "sunken" living room, accessible only by descending two steps. She had placed the charging base for the Roomba in this room, so when she ran the Roomba, it could never leave the room without her picking it up

and carrying it to another room. She wasn't willing to go to this effort, so the Roomba only cleaned one small area of her home.

Although the physical structures of the home were constraints, they were also actively employed to make barriers and workarounds by participants. For instance, in the example of the "sunken" living room, although the participant would not pick the Roomba up to take it out of the room, she would sweep dirt from her hallway down the 2 steps in the living room so that the Roomba would sweep it up.

The impact of the physical space on the functioning of the Roomba often lead to the issue of intervention — of whether or not and to what extent the participant was willing to assist the Roomba in its work. Most commonly, this lead to either creating or removing obstacles.

The Roomba navigates a space based upon a predetermined pattern. However, this pattern is altered whenever the Roomba bumps into an obstacle and it changes its course. This introduces important variability in the Roomba's movement and helps to achieve greater coverage. But at times, certain obstacles would prevent a Roomba from getting to a space that needed cleaning. Because of a lack of space, SD, a single father, slept in the living room. Many of his clothes were piled in the space between the couch and his bed. In order for the Roomba to clean the area around and under his bed, SD had to pick up his clothes so the Roomba could access the space. Once the Roomba had finished in cleaning the area, SD would put his clothes back in their storage place. Surprising, and despite the fact that he had to repeat this task every time he ran the Roomba, SD did not mind this. Rather he characterized it as:

"…the way you work with the thing, I have to help it so it can do its job, its like we are partners. We were working together, you know, that's what I like, because I knew if I exposed an area it would probably get to it, and if I didn't, I probably wouldn't."

In addition to removing obstacles, some participants created obstacles. In most cases, this was to prevent the Roomba from accessing a space. The Roomba comes equipped with 2 virtual walls. These devices are placed on the floor and when turned on, emit an IR beam that if sensed, will not be crossed by the Roomba. However, only one of the participant families used these devices. Instead, most constructed obstacles with whatever was immediately at hand, such as boxes or chairs. In a few cases, participants created obstacles not so that the Roomba would not access a space but so that the Roomba would be confined to a space and thus, purportedly, clean it more thoroughly. For example, SD kept a bird as a pet. The area under the birdcage was constantly littered with bird seed. In order to constrain the Roomba to clean the area under the cage, SD used a chair and a couch to "fence in" the Roomba.

6. DISCUSSION

From the interviews and descriptions of experience of using the Roomba, it is clear that a robotic vacuum differs from a traditional vacuum in several ways. First, the point of entry for the product into the family is critical, and affects the social relations of the family. Second, unlike other cleaning products that are described merely in terms of functionality, the Roomba is described for its functionality, aesthetics, and symbolic merit.

In one family, the Roomba was introduced to one member of the family, rather than the entire family. In this case, this individual became the sole user of the Roomba, continuing and reinforcing her role as the primary housekeeper. She reported that although her husband was casually intrigued with the Roomba, he never operated it or even played with it because it was a device for cleaning the floors, which was not his task.

This example suggests that the way the Roomba was introduced to participants was a significant factor in any changes to their housekeeping practices. Although this is just one case, we believe that when the Roomba was introduced to multiple members of a family, a specific set of relations was established that enrolled the entire family in the use of the Roomba, leading to the refiguring of housekeeping practices. In contrast, when the Roomba was introduced to a single family member, the same experience did not unfold. A better understanding of the relationship between introducing the technology in a particular context, and shaping the experience and effect or consequences of using the product, is needed

Families who were introduced to the Roomba together created social relationships with the product, even making cleaning a social activity. Two of fourteen households named their Roomba vacuum, using a male gendered name. The S household named it after a butler character on television, and JS confessed to talking to it while it worked:

"We named the vacuum Manuel, as in the John Cleese show Faulty Towers, where Manuel is their butler who is always making blunders and doesn't speak English well. We named it because it has a personality, I mean well, it's doing the work of a person may be a part of it, and it seems to be sort of intelligent, has a little bit of intelligence in it."

Q: What kind of things do you say? *"'Hey, come on over here. You've already done that.' It's just fun, though, to see the path that it took. I watched in the beginning to see how thorough it was. It looked freshly vacuumed, which is good."*

The L family named it after a famous robot character. They had named previous vacuums in the family, using female gendered names such as Big Bertha the Hoover:

PL: "Well, my parents named it Robby right away, after the old Robby the Robot. N called it I-Robot."

Seven of the fourteen families created social relationships with the Roomba. Along with naming the product, they used it in groups of two to vacuum together, made attributions about how pets related to the vacuum, and used it as a platform to learn about robotics and science. MJ said "excuse me" to the vacuum if she bumped into it when walking through the house.

While the process of cleaning was often described in emotional terms, cleaning products were only described in terms of functionality or lack thereof. However, the Roomba inspired more robust descriptions, beyond product function. Researchers have theorized that exposure to unfamiliar products is an affective event that triggers a series of cognitive and emotional responses, linking the unfamiliar to the familiar [28]. Research on three disparate bodies of literature — human factors [14], industrial design [12], and marketing and semiotics [1] — have been combined to describe three dimensions of artifacts that figure in this process. These include functionality, aesthetics, and the

potential that a product has to act as a value-laden symbol for its owners.

The Roomba was described by individuals and families in not only functional, but aesthetic and symbolic terms. This is significantly different from the descriptions of other cleaning products, which are accepted for their functionality, or rejected or modified to compensate for a lack of functionality, without mention of aesthetics or symbolic value.

Nine of fourteen families made comments about desirable and undesirable aesthetic qualities of the Roomba vacuum. On the other hand, no one discussed the aesthetics of the Flair vacuum. JS disliked the way the Roomba bumped the furniture; WJ disliked the "clackety-clack" noise the Roomba made as it worked. NL and PL liked the feedback sounds, and brainstormed a list of sounds they would like to add to the Roomba.

Symbolically, two of three families identified with the Roomba. WJ and MJ liked having a "high-tech object" in the home. Although the S family felt the vacuum was not suitable for a family who lived in a historic house such as theirs, they also felt that because they had the latest computing technology, it was fitting that they were the first family to own a Roomba in their neighborhood. They showed it to neighbors and even loaned it to friends for a few days:

"We showed it to most of Ellie's friends. All her friends had come over, and they got a little introduction. So it's being up on technology, like it's okay. That goes on well with K, because he is always up on technology, so it's just another gadget."

It seems feasible that the aesthetic, symbolic and emotional responses to the Roomba were driven by social associations inspired by the product. Its novelty, autonomy, and ease of use triggered emotional responses, unlike other cleaning products mentioned by participants during the study.

7. IMPLICATIONS FOR DESIGN

This exploratory study was structured to examine initial and broad themes related to the use of robotic products in the domestic environment. However, we can offer the following implications for the design of robotic technology for the home.

7.1 How the technology is introduced is critical

First, critical attention must be paid to how robotic technologies are introduced into the home. That process, as much and in some cases more than the technology itself, will have impact on the established social norms and practices of the domestic environment [25]. Introduction of technology into the context of the home is a design challenge first, and a technical challenge second. Given the conjectured importance of how a technology is introduced — particularly who is enrolled in the use of the technology — certain imperatives in the development of domestic service robots need to be re-considered. Typically, the challenge in developing domestic service robots (or most any technology for that matter) is seen as a technical or design challenge, somehow separate from being a social endeavor of introducing and making use of the product. However, such a position inaccurately and inappropriately relies on a mythical "power of technology" to have impact.

7.2 The use of the technology becomes social

Second, it is feasible to conceive of robotic technology as one that turns mundane tasks into social activities. Our research showed that the technical language of robotics is not foreign to consumers, and that knowledge of these novel functions seemed to create social relationships with the product.

7.3 Homes and service robots must adapt to each other

Finally, the design, social context, and norms of the home need to be considered in tandem with the form and function of the robot. For example, just as wireless technology has changed the way a family accesses the Internet, using it along with other media in the home, robots and homes of the future might mutually adapt and support each other.

8. CONCLUSION

This paper presented qualitative, inductive research on the use of domestic service robots in the home. We used an ecological approach to broadly explore the use of this technology in this context, and to determine how an autonomous, mobile robot might "fit" into such a space. Our intention is to learn how interaction design and design research can have impact on the field of human-robot interaction. Although this is exploratory work, we can offer some intriguing initial findings on how the technology is introduced and assimilated into the family, how the use of such technology becomes social, and how homes of the future might adapt along with future products. Our future work will further test the ecological adaptation of robotic products in domestic environments.

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