Interaction Expands Function: Social Shaping of the Therapeutic Robot PARO in a Nursing Home

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ABSTRACT
We use the "social shaping of technology and society" framework to qualitatively analyze data collected through observation of human-robot interaction (HRI) between social actors in a nursing home (staff, residents, visitors) and the socially assistive robot PARO. The study took place over the course of three months, during which PARO was placed in a publicly accessibly space where participants could interact with it freely. Social shaping focuses attention on social factors that affect the use and interpretation of technology in particular contexts. We therefore aimed to understand how different social actors make sense of and use PARO in daily interaction. Our results show participant gender, social mediation, and individual sense making led to differential use and interpretation of the robot, which affected the success of human-robot interactions. We also found that exposure to others interacting with PARO affected the nursing staff's perceptions of robots and their potential usefulness in eldercare. This shows that social shaping theory provides a valuable perspective for understanding the implementation of robots in long-term HRI and can inform interaction design in this domain.

Categories and Subject Descriptors
H.1.2. User/Machine Systems; I.2.9. Robotics: Commercial robots and applications; K.4.2 Social Issues: Assistive technologies for persons with disabilities

General Terms
Human factors

Keywords
Socially assistive robot; human-robot interaction; qualitative study; social shaping of technology; older adults.

1. INTRODUCTION
In a video demonstrating the use of the socially assistive robot PARO in eldercare (http://www.parorobots.com/video.asp), the camera pans across a large open space furnished with a few long tables and some chairs on a linoleum floor. Nursing home residents, most of them in wheelchairs, sit sleeping or staring into space, rarely talking or making eye contact. The caption reads "before introduction." A few seconds later, the scene switches to one filled with activity – the residents are talking, smiling, and sitting close together in small groups. In their arms and laps, being passed from one person to the other and the focus of everyone's attention, is PARO – a robot shaped like a baby seal. The caption now reads "1 month later." Scenes from 6 and 10 months follow, with residents vigorously petting PARO, talking to it, and even kissing the robot. While nursing home staff occasionally pop into view, the camera focuses on the elderly and PARO in their midst.

PARO is designed for use in a mode similar to pet therapy, often with older adults, particularly those suffering from dementia or other cognitive disabilities. Long-term studies of interactions between residents and PARO in nursing homes around the world have shown that its use can lead to positive psychological and physical effects [1]. Existing research has largely focused on documenting PARO's therapeutic efficacy through physiological, psychological, and behavioral measures of individual users (e.g., [2], [3], [4]), without exploring the mechanisms through which such effects occur. The video clip described above suggests that the psychological and behavioral changes seen in older adults interacting with PARO is due largely to PARO's presence, without detailing how nursing home residents started interacting with the robot, or how they shifted from withdrawn individuals to a gregarious group. This produces a technologically determinist framing of the robot, which posits that social change is the direct result of technical intervention. Recent work on the development of guidelines for PARO's use in nursing homes [5], and the social analysis we present in this paper, suggest that there is much more to these successful interactions than just a well-designed robot.

This paper explores aspects of interactions with PARO that have not been addressed in prior research – the broader social context that scaffolds interactions between older adults and PARO in ways that can produce psychological, physical and social benefits. We describe a three-month-long observational study of PARO's public use in a local nursing home. We apply the framework of social shaping of technology to analyze collected data, in contrast to the technologically oriented perspective described above. This approach emphasizes exploring the social dimensions of technology design, adoption, and use, including identification of salient groups of stakeholders who are affected by and/or have an effect on robotic technology. In line with previous research on the social shaping of technology, our study particularly focused on identifying the key social factors and actors involved in the use of PARO in the nursing home, particularly attending to their roles in supporting interactions between older adults and PARO.

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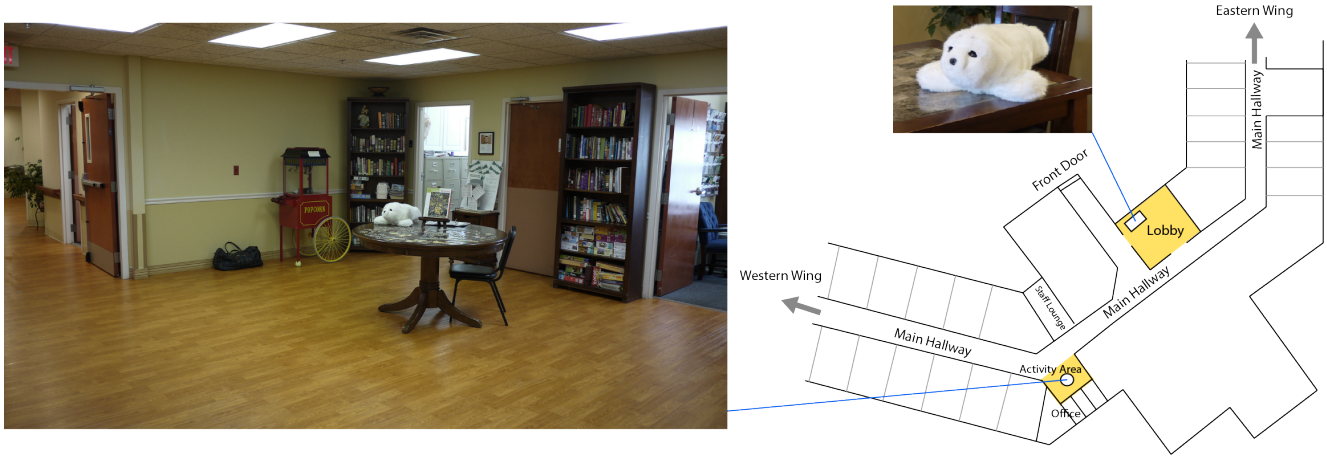

Figure 1. Building layout and the physical settings where PARO was observed (PARO is on the table).

Our research contributes to a growing area of study investigating how HRI unfolds within the social context of homes, hospitals, and other organizations (e.g. [6], [7]). Initial research has shown that studies of HRI "in the wild" can challenge design assumptions and identify social factors that affect how robots are adopted and used, but are not available in a laboratory environment (e.g., [7], [8]). After describing prior work related to our research, we detail our approach and the research context, and then present qualitative results from our observations. The latter include detailed description of repeated patterns of interaction as well as exemplary individual cases, and the results of pre- and post-interviews with staff. Although the study focuses on PARO, we expect our approach and insights to be relevant to interactive robots and other emerging technologies more generally, as they become increasingly available for everyday use.

2. RELATED WORK

2.1 PARO as a Companion Robot

PARO is a therapeutic social robot designed by Takanori Shibata at the National Institute of Advanced Industrial Science and Technology (AIST) in Tsukuba, Japan. The built-in tactile, balance, and light sensors and microphones under its soft hypoallergenic fur enable the robot to sense touch, sound, and changes in position (e.g. hugging). PARO can react to stimulation with physical movement (e.g., tail wagging) and vocalizations simulating a baby seal. It is often used as a social companion for children and older adults, especially seniors with dementia.

Most prior PARO studies were conducted in the context of use (e.g. nursing homes), with the main aim of measuring PARO's psychological, physical, and social effects on older adults, such as improved mood [3] or decreased stress levels following interactions with PARO [4]. Researchers have also collected and reported on examples of PARO's successful interactions with older adults (e.g., [1]), which have been used to develop guidelines on how to use PARO [5]. Those studies focused on interactions within a small group setting. Wada [9] also placed PARO in a public area in a senior living center and showed increased interaction among the residents; however, how interactions among residents or between residents and PARO developed and were maintained was not analyzed.

Our study builds on existing research on PARO's implementation in eldercare by using a qualitative approach and the social construction framework to perform an in-depth study of the development and maintenance of interactions between social actors and PARO in a nursing institution.

2.2 Social Shaping of Technology

A dominant narrative in technology design in general, and in robotics more specifically [10], posits a linear cause-and-affect relationship between technology and society according to which technological developments leads to social change (and often progress). The social shaping of technology framework counters the idea that the adoption, use, and consequences of technology can be understood in this way. It suggests an alternative analytical focus on how various actors interact with and make sense of technologies within the broader social context, which includes social norms, values, and relationships. In this framing, technologies do not fail and succeed based on their technical merits alone. They are socially and culturally constructed as successful or unsuccessful through the actions and interpretations of various groups of relevant stakeholders [11], users [12], and even invisible social actors [13]. In describing the success of a technology, it is important to ask whom the technology is working well for, and how it impacts users in differential ways.

Social actors make sense of technologies in relation to what they see as salient social concerns and values, which play a defining role in how they design, adopt, use and make sense of technologies [13]. This possibility for technology to be given different meanings in varying social contexts is called "interpretive flexibility" [11,13]. Shibata's description of PARO's design logic suggests interpretive flexibility is an important component of the robot's everyday functioning: "PARO has a limited number of functions as a machine. But, I designed PARO to evoke associations in the human's mind. Humans have a lot of experiences and memories, so when people interact with PARO they remember something, or associate with something… It is not necessary for PARO to have all the functions, the interaction can enlarge the number of functions."[1] Accordingly, we suggest that understanding the social mechanisms of successful (and unsuccessful) interactions with PARO is crucial to understanding its therapeutic effects and generalizing from them.

2.3 Social Shaping of HRI

Though they do not refer to social shaping specifically, numerous studies of HRI "in the wild" —in the course of interactions with

[1] Talk at the Japan Society, New York, NY, June 2007.

untrained users in real world environments— have shown social factors influence interactions with and evaluations of robots. Šabanović et al.'s [8] observational study of interactions between conference-goers and a social robot showed the social context can have a significant effect on people's behaviors. Alač et al. [14] displayed how robot sociality is relationally defined through the actions of various social actors in its environment, including children. Studies of domestic Roomba use showed that robots can be perceived as social and affect the cleaning behaviors of residents when situated in a socially rich and meaningful environment [6]. User gender was identified as a social factor that affected people' sense-making about a robot in a hospital [15].

Other researchers have used ethnographic observation to evaluate whether robots are successful in daily use, and to understand how people make sense of them in everyday circumstances. Mutlu and Forlizzi [7] identified several non-technical factors, including workflow and political and social relationships among actors, that had an effect on user evaluations of a delivery robot used in a hospital. Vertesi's [16] studies of the scientific team using the Mars Exploration Rovers identified both individually embodied sensemaking of the robot's functioning and the organization of the collaborative process as factors that contributed to the success of the mission. These ethnographic studies show how social behavior and meaning are constituted through dynamic interactions among social actors and technical affordances in contexts of use.

3. METHODOLOGY

In order to understand the social shaping process of human-robot interaction, we performed an observational study of PARO in the nursing home of a local retirement community in the United States over the course of three months. Our main aim was to understand how people voluntarily interact with and make sense of the robot, and when and how the robot is construed as engaging in this environment. In line with previous studies on the social shaping of technology, we particularly focused on the attitudes and behaviors of different groups of actors (i.e. staff, residents, visitors) towards PARO and others in the environment. In order to get the overall view of participants' interactions with PARO, we used both quantitative (on-site coding, interactor counts) and qualitative methodologies (observational field notes, pre- and post- interviews of the staffs, on-site interactor interviews).

3.1 Research Context

The nursing home in which we performed the study was a single floor building and served people needing long-term care (e.g., upper-/lower-limb disability, dementia) or short-term assistance and rehabilitation. Both authors have been doing research in this institution for a little over two years, and the first author spent three months prior to this study observing the daily activities in the field site. Based on this prior work and the results of a two-week-long pilot observational study of public spaces in the nursing home, we chose two areas as our field sites—the lobby and the activity area (Figure 1). They are both located in the central area of the building in proximity to the main entrance and hallways, so they have many passersby (See Figure 1). The lobby was furnished with a few sofas and had a fireplace for resting and chatting. The activity area had a TV and a puzzle on the table. After the first month of the field study, we found that the low walls surrounding the lobby occluded the view of passersby, making it difficult for them to see PARO. We then decided to put PARO only in the activity area for the remainder of the study.

We brought PARO to the nursing home two or three times a week, for one hour during each visit. We made a total of 35 visits in a continuous period of 13 weeks. PARO was placed at the center of a table in the chosen areas. People were free to interact with the robot as they liked without guidance from researchers.

Eight months prior to the study described here, ten residents with dementia and two therapists in the nursing home participated in a study using PARO for group sensory therapy for two months [17]. After that, the therapists kept PARO for their own use in individual visits or group activities. Some residents and staff had therefore seen or interacted with PARO before the study.

3.2 Participants

Three main groups of people participated in our field study: residents, staff, and visitors. There were on average 49 documented participants in the field site per session. Only 19% of them were residents, while staff and visitors comprised 55% and 26%, respectively. As we had done field observation and interviews before the study, we had no difficulty identifying the different types of participants by sight. Both long-term and short-tern residents had some physical disability and required the assistance of walkers or wheelchairs. The staff usually wore uniforms or nametags. We identified other participants as visitors.

The majority of the long-term residents had dementia. Those in the later stage of dementia had difficulties expressing themselves and responding to conversation and often fell asleep during the daytime. Many residents also suffered from hearing loss and decreasing eyesight caused by aging. Partly due to these factors, social interactions among the residents were not common. Staff included nurses, nurse assistants, housekeepers, social workers, general managers, and therapists. Visitors were usually family members of the residents and varied widely in age, from babies to seniors. The majority of residents and staff were female, but the numbers of female and male visitors were almost equal [18].

3.3 Data Collection

Data collection was performed by the first author, who took all field notes, and two research assistants who helped with on-site behavioral coding. We used onsite coding and interactor counts to measure interaction frequency for different behaviors (e.g. petting PARO, talking to other people) and the number of interactors and passersby. Observational field notes collected detailed interaction information, including behavior and utterances during the interactions; pre- and post- interviews and informal on-site interviews were performed to understand what participants thought of the robot. Analysis of quantitative data was reported in [18], and here we present the qualitative data and analysis.

3.3.1 Field Notes and Informal Interviews

We started observing the nursing environment and activities one month before we introduced the robot into the space in order to understand the day-to-day dynamics of the space. The first author also used this time in the field to build rapport with some of the research participants, which allowed her to get a more comprehensive idea of the institutional context and the different social actors in the environment. Throughout the field study, the first author kept field notes with thick description of observed interactions and the contexts in which they occurred, including how people interacted with PARO, the interactors' emotional expressions during the interaction, and verbal utterances about or to PARO. This information was used for providing details about the interaction across sessions, particularly in terms of how interactions occurred in groups and how they developed over time with specific interactors. Along with information collected through informal interviews with key informants during or after the observational sessions, rich contextual information, such as

the health or emotional status of the residents and institutional regulations of the staff, helped us interpret the intentions and attitudes behind the observed behaviors. After the observational sessions, the first author conducted brief and semi-structured interviews with participants who consistently interacted with PARO to learn more about their sense making about the robot and their response to observing others interacting with PARO. This additional information about the participants' views allowed us to understand the effects of situating PARO in a public context beyond just the immediate interaction.

3.3.2 Staff Interviews

We conducted interviews early on in and after the study with eight staff members who were picked either because their office was near the field sites or because they came to the field sites in the beginning of our study. The interviewees were three general affair staff, one social worker, one nurse, two occupational therapists, and two recreational therapists. Only the two recreational therapists had long-term experience with PARO, two other interviewees had heard about the robot prior to this study, and one interviewee had interacted briefly with PARO.

The interviews were semi-structured, and probed the staff's ideas about robotic technology and their perceptions of PARO. The goal was to find out whether the staff's perception of PARO would be affected by exposure to the robot being used in the public areas of the nursing home. In the pre-interview, we asked about their general impression of robots, their understanding and perception of PARO, their ideas about future robots, and how they want robots to work for and relate to them. In the post-interview, we asked again about their general perspectives on robots and PARO in particular, and talked about potential applications of PARO.

3.4 Data Analysis

We analyzed field notes collected during 35 sessions and the formal and informal interviews with staff, residents, and visitors to find salient patterns and themes in the interactions, particularly focusing on identifying social factors that affected the observed human-robot interaction. We used an anthropological approach for our qualitative data analysis (Figure 2) and focused on finding behavioral regularity in the documented interactions that could be expressed as patterns [19]. In order to discover the patterns, we coded our field notes and interviews in an open-ended manner [20] using a flexible and extendable coding schema.

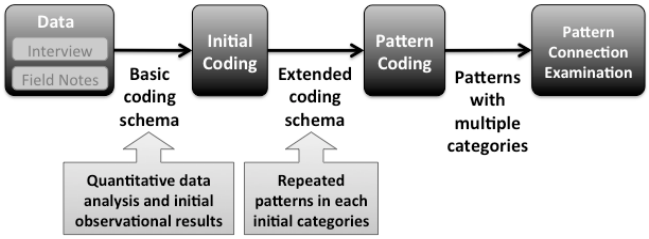

Figure 2. Data Analysis Process.

In the initial analysis, we developed a basic coding schema based on features that were easily identifiable in field observations (e.g., gender, group/individual interaction) and based on the analysis of quantitative data (e.g., interactor type). This gave us codes such as gender (female or male), interactor type (resident, staff, or visitor), group or individual interaction, direct or indirect interaction with PARO, long or brief interaction, ignoring PARO, and other people's intervention during PARO interaction. By reviewing the categorized and grouped field notes and interview transcriptions, we found some other recurring phenomena and developed an extended coding schema. This included mediation type (staff, family, or resident), interaction of a couple, individual interaction patterns of frequent interactors, changes in interaction and perception of PARO, and scientific and relational framing of talking about PARO. We applied these new codes to the data in the pattern coding stage, while continuing to identify new codes and using them to analyze the data until we were satisfied that we had described the main reoccurring patterns and their frequency. We finally reviewed interactions across patterns grouped in different categories to find any connections between them.

4. FINDINGS

The quantitative analysis of the behavioral data from the study showed that there were few cases of constant and repeated interaction with PARO for more than 10 minutes in a single session [18], and that a majority of people in the field site (59.15%) ignored the robot. Those who did interact with PARO preferred indirect interaction (e.g., observing PARO from a distance) to direct interaction (e.g., touching PARO). People who interacted with PARO directly were more likely to interact non-physically (e.g., looking, smiling, talking) than physically (e.g., petting, hugging). We used our field notes and qualitative data analysis to identify social factors related to these particular patterns of interaction, including those related to the social situation and to the participants' sense making about the robot. We identified four major social factors that affected interaction with PARO in the public space: participant gender, social mediation, individual sense making about PARO, and the influence of exposure to PARO on participant evaluations of PARO in particular and robots more generally.

4.1 Gender Differences in PARO Interaction

In our study, female participants outnumbered the males (M:F=1:3.9), with the discrepancy being particularly noticeable among staff and residents. Despite having more data for female participants, our analysis indicated gender-based differences in interaction with and sense making about PARO. The quantitative data showed that female participants had more direct interaction with PARO (e.g., petting or talking) and male participants usually interacted with PARO indirectly (e.g., eye contact) [18]. Out of 20 high interaction frequency cases, 19 were females.

The qualitative analysis also identified differences in the frequency in which participants of different genders used particular interaction types (coded as direct/indirect and relational/analytical) with PARO. Among participants who had direct interactions with PARO, females usually expressed their appreciation of the robot's appearance and movement in relational terms (e.g., "It's cute!" "Look at its wagging tail!"). Moreover, many female interactors (including residents, staffs, and visitors) talked to PARO as if it was alive (e.g., "Hi, how are you doing?" "You are so cute, dear."), which was not observed with any of the male participants. Of 79 females documented in our field notes who approached PARO for interaction, 63 of them interacted with PARO in this way. The male participants, in turn, displayed a type of interaction with PARO that rarely occurred among female participants. Six out of eight male participants who were documented as interacting with PARO approached the robot to analyze its technical functions. They treated PARO as a toy or tool instead of as a creature. This type of interaction is exemplified by the way in which a couple and their grandson approached PARO. While the wife petted PARO and kept

describing how cute it was to the child, the husband asked the researchers who designed the robot and where it was produced. Other male participants asked similar questions: "Is it a robot?" "Who designed it?" "Can it respond to sound?" Turkle calls this analytical framing an "engineer style" interaction [21].

Among participants who interacted with PARO repeatedly, male Resident B (R-B) predominantly showed the "engineer-style." R-B was staying in the nursing home for a few weeks to rehabilitate his legs. When R-B approached PARO for the first time, he observed it from different directions, picked it up and checked its bottom, touched it and saw how it responded, and asked the researcher questions about its functions. After he had learned enough about PARO, he stopped paying attention to it. He showed up a few times in later sessions and played with puzzles next to PARO without looking at it. When other people asked him about PARO, he said it is a robot brought by people from the university.

Our analysis also shows that in 13 of 23 cases when a couple passed through the hallway, it was the female that noticed PARO first and talked to the male about it, while the male showed little to no interest in interacting with it. In one case, a couple quickly passed by the lobby. The wife noticed PARO and excitedly pointed it out to her husband. The husband just commented he had seen it before and did not show much interest. In two other cases, the female partner was excited about PARO and brought their male companion back to the area to show the robot to them. On both occasions, the male stayed in the hallway and looked at their companion petting and talking to PARO from a distance without interacting directly with the robot.

These emergent patterns in our analysis show the process of approaching and interacting with PARO is differentially constructed by participants in accordance with their gender, possibly relating to their interpretations of stereotypical gender roles and behaviors. This finding suggests that, beyond thinking purely about the physical affordances of the robot, we should also consider the cultural and social affordances of these features and how they relate to gender, but also potentially race and class.

4.2 Mediation By Other Social Actors

From the PARO video mentioned in the introduction, we expected older adults with dementia to spontaneously and voluntarily start interacting with PARO. On the contrary, in the 35 visits we documented, only three residents got interested in PARO and started interacting with it without any intervention by others. In agreement with Wada's development of PARO use guidelines [5], we found that mediation by other human actors (including staff, visitors, and other residents) generally had a positive effect on the residents' propensity to interact with PARO. In both our pilot study and three-month observation, we identified that residents with dementia were often passive to environmental stimuli. In most cases, even when they noticed PARO, they were hesitant to interact with it without someone to guide them. When the staff and visitors, especially family members of the residents, approached residents who were near PARO and talked to them about the robot or showed them how to pet it, we usually saw the resident become more involved with PARO. The quantitative analysis showed that participants' interactions with PARO lasted longer when they had talked about the robot with others [18], and our observational data showed that many residents had more frequent interaction with PARO following introduction of the robot or mediated interaction by other participants. For example, Resident M (R-M), who was in the late stages of dementia and had severe hearing loss, was initially not interested in PARO. After the staff showed her how to interact with PARO by petting it and talked to her about the robot's gaze and movements, she started to pet and look at it. Her interest in PARO increased as she interacted with it more and more. In a later session, R-M's family saw PARO and encouraged her to interact with it. R-M started to talk to PARO and even discussed PARO with other residents. Although her hearing problem caused her conversations about PARO to be short, the other residents also started interacting with the robot after the conversation. Similarly, Resident D (R-D) took an occasional look at PARO but swiftly shifted her attention elsewhere. She would show her interest in the robot mainly while other people talked to her about it or there was someone to talk to and PARO could become a conversation starter topic.

In two observed cases of residents having both family and staff mediation while interacting with PARO, we noticed that mediation by family provoked stronger tendencies in residents to continue interacting with the robot. Resident F (R-F) had mild dementia and couldn't remember PARO over sessions. Her first interaction with PARO included an intervention by her daughter, who had seen PARO and thought R-F might like it. She took PARO to R-F and put it on her lap. R-F looked surprised at first, but was quickly engrossed in observing PARO's movements and discussing the robot with her daughter. The second time, a caregiver encouraged R-F to interact with PARO by petting its head and touching its whiskers. R-F only touched it once and seemed hesitant to interact with it further. The caregiver then gave up and turned her attention to a puzzle. While playing with puzzles, R-F looked at PARO and petted it occasionally and with increasing frequency. R-F showed interest in PARO in both sessions, but the family's mediation helped her overcome her uncertainty faster than mediation by the staff.

Another type of mediation we noticed on one occasion was a resident interacting with PARO treated as a model of appropriate interactions to new users. Resident E's (R-E) interaction with PARO led other residents to change their impressions of and start interacting with the robot. R-E enjoyed talking to PARO. She usually approached it and talked to it as if it was a real animal, although she had spoken to researchers about it being a robot. One day, a newcomer saw PARO for the first time and displayed a negative attitude when her family introduced it to her. R-E approached later and started talking to PARO. The new resident observed her interaction, and told her, "You are a nut!" R-E smiled and didn't respond. After R-E left, the newcomer looked at PARO for a while and stopped the staff in the hallway and talked to them about PARO. Then she approached PARO, and started petting it and saying, "Who are you?" "Where are you from?"

As the abovementioned examples show, the interactions we observed were affected by the social context, which included other actors encouraging and modeling appropriate behavior towards PARO and ascribing social agency to the robot. The relationships the residents built with the robot were dependent not only on the capabilities of the robot and the interactors themselves, but also on the behaviors of other people in the space. This finding echoes Alač et al's [14] description of robotic sociality as constructed in situated interactions with people.

4.3 Individual Sense-Making About PARO

Alongside the described general patterns of interactions, we found that some residents had more consistent or frequent interactions with PARO. Those residents were all female and long-term residents of the institution. They interacted with PARO numerous times during one visit or in multiple visits. As this type of

repeated, long-term interaction provides an opportunity for extended therapeutic effects of the robot, we analyzed successful individual interactions across visits to look for shared patterns. What we found were individualized patterns of interaction, with each resident developing their own way of understanding and using PARO. While one resident used PARO to reflect on personal life problems and emotions, another resident used PARO as a tool to initiate conversations with others, and a third interacted with it as an emotional companion. We describe these three examples below to illustrate how personal interpretations and needs can be interwoven with the practices of PARO's use.

R-E showed great interest in PARO since the first time she saw it; she approached the robot spontaneously and had a long talk with it. She interacted with PARO in exploratory as well as reflective ways. She asked PARO, instead of the staff and researchers, many questions to figure out what it is (e.g., "Who are you?" "Are you a cat or a dog?"), its behavior and history (e.g., "Are you looking at me?" "Are you sleepy?" "Did they mistreat you?"), and its emotions (e.g., "Are you mad at me?" "Are you sad?" "You want me to leave?"). Her conversations with PARO reflected some personal history and emotions. Because she was a newcomer at the nursing home, in her first talk to PARO, she portrayed a sense of abandonment "Did they go off and leave you here? My son left me here. I want to go home, but I can't. They don't want me to stay with them." "Do you feel lonely? I feel lonely, too." She also projected her feelings about herself in comparison to PARO, such as "You are so pretty. I don't want to touch you. My hands are old." The way R-E talked to PARO was like talking to a pet, but she preferred to talk to PARO even when there was a therapy dog in the vicinity. When we interviewed one of our key informants, a therapist, she mentioned R-E liked to talk to people and she was still in the progress of adapting to her new environment. In R-E's case, she interacted with PARO socially, but also released her frustrations implicitly to the robot. For her, PARO seemed to function not only as a companion but also as a confidant.

As a dog lover, Resident J (R-J) approached PARO similarly to how she treated the therapy dog in the nursing home. She called PARO "woofie," and petted its head. She also talked to the robot about what she was doing, such as "I'm waiting for supper." When she approached PARO, half of the time there were other residents around. Many residents suffered from hearing loss or dementia and most of the time R-J did not get a response to her talk and left. Her interactions with PARO were usually very short. Even though there was no response to her talk, R-J repeated the behaviors every time she greeted PARO. In one session, R-D responded to R-J's talk with PARO, and they had a long conversation ranging in topic from PARO to their backgrounds and ages. During that time, R-J still interacted with PARO by looking or petting it occasionally. In this session, her interaction was five times longer than any individual interaction she had with PARO. PARO, for R-J, was either a conversational partner or a way to initiate conversation with others. The latter point supports prior research describing PARO as a social mediator [17].

In our preliminary observations in the field sites, we found that R-D enjoyed social interaction with people. She sought out chances to have conversations with the staff, resident, or visitors, but it was not easy for her to find new people to chat with and maintain a conversation. R-D was first introduced to PARO in the previous group study with PARO, but usually forgot the robot by the next visit due the memory loss caused by dementia. R-D tended to show her interest in PARO when it presented a chance to have social interaction with other people. In one visit, R-D found PARO and petted it while observing the researchers' reaction to her interaction and having a conversation with the researcher about it. Once the researchers stopped talking to her, she quickly lost interests in PARO and paid attention to other things. In another visit, R-D started off by ignoring PARO and watching TV. When two staff approached PARO and her, and talked to her about how cute it was, she started petting the robot and happily conversed with the staff. Shortly after the staff left, she lost interest in PARO again. For R-D, PARO functioned as a tool to generate desired social interaction with other people.

In our study, R-M was the person who interacted with PARO the longest. She had advanced dementia and a serious hearing impairment. Unlike R-E, she interacted with PARO quietly by looking at and following PARO's movement by nodding her head. R-M struggled with sleepiness due to her dementia, but she consistently interacted with PARO and was fully engaged visually with it between periods of dozing. Staff and family recognized her attachment to PARO, and had her interact with PARO at any chance possible. However, toward the end of our study, R-M's interaction decreased over time. She got distracted by TV shows and did not fully concentrate on PARO. Even then she did not stop interacting with PARO, but maintained a more implicit connection. While watching TV or napping, R-M put her hand over PARO or looked at PARO occasionally for a short period. She still showed her affection by smiling any time she saw PARO. While she showed much excitement in the beginning, later on companionship with PARO merged into her daily routines. R-M's interaction shows the dynamic properties of interpretative flexibility and the social shaping process, as well as the ebb and flow of relationships that robot designers need to accommodate.

In the abovementioned examples, all participants treated PARO as a "relational artifact" [21], but they socialized with PARO in varied ways that fit their own needs. This was arguably made possibly by the interpretative flexibility of PARO's design, which enabled participants to "enlarge the number of functions" it performed for them.

4.4 Organizational Influence of PARO Use

Along with observing how different social actors behaved towards and made sense of PARO, we found that public exposure to PARO in the nursing home caused a ripple effect in terms of perceptions of PARO's use beyond the immediate interactors. The visible interactions residents had with PARO not only shaped the ways the staff treated residents by having them interact with the robot, but also enabled the staff to developed new ideas and practices of using PARO in their work.

R-E and R-M, as mentioned previously, were very actively involved in interaction with PARO. Their interactions with PARO not only caught the staff's attention but also encouraged discussion about the interactions among staff. In one session, as R-M followed PARO's head movement nodding her head, one nurse, one recreational therapist, one nurse assistant, and one general staff talked in a circle as they observed her interaction with PARO from a distance. They quietly made comments about how cute R-M's reaction to and affection toward PARO were. They also discussed PARO's positive effects on R-E. In later sessions, we observed a few different groups of staff and visitors positively commenting on R-E's and R-M's interactions with PARO. At the same time, we observed minor changes in the staff's daily routines. Normally, the staff would settle some of the residents in the activity area after recreational activities, moving incoming residents to any free space around the table. After

observing R-M's interaction with PARO, the staff would put R-E next to PARO, or in a spot where the robot was reachable. Some occupational therapists also started showing PARO to their patients as they did walking rehabilitation in the hallway.

Some staff we interviewed before and after the study showed changes in their general perceptions of robots after observing the residents' interactions with PARO. Two out of eight staff members described robots in functional and mechanical ways in the pre-interview. They considered robots as tools providing physical help to humans. Both of them were not familiar with PARO before the study, but passed by the field sites frequently during the study. When interviewed after the study, they mentioned gaining a new understanding of robots and what they could do beyond heavy duty lifting or cleaning. They discussed that robots, like PARO, could also be companions for children or elderly. Six months after completing the field study, in an interview with the therapist who continued to work with PARO after the study, we learned that the public exposure to PARO had changed some people's perception of the robot and many staff recognized other ways to use PARO in their work. She said some staff who initially thought PARO was a toy had more positive reactions to its therapeutic effects after observing the residents interacting with PARO. Moreover, some staff, such as the nurses, started borrowing PARO to comfort anxious dementia residents or as a social companion during individual sessions with residents.

These results show a long-term effect of exposure to PARO in the nursing home. The residents' interaction with PARO impacted the staff's daily routines and their conceptions of robots, which in turn supported further interactions between residents and PARO. This feedback loop was visible due to the long-term nature of our study, but is crucial for institutional adoption of robots.

5. DISCUSSION

The purpose of our study, in accordance with the social shaping of technology framework, was to shift the focus of human-robot interaction analysis from the robot-interactor dyad to a broader social context that involves multiple social actors, the social and physical environment, and dynamic interactions among them. The social shaping framework allowed us to identify essential social factors and actors that supported the successful interaction of elderly nursing home residents with PARO, and to see how the robot's interpretive flexibility allowed it to be incorporated in different kinds of interactions. Along with other human-robot interaction studies in a broader context [6, 7, 8], social shaping theory provides an alternative model for exploring the complexity of HRI in a dynamic everyday setting. This approach can be particularly useful in figuring out how robots can be integrated into social institutions, and in identifying social factors that future robot designs should take into consideration.

Our study identified different ways in which social factors shaped how participants interacted with PARO. Effects of participant gender, which emerged in our study in relation to different interaction styles participants displayed toward PARO, have been previously noted in research on assistive robots for eldercare [22]. Our study suggests that socially normative gender roles and related behaviors, such as nurturing or tinkering with technology, were reflected in people's perceptions of PARO and their interactions with it. We also found that the individual history and needs of participants, as well as their current social relationships, influenced how they interacted with PARO, as has been previously noted by Turkle [21]. Additionally, PARO's interpretive flexibility and underdetermined design, mentioned as part of its deliberate design logic in Section 2.2, left open the possibility for participants to develop diverse ways of using and interacting with the robot. Mutlu and Forlizzi's study of a service robot's use in a hospital [7] similarly showed users developing varying perceptions of the robot depending on the context of use and their role in the organization; however, the robot's design was not flexible enough to enable users to successfully adapt it to different situations. Our findings with PARO suggest that, particularly in cases where robots might be used by diverse users (such as the older adults, staff, and visitors in this study) and in differing contexts, leaving space for multiple interpretations as a design criterion can increase the spectrum of successful interactions. INTERACTION EXPANDS FUNCTION.

As in previous studies (e.g. [8]), we saw interactions in the real world often involved and affected groups of participants rather than being limited to one-on-one interactions between a person and a robot. Participants' interactions with PARO were affected by the behaviors and perspectives of other actors (similar to [14]), as well as social norms and expectations. We saw a positive feedback loop occur between mediation provided by staff and residents leading to successful interactions, the public visibility of successful interactions and increasing ease that residents showed toward the robot, and growing interest and commitment of residents and staff to using the robot. This further supports the need to take a more holistic perspective when trying to understand the factors that influence long-term interactions between participants and a new robotic technology, and its institutional adoption. Lee et al [23] similarly documented that observing successful and unsuccessful interactions with the Snackbot inspired participants to try new ways of interacting with the robot, and also created new social contacts among participants and non-participants. Limiting the scope of research to direct interaction with the robot can cause us to ignore such indirect effects and behaviors that shape interactions, which we also noticed in prior studies of PARO's use in group therapy activities [17]. We therefore suggest that designing robots for everyday use will need to address not just the characteristics of the robots themselves, but the human-robot interaction system or experience as a whole.

In contrast to a design focus on the attributes of individual robots (e.g., its appearance, functions), which is common in social robotics, our work suggests a need to shift to designing the interaction. This means constructing affordances and interaction possibilities that the robot can provide so that its functions can be added to and amended through interaction, and also identifying specific interaction patterns and modes of implementation of the robot that lead to successful user experiences. PARO's underspecified yet socially evocative cues (e.g. a familiar animal shape that suggests pet-like interaction without evoking specific expectations from the interaction) enabled diverse users to make sense of the robot and adopt it in their own way. In terms of the integration of novel technologies such as robots into eldercare contexts, our research further suggests that providing appropriate mediation (someone to introduce the robot, or model its appropriate use) is a necessary component for ensuring successful interaction for more people. We suggest designing robots with the assumption that they will need to be supported by humans to some degree, rather than that they will be autonomous, and in the process making sure that the level and kind of support the robot needs is acceptable to and can be performed by potential users.

Focusing on the ways in which different social actors affect the robot's interpretation and use also has ethical consequences for design and research in assistive robotics. Staff and older adults are

often studied as users of technology, rather than active creators of its effects. We show they do important work to scaffold and construct the robot's sociality and its therapeutic function. This perspective focuses attention on people's agency, rather than just on the consequences of robotic technology, and suggests we need to pay more explicit attention to the involvement of users in implementing robots and the work they do to scaffold and construct human-robot interaction.

Our study is limited by its focus on one robot, the nursing home as a specific context of use, and the specific nature of the participants (older adults with dementia, busy nursing staff). The specific social factors we identified may not hold for a different robot or environment. Our study, however, contributes a theoretical framework and qualitative method for identifying and analyzing the social aspects of technology use and implementation that can inform the design and implementation of other assistive robots.

6. CONCLUSION

Adding to previous HRI research on interactions between people and robots situated in real-world settings, this work provides a new theoretical perspective that extends beyond dyadic human-robot interaction and can guide the study of the social factors that support the successful use of robotic technologies. The results suggested four key social factors—gender, mediation by staff and family, individual interpretations of PARO, and the feedback effects of observing interactions between residents and PARO that inspired other social actors to support the robot's adoption—which fostered the social shaping process of PARO's implementation in the nursing home. Our results and application of social shaping to HRI suggest that the analytical unit of HRI research should be expanded to include other social actors in the environment that scaffold interaction with and adoption of robots.

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