Steps Toward Participatory Design of Social Robots: Mutual Learning with Older Adults with Depression

Hee Rin Lee[1], Selma Šabanović[1], Wan-Ling Chang[1], Shinichi Nagata[2], Jen Piatt[2], Casey Bennett[3], David Hakken[1]

[1]School of Informatics and Computing
Indiana University
901 E. 10th Street
Bloomington IN 47408
{hrl,selmas,wanlchan,dhakken}
@indiana.edu

[2]School of Public Health
Indiana University
1025 E. 7th Street
Bloomington, IN 47405
{snagata,jenpiatt}
@indiana.edu

[3]Faros Healthcare
44 Vantage Way, Suite 400
Nashville, TN 37228
casey.bennett@faroshealth.com

ABSTRACT
This paper presents the results of research aimed at developing a methodology for the participatory design of social robots, which are meant to be incorporated into various social contexts (e.g. home, work) and establish social relations with people. In contrast to the dominant technologically driven robot development process, we aim to develop a socially robust and responsible approach to robot design using Participatory Design (PD) methods. The PD process builds on participants' self-identified issues and concerns, and develops robot concepts according to participants' interpretations of the capabilities and potential applications of robotic technologies. We present methodological insights from an ongoing PD project aimed at designing socially assistive robots with older adults diagnosed with depression and their therapists, and identify remaining challenges in this project. We particularly focus on supporting mutual learning between researchers and participants and on promoting active participation of older adults as "designers" (rather than consumers) as foundational aspects of PD. We conclude with reflections regarding how this work can contribute to the further development of social robots and relevant PD methodologies.

Keywords
Participatory design; social robots; socially assistive robotics; older adults; depression; mental health; methodology.

1. INTRODUCTION
A growing trend in robotics is the development of robots that can function well in everyday spaces such as private homes (e.g., [1]), schools (e.g., [2]), nursing homes (e.g. [3]), hospitals (e.g., [4]), and malls (e.g., [5]). Governments and researchers in developed countries around the world, including the United States, Japan, South Korea, and the European Union, actively support the integration of such "social" robots into society [6-10]. The entry of robots into intimate places and roles, including caregiving, education, and companionship, raises concerns about the psychological well-being and development of users [11], human rights (e.g. dignity and self-determination [12,13]), and privacy [14]. The responsibility for making decisions about appropriate robot applications has so far been largely in the hands of robot designers; however, the societal significance and breadth of these concerns suggests a more inclusive, participatory process is necessary. How best to incorporate a rich understanding of the social into robot design, including an understanding of the social construction of values, meanings, and social interactions in robotics itself, and how by doing so to create more socially robust [15] and responsible social robots, remain open questions.

We see the fundamental problem facing the development of social robots as a social one: designing social environments (rather than standalone robots) with properties that foster positive human-robot interaction. The way humans design effective social environments is in itself social, so the task facing social robot development is the discovery of a social process for creating organizational environments in which humans and robots can interact regularly and, in effect, "naturally." The properties of such social environments will vary according to particular contexts, so the design challenge is to develop procedures for creating diverse and multiple appropriate social environments. We suggest prior work in Participatory Design (PD) has constructed principles and procedures for the development of information technologies and the social environments needed for their successful use in organizational settings. Our current aim is to adapt PD methodology to deliberation about and design of domestic social robots to support mental healthcare.

In this paper, we describe our experiences building up a PD methodology for developing socially robust social robots. As a case study, we explored PD methods with older adults diagnosed with depression. We decided to focus on eldercare applications because they are a major area of development for social robotics, and on depression because it is the second leading cause of disability among older adults in the US [16]. Rather than focusing on the specifics of this population, however, our aim is to provide a discussion of our process and relevant insights that can be informative for social robot design more generally. In particular, we describe how researchers and participants can be supported in an iterative practice of *mutual learning*, instead of interacting as experts and informants. The PD process showed immediate benefits for our participants, who belonged to a group of users with few prior chances to actively articulate their ideas and concerns about how robots could productively fit into their lives and whose voices were generally not seen as authoritative. In the long run, we also expect it to be useful for producing socially robust and responsible robot designs that are representative of user values and therefore more acceptable to them [17].

HRI'17, March 6–9, 2017, Vienna, Austria.

DOI: http://dx.doi.org/10.1145/2909824.3020237

2. BACKGROUND

2.1 Current Social Practices of Robot Design

As robots enter into everyday contexts, their design requirements are increasingly based not only on functional concerns, but also on subjective evaluations by users and on their fit with and effects on different contexts of use. To facilitate robot acceptance, designers and researchers have been developing social capabilities to enable humans to interact with them intuitively and naturally [18,19]. The design of robot sociality has largely been based on the idea that robots should resemble humans or other social species (e.g. animals) to trigger people to respond to them socially. With this in mind, HRI researchers have explored the anthropomorphic appearance of robots [19-21], humanlike behavior (or movement) of robots (e.g. gaze [22]), and social roles for robots (e.g. butler, maid) [23]. Kahn et al. suggested more complex design patterns for sociality [24], mimicking human modes of social interaction, such as personal introductions for a robot, or giving robots personal interests and a history to share with participants.

The efficacy of these social cues in human-robot interaction is commonly established through evaluations in laboratory experiments, or through ethnographic or user-centered studies of robots in everyday use contexts. While the former method provides generalizable but decontextualized design guidelines relating to specific design factors, the results of the second is more socially situated but difficult to apply directly to robot design. The user-centered approach retains the researcher's control of the research process. All three methods therefore fall short of actively involving users in producing the social structures necessary to enable socially robust robot use in everyday contexts, suggesting the need for alternative design methodologies for social robots.

2.1.1 Lab Experiments as a Social Context for HRI

One of the most popular methods for finding ways to engender social effects in HRI is through psychological lab experiments [24-26]. In this method, researchers design and control the social environment in which participants and robots meet: they define hypotheses to be tested, invite participants into a controlled lab context, and ask them to follow instructions to measure the effects of select social factors on HRI. This process allows researchers to isolate and statistically evaluate specific factors to find design features that contribute to robots' generalizable sociality and can be smoothly deployed as design requirements. However, lab studies have a limited ability to reflect the social context and human labor that contributes to robots' sociality in everyday use. As social critiques of robotics have mentioned, robot sociality is constructed through socially situated interactions with humans, whose actions are mutually shaped through their interactions with robots and with their broader social environment [27,28]. Robot sociality outside the lab is therefore likely to be enacted differently depending on the social situations of users. Participants in lab experiments have restricted roles and capabilities of structuring the social context, as the ideas they can express and actions they can perform are constrained by the study design. Both the limited roles of participants and the confines of the experimental environment present quite a different social context from that in which robots are eventually meant to operate.

2.1.2 Ethnographic Studies for HRI in the Wild

Ethnography has been another method used to explore robot sociality [1,4,28]. Ethnographic studies are conducted "in the wild" and focus on understanding situated uses and emergent meanings of robots in different social contexts. While lab experiments focus on certain features determined by researchers' hypotheses, ethnographic methods seek to provide a more holistic understanding of people's interactions with robots that emerge from the context under study. However, the results of ethnographic studies are often complex and locally specific, and therefore difficult to reflect back to robot design. Also, the role of participants in ethnographic studies is still constrained to providing information for researchers, rather than participating as active collaborators in setting the agenda for and making sense of the robot design process. Finally, while ethnographic studies depict the relationships and interactions between different actors and contextual factors in local cases, they do not provide a method for developing successful social relationships and uses for robots in other contexts.

2.1.3 User Centered Design

HRI researchers have also employed user centered design methods to find appropriate modes of and uses for social robots. User-centered design researchers often conduct user studies, including survey, interviews, or focus groups, to understand the needs of prospective users within specific contexts [29-31] and develop robots based on their findings. For example, in [31], researchers explored the design of a social robot delivering snacks in a workplace by conducting multiple interviews and a survey to understand workers' idea about snacking. The researchers then iteratively applied the resulting contextual understanding to the robot design. However, the researchers determined the main research directions (e.g. workers need a social robot delivering snacks) based on their assumptions. Workers had a chance to express their thoughts about snacks, but not opportunities to bring up other issues that were important to them. Participants acted as informants to the research team, rather than as collaborators actively joining in the agenda-setting and decision making process of design. Similarly to user-centered design, PD focuses on the opinions of users to identify appropriate designs and uses for social robots. However, PD also addresses the social position of participants within the research process by developing ways to empower them to make decisions and act upon their surroundings and issues they find salient.

Previous work on designing and evaluating robots has rarely allowed for the development of robots in tandem with the social structures of their use. In this paper, we propose Participatory Design (PD) as a method that can structure the relationship between the participants and researchers so that the design process produces not only specific design factors for robots, but also empowers participants, develops socially appropriate meanings for robots, and constructs sustainable social structures for using them. Rather than evaluating existing robots or contexts of use, this method aims to build the sociality of robots and the social practices of their implementation together with participants who have rich experiences and knowledge of the relevant contexts of use, as well as the needs for and potential situated meanings of robots. We suggest PD methods can facilitate the development of more nuanced and contextually meaningful robot applications that include the interpretations of users as contextual experts and the appropriate social infrastructures for the implementation of robots in daily life. In the following section, we explain how PD has been used within HRI to make robots substantively social.

2.2 Making Robots Substantively Social Through User Participation

PD posits an active role for users as direct contributors to the robot design process, who can provide contextual expertise and social know-how. This contrasts with the passive roles robotics researchers currently envision for users, as naïve lay people who evaluate robot designs based on a simplistic understanding of robots and who will hopefully develop into "sensible users" making informed decisions about robot capabilities they prefer to consume [32]. In this section, we discuss how HRI researchers have employed PD in HRI so far [33-35], particularly focusing on the roles and power relationships between participants and researchers. We show how PD creates opportunities for robotics researchers and other stakeholders to collaboratively "identify opportunities to influence technological change and its social consequences at an early stage—moments at which accountability and control could be exercised" [36,37]. With this in mind, we trace changing *participant roles* in design, from amending existing platforms, to developing robot concepts, and participating in mutual learning with researchers.

2.2.1 Participants amend existing robot platforms

Several studies have involved participants in the design of contextually appropriate behaviors for existing robotics platforms. Azenkot et al. conducted a PD study to investigate how assistive robots can guide blind people in an indoor environment [35]. Researchers employed the existing PR2 platform and participants, including both designers and non-designers with visual impairments, suggested how the robot should behave to help them navigate indoors. The Robots for Humanity project was initiated by a user with a mobility impairment and involved his wife and a robotics design team in a PD project to develop an assistive mobile manipulator using the same PR2 platform [38]. These studies employed currently available, technically highly developed robots as a given, and tried to make them more social by allowing participants to define contextually useful behaviors.

2.2.2 Participants conceptualize new robots

Caleb-Solly et al. used embodiment and scenario-focused workshops to explore older adults' ideal domestic robots without bringing in specific robot platforms [39]. In previous work, we conducted participatory studies inspired by collaborative ethnography [40] and PD [41] to develop concepts for domestic robots with participants in S. Korea based on the householders' own identification and understanding of issues they found most significant and their interpretations of home technology. We first asked householders to draw the main social actors in their home, and to describe the labor division among them. With this in mind, they then drew and described ideal domestic robots that might support their needs in the home within these social dynamics.

2.2.3 Participants and researchers as mutual learners

Green et al. [42] describe the development of CERO — a fetch and carry robot to assist physically disabled workers in the office – through a long term collaboration between two organizations, the Swedish National Labor Market Board (AMS) and the Center for Autonomous System (CAS). The researchers conducted task analysis, focus groups, and experiments with office workers. Frennert et al. [33] used a participatory approach to robot design by holding workshops with older adults to explore whether they would consider having robots in their homes, and later asking older adults to evaluate assistive robot mock-ups at home to explore the potential uses and appearance of assistive robots. This study allowed for mutual learning between researchers and participants: participants learned about technical options from researchers, and researchers learned about contextual issues from participants. The process positioned researchers and participants on more equal footing so both could address their concerns actively with each other, which is an important criterion for PD.

2.3 Empowering Users Through Mutual Learning in Participatory Design

Ever since its inception in 1960s [36,43], PD has emphasized power dynamics and social hierarchies between researchers (designers) and users as central issues in technology design. In PD, designers share decision-making with users while designing products, and users shift their roles from being informants in the traditional design process to acting as authoritative participants in co-design. Users in PD not only provide information but also learn design and technology know-how from designers, and apply it to the development of new technology concepts. Designers also learn about the values and meanings related to technology and accompanying social interactions. This process of "mutual learning" is a way for PD to address the power imbalance between researchers and users common to scientific and design research, and to empower diverse users with active knowledge about technology and allow them to take part in the conceptualization of robotic sociality. Also, mutual learning aims to cultivate critical discussions between users and researchers of the potential social applications, meanings, and consequences of robots. PD's focus on power issues differentiates PD from user-centered design studies in HRI [29-31]. Considering the importance of tackling power issues in design to PD, our project explores the mutual learning practices among our research team, older adults, and therapists while designing Socially Assistive Robots (SARs).

Users' active roles in PD also closely related to constructing ways to make robots substantively social. In our study, making robots social means finding a way to socialize them in the sociologist's sense, that is to allow for them to be socially constructed by diverse groups of people through interaction and to affect other actors and their social contexts in the process. We insist that the socially responsible design of robots requires that this socialization be explicit, open, and reflexive as to the values and priorities being inscribed into emerging robotic technologies. In trying to work out a set of PD principles on which these could be structured, we are working with a specific population, a group of older adults living in Indiana, diagnosed with depression, having additional co-occurring physical problems, and receiving social service benefits from a not-for-profit agency. As is generally the case with PD, our aim for this work is not to identify appropriate robot characteristics or ideas to stimulate designers, but rather to co-create with participants a process for integrating the social into the design of SARs in the home context.

3. A CASE STUDY OF SOCIAL ROBOT PD

Since 2014, we have been involved in a PD project with five older adults and ten clinical and caregiving staff who serve this population, recruited with the help of a local healthcare provider. The research team consists of one participatory design researcher, a health technology developer, three human-robot interaction (HRI) researchers, and two recreational therapy scholars. The project focused particularly on how Socially Assistive Robots (SARs) [44] might be used by older adults experiencing chronic depression and co-occurring physical illness while living independently in their homes. We decided to explore how to use PD in this domain because it corresponds to the robotics community's push to make robots more social and widely available, and with the turn to community-centered healthcare. We particularly chose older adults with low-income and limited education as co-designers since their knowledge has been marginalized within the assistive robot design process [17] Also, 15-20% of older adults in the US suffer from depression [45], making it a leading cause of disability.

To facilitate mutual learning as a key research aim, we iteratively developed five PD sessions (see Table 1), recognizing that merely bringing older adults together with researchers does not result in co-design, but that co-design requires methods that provide opportunities for both parties to familiarize themselves with each other's knowledge and build a relationship of trust. The PD process started with a series of semi-structured interviews carried out with five older adults in their homes, and with five non-medical, mental health therapists in their offices. Following the interviews, we held four PD workshops with our older adults and a final workshop with a second group of mental health therapists to discuss their perceptions of socially assistive robots, and how they might be used in patients' daily lives at home. Mutual learning occurred throughout the five sessions as 1) older adults were gradually exposed to existing robots and robotic sensors, and 2) researchers learned about the challenges older adults faced in addressing aging and depression. By exchanging ideas and experiences, researchers and older adults built up trust over time, making older adults feel more secure in expressing and developing their ideas with researchers, and researchers more understanding of and open to suggestions by the participants. We included clinical staff as participants to get a more multifaceted understanding of older adults' issues and the healthcare context.

All interviews and workshops were recorded and transcribed, and members of the research team coded the transcripts to identify common themes (See [34] for details on the analytical approach). The number of participants fluctuated during our study. This was due to their changing health conditions (depressive episodes, physical health issues). All participants wanted to continue the study when they were mentally and physically able.

3.1 Interviews with staff and older adults

At the beginning of the study, two members of the team, one an HRI researcher and the other a trained therapist in community mental health, visited the older adult participants in their homes to perform initial interviews. Carrying out interviews in participants' homes, researchers learned about participants' home contexts including housing arrangements (size, condition, availability of pets etc.). The contextual information provided common ground to researchers and participants when designing robots for older adults' homes in the subsequent sessions. It also helped older adults start developing a mutual trust and respect with the researchers in a space that was familiar and comfortable for them.

The interviews covered topics related to participants' everyday pursuits and activity levels, their social circle, and the realities and challenges of aging and living with depression. When interviewed, the older adults described their health problems and the courses of therapy that they would like to see, and documented their interest in participating in a project related to SARs. The patients had ideas for maintaining their psychological wellness, but they still struggled with negative emotional moments. One of the main daily life challenges they pointed out was loneliness, closely related to their physical health problems and financial issues. They all mentioned that social interaction with friends, family members, and pets made them feel better, and social isolation increased feelings of depression. Two of the five older adults had pets, but mentioned \caring for them was challenging (in later workshops, both pet owners said they had lost their pets). All five participants had been employed in the past, but only one was still working during the study. All of them used computers, but only one regularly and with enjoyment for emailing, online reading, and shopping.

Table 1 Overview of the PD process in our study, showing the mutual learning achieved by the research team and participants (Tinted rows show sessions with older adults, while the untinted rows show sessions with therapists).

Steps	Methods	Mutual learning process	
		Researchers	Participants
Step 1.a. Initial interviews with older adults	Home visit and tour	Learned about domestic environments and experiences of older adults	(participants: older adults) Met researchers, introduced to project
Step 1.b Initial interviews with therapists	Interview & presentation of existing robots	Learned how therapists interpret existing robots & see them as applying to their work	(participants: therapists) Introduced to project and capabilities of existing robots
Step 2 Workshop 1: Introducing socially Assistive Robots	Focus group: present existing robots and critique	Learned how older adults interpret existing robots, what they like & dislike about them	(participants: older adults) Learned capabilities and applications of existing robots for daily life
Step 3 Workshop 2: Designing a robot together	Focus group: discuss & visualize ideas of older adults	Learned older adults' everyday challenges, how they think robots might be used to address them	(participants: older adults) Learned how their issues could be developed into robot design possibilities
Step 4 Workshop 3: Design a robot for your everyday life	Focus group: Develop holistic robot design with older adults	Learned ways how assistive robots can be situated in older adults' domestic environments, develop full robot ideas	(participants: older adults) Learned how their ideas could be developed into robots for their homes
Step 5 Workshop 4: Robotic technology and design with robotic parts	Focus group: present robotic parts (e.g. sensors)	Learned how older adults would use different sensors in robots, also ethical concerns about data collection and use	(participants: older adults) Learned what types of robotic parts are available, discussed what kinds of uses they might have in the home to support health
Step 6 Workshop 5: Staff's perspectives of robots in patients' homes	Focus group: Present older adults' robot designs	Learned how therapists interpret older adults' design ideas, what they see as useful and problematic	(participants: therapists) Learned how older adults envision their ideal assistive robots collaboratively imagined with researchers

The therapist interviews were performed by a team member employed as a researcher in the same healthcare organization. In the interviews, the researchers learned additional information about the regular work patterns of therapists and their perspectives on the daily lives and challenges of their older adult clients. All five therapists showed interest in integrating more digital technologies, including robots, into their practice. After viewing videos of three different assistive robots (Care-O-Bot[46], GiraffPlus [47], and Paro[44], see Figure 1), therapists commented on the usability and appropriateness of such robots for their population. These robots were chosen as examples of different forms (mechanical, animal-like) and uses (domestic assistance, telepresence health, and companionship) of SARs. The therapists worried about the complexity of robots as their clients were not technically savvy and overwhelming them would not benefit their therapy. They also saw possibilities for robots to enable their clients to live on their own, particularly alleviating loneliness and providing companionship. The therapists suggested a holistic way of treating clients. They mentioned that their psychological problems cannot be separated from other factors in daily life. For example, most clients had physical health problems (e.g., diabetes, obesity) along with their mental disabilities. The client's' life issues (e.g., money management, transportation, sociality) should be treated along with their health issues to promote overall wellness and quality of life.

Following the interviews, we performed four workshops to provide older adults with information about SARs, learn how they perceived different robots, and collaboratively develop concepts and scenarios about appropriate SARs' use in older adults' homes. Through the workshops, we tried different ways to develop our understanding of older adults' needs and preferences regarding robots, and to increase their engagement as robot designers.

3.2 Workshop 1: Introducing Socially Assistive Robots

The first PD workshop included four older adult participants and three HRI researchers; an additional member of the research team helped with video recording. The researchers learned about how older adults interpret and critique existing robots from older adults' perspectives, while older adult participants learned about currently available robot technologies for people like them.

In the first hour, the participants viewed and discussed videos of four different robot systems (the three seen by therapists – Care-O-Bot, GiraffPlus, and Paro – and a fourth communication robot called Papero that could be used in the home). After showing participants each robot on video, we asked them about their initial impressions of the robot, whether and how they might use the robot in their homes, and what they would want to change about the robot. The second hour was devoted to hands-on demonstrations of four robots (Paro, Keepon, Roomba, and the programmable social robot Mugbot, See Figure 1). Participants again discussed their impressions of the robots, how useful they might be to them, and any possible changes.

In contrast to expectations that older adults might be wary of robots as advanced technologies, the participants had no hesitation about discussing robots or considering how they might fit into their homes. They described several ways in which SARs could be useful to them, commenting they would be likely to buy some of the devices we showed. Their actions and comments indicated that, of the devices described in the videos and demonstrated live, Paro was most preferred because it was easy to maintain, and could alleviate negative feelings and loneliness. Three participants wanted to take it home with them immediately. The older adults also evaluated the GiraffPlus positively, particularly commending its ability to connect them remotely with friends, family, and caregivers. In contrast, the most machine-like of the robots portrayed in the video (Care-O-Bot), and the demonstrated robot that needed active programming (MugBot), were quickly dismissed by the participants as too technical and not easy to use.

In addition to comments participants made about the robots, the discussion of robot functions reflected their everyday needs. The participants gave more details of their concerns and emphasized some topics previously mentioned in interviews. They mentioned the importance of companionship and usability in their discussions of the presented robots. In line with the therapists' interview results, participants saw ease-of-use as one of most important robot features. In this workshop, we saw that the participants attempted to connect robot "functions" to their needs and life experiences, as if they were purchasing robot functions.

Figure 1. Older adults saw videos of Giraff Plus, Care-O-Bot, Papero (left to right, upper row), and Paro (left, lower row) and interacted with another Paro, Roomba, MugBot and Keepon during the first workshop (left to right, lower row).

3.3 Workshop 2: Designing a robot together

The second PD workshop brought three of the original four older adult participants together with four researchers to develop their own designs for a social robot that could assist people like them. In this session, researchers learned about older adults' everyday issues and how the issues could be related to robotic technologies, while older adults practiced ways of translating their current life challenges into robot design possibilities. In this workshop, researchers rapidly drew sketches of participants' design ideas as a common reference point, which the group further critiqued.

We started off by asking participants to name some of the challenges they faced the last time they had felt sad or lonely. They first mentioned physical problems, like cleaning up and lifting things. Participants later brought up social challenges: distance from loved ones, lack of social activities and opportunities to volunteer in the community, and a general lack of companionship in day-to-day life. After identifying these common problems of daily living, all three participants described the appearance and functions of robots they would like to have, as the two HRI researchers visualized their descriptions through quick sketches (See Figure 2). We chose this method to lower the barrier to participation, while giving participants control over the design content and a shared representation of their ideas to further critique and develop the design as a group. The resulting designs focused on robots that could provide companionship—greet the participants in the morning, discuss the news with them, accompany them on walks—and had a humanlike presence and appearance. Participants pointed out various health-related functions robots could perform, including providing reminders and suggesting healthy things to eat, wear, and do during the day.

The main design theme in the second workshop was again social companionship, which participants mentioned 13 times while discussing daily challenges and 38 times in the stage of robot design sketching. The participants described different types of social companionship along with other functions they needed. For example, they suggested the coffee maker robot could talk to them. Participants also reframed problems related to taking the wrong medicines, accidental injuries, taking care of pets, and limitations of living spaces mentioned in workshop 1 as design requirements for a medicine taking reminder, safety guard, house chore and physical assistance, and concerns of robot size. They developed a better capability of framing their problems in relation to robot design. The need to maintain control of the robot emerged as a new topic, with participants mentioning they did not want the robot to be too smart or autonomous.

In the robot sketching stage, participants reflected more diverse needs than while reviewing life challenges, and focused on specifics more than generalities. We recognized the way participants designed the robot was connected to their association of needs to potential robot functions. Their lack of familiarity with design practices made it difficult for participants to have a more integrated concept of a robot they could use to address their needs.

Figure 2. Three drawings produced during the second workshop show different types of robotic companions.

3.4 Workshop 3: Design a robot for your everyday life

The third PD workshop allowed researchers to work with older adult participants to better ground their ideas in their domestic environments and daily practices, and to consider more general design characteristics of robots that could help people "like them." Four older adults and five researchers joined the session.

We started the session by viewing floor plans of participants' homes, which we drew based on our visits during the first interview. We then discussed how participants used different spaces in their homes, and where and how they would want robots to be present in those spaces. We had used this method in a previous study to integrate the social dynamics at home into robot design [40]. We discussed what robots should look like, and the particular functions they should have to fulfill participants' needs and the constraints of their domestic environments. Participants each had one researcher working with them to discuss their design ideas and sketch them. The resulting designs included a mechanical, zoomorphic, and humanoid robot (See Figure 3), and diverse functions (e.g. cleaning, reminders, answering door).

This workshop allowed us to see how the older adults connected their own needs and values to the design of a specific robot, as well as to identify some common themes among participants. All participants mentioned wanting to talk to the robot and using it as some form of companion (e.g. watching TV together). Two of the four participants wanted the robot to help them manage interactions with others (e.g. remind them they haven't talked to a family member for a while, tell them when a conversation was too long). All the participants modeled the robots' roles based on familiar things (e.g. pets, house helpers, the Paro robot they had seen), wanting the robot to augment these roles or replace companions that were gone (e.g. a dog that had passed away). Participants also discussed concerns about using robots in the home, such as private places they did not want the robots to go (e.g. bathroom, bedroom), and the ease of use and maintenance.

Going through participants' daily routines as part of the robot design enabled the participants to take a relatively holistic perspective to robot design compared to their designs in workshop 2. This time participants thought about the robot as an integrated application instead of as a collection of individual functions. When they discovered a need in the process of imagining using the robot in their daily routines, they spontaneously added functions and adjusted the design and scenarios of their robot prototypes. We could say participants showed their ability to envision robots relevant to their issues in more comprehensive and "designerly" ways in this workshop, thinking how different functions might interact with each other and the use context.

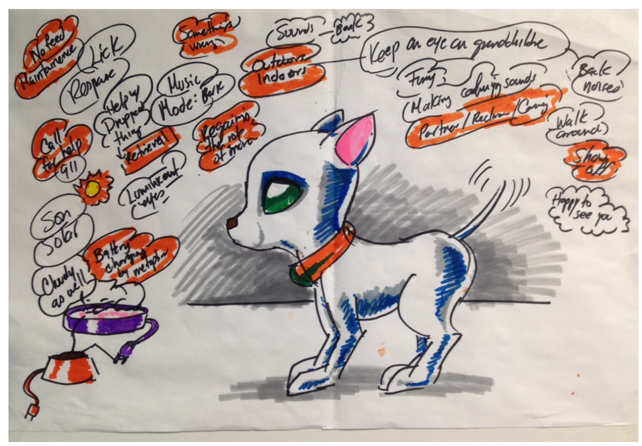

Figure 3. Participants designed robots with more comprehensive and holistic functions.

3.5 Workshop 4: Robotic technology and design with robotic parts

During the fourth PD workshop, we sought to involve participants more directly in the technical development of robots. Our initial plan had been to do this during the second workshop, but the participants' negative reaction to MugBot, the programmable robot we demonstrated to them, inspired us to reconsider and guide the participants into the process of technical design more gradually. In this session, researchers learned how different sensors could be used in older adults' everyday lives; older adults learned the capabilities of different robotic components, which enabled them to suggest alternative ways to construct SARs. Four researchers and four older adults participated.

We presented several robotic sensors (e.g. light sensor, microphone, natural-language processing), and gave participants time to test them out, then asked participants to imagine how they might use them in the robots they had designed in the previous session (shown in Fig. 3). We also discussed sensors that were already used in existing robots, such as Paro and a prototype robotic face, and whether participants had any concerns about using such technologies in their homes.

Participants suggested including environmental sensors (e.g., sound, dust, and humidity sensors) in their robots to examine the physical condition of their home (e.g. knowing it's time to clean). Also, participants requested a finger print sensor to manage access to collected sensor data. Regardless of the data's usefulness for clinical purposes, participants emphasized that sensor data should go to them alone, and did not want to share information collected by the robots with medical professionals. Participants also wanted to keep tight control of their robots, rather than having them act autonomously. For example, the robots would be controllable only by the owner's voice. Several themes from previous workshops were reiterated, such as robots reminding participants to take medicines and attend appointments. Participants repeated their desires to use the robots for companionship and emergency assistance in their daily lives.

In the fourth workshop, participants expressed their ideas from a design perspective more frequently than in the preceding ones, especially when they helped us figure out what to do with sensor information and how to apply it to robots. For example, one participant began asking questions about sensors in the robots that were demonstrated after the sensor training. Another participant said "What about different animals?… If you like cats, you could make one like a cat that does things that you'd want it to do." A third participant said, "But that [robot] would cost a lot more than the animal…whoops!" These examples show participants considering robot design as a more generalist enterprise, rather than a wish-list of characteristics they might prefer to buy, which requires the balancing of the preferences of different users, costs, technical capabilities, and various social values and daily needs.

3.6 Workshop 5: Staff's perspectives of robots in patients' homes

The fifth PD workshop brought our research team together with four therapists to discuss the robots that were developed by older adults in the four workshops, and how such technologies might be useful in therapeutic practice. In this session, researchers could understand older adults' needs from a therapeutic perspective; therapists learned about the needs their patients had expressed and how robotic technologies might be sued for their therapies. Four therapists and four researchers joined this session.

We first asked therapists to describe their clients' typical problems from a clinical point of view. They pointed out that lack of purpose, interest, planning skills, and insomnia during holidays are common challenges for clients with clinical depression. They explained that older clients with clinical depression were often institutionalized for long periods of time, during which they did not make decisions for themselves. They were therefore used to relying heavily on others for help with everyday life. This made their needs for assistance and social reassurance more pronounced than those of other older adults. Therapists accordingly agreed with participants that medicine and appointment reminders would be helpful functions that technology could fulfill. The therapists also suggested that recording sleep and physical activity would be helpful for clinicians.

In contrast to the potential benefits emphasized by participants, the therapists commented on several concerns. Therapists worried technical failures could cause clients serious frustration. Possible fixation to the robot could be another issue if a participant stops trying to establish relationships with other people, which might be a concern with older adults with depression who are socially isolated. Also, having a robot may bring another source of anxiety if a participant worries others could disapprove of their robot. Therapists emphasized the importance of communication; thus, they suggested that the robot asking questions or giving suggestions could be effective functions to motivate patients. They also expressed a general interest in the potential of SARs for use with older adults in domestic environments, and expressed a desire to further contribute to our studies and future projects.

4. DISCUSSION

Throughout our sessions, we examined ways to enable mutual learning between researchers and participants, aiming to facilitate a balance of power between the two groups. As a result, our research suggests the following PD principles as possible ways to position users and researchers within the robot design process.

Including users in robot design as experts on local conditions and needs.

Our work has demonstrated that our "users" (in our case those diagnosed with depression and registered for social services as such, as well as having substantial co-occurring physical problems) have ideas about how to conceptualize robots and how they might be of use to them. These ideas at a minimum can be used to provide some design inspiration to roboticists. However, we have yet to discover how to develop our users further into active participants in a SARs participatory design team and thus how to promote the likelihood that they participate actively in the design process. Our work shows that specific procedures need to and can be developed to help them move beyond framing robots as consumer items and toward thinking of them as things to be created together with other stakeholders. Some aspects of this challenge might be related to the length of time of user/participant involvement in our research. The participants opened up over time and began to think in more "designerly" (rather than consumption-oriented) ways in the last two workshops. Another challenge was possibly the social status of our participants, who had significantly lower educational and socio-economic levels than the researchers. Through the workshops, participants became more confident of their contributions. Getting more comfortable with working with the group over a longer time and gaining even more knowledge about the capabilities and functional aspects of robotics might have helped participants embrace their role as designers and decision-makers in later workshops.

Considering users' relations to other actors and institutions.

When HRI researchers investigate users, users are generally understood as individuals (and sometimes groups) interacting with a robot. However, users are also social actors who have various relationships to other social actors and institutions. To develop robots for older adults with depression, we invited not only the older adults but also their therapists and other care staff. We also developed a relationship with the non-profit health institutions that helped us coordinate our participants and are the stable bond between the older adults and therapists, and likely use contexts for future social robots. When collaborating with different social actors, we developed relationships with stakeholders considering the power relationships among them. We started our studies with older adults, since older adults normally have a limited voice and power in the healthcare context. We also acknowledged researchers might generally value therapists' ideas more than those of older adults, due to their institutional role and formal training. Although therapists' knowledge would be beneficial to develop robots, older adults are the primary users who need to be empowered in the robot design process. That is why we met with older adults more often than therapists, and why we met with them separately so both groups could express their ideas freely. A possible role for HRI researchers in PD studies would be not only finding valuable information from participants, but aggregating different stakeholders and facilitating relationships among them.

Providing benefits to participants as PD collaborators.

Our PD work with older adults of lower socio-economic status made us reflect on the relevance of such practices for the participants, not just the researchers and the future of robot design. Our participants came from a particularly vulnerable group in the general population, not just in terms of age, but in relation to their access to social, economic, and political networks through which they could make a difference in their own and other peoples' lives. We found our participants valued the workshops far beyond the monetary compensation they received for attending, as a place where they could socialize and where their voices were heard. Several times, as we were working to prepare a follow-up workshop, the participants' therapists telephoned us to ask when the next workshop would be – their clients were eager to attend. In an environment in which funding for health services is being cut to the minimum, PD research became a social and intellectual outlet for participants. In our discussions, we noticed a general lack of empowerment among our participants, who often expressed they did not have enough control over their own bodies and lives and no significant role in society. Continued work with the design team might ameliorate this, particularly as users see their ideas implemented in future robot design. While this in itself is a positive effect, it raises the question of how to make such engagement more sustainable after PD projects and attendant financial and social support are over. As collaborators, finding ways to provide direct benefits to the participants is an important part of our PD approach.

Balancing the power of researchers and users to determine the sociality of robots.

Researchers' knowledge, learned and cultivated within academic environments, has so far been essential to make robots more social. However, the HRI community may have overemphasized researchers' expertise at the expense of including more diverse perspectives of potential users and stakeholders. Researchers have their own values and assumptions when they are interpreting the responses of research participants (e.g. HRI researchers have embedded stereotyped images of older adults into assistive robot design, which prompted older adults to reject the robots despite their perceived potential usefulness [17,48].) On the other hand, users' mindsets are distinct from those of researchers. Participants evaluate and categorize robots based on how they fit within their everyday space or how the meaning of robots resonates with their values [49]. Although experiments involve users in evaluating robotic technologies, they do not allow users to express their thoughts with their own language and priorities, as the study's frame is determined by researchers. Users can only tell whether the features HRI researchers deemed important are preferable to them or not. Even with ethnographic and user-centered studies, the danger of framing users from researchers' perspectives and obscuring users' concerns persists [50]. Researchers determine the representations of users from their perspectives, which do not necessarily align with the participants' priorities and concerns. Social scientists [51,52] and anthropologists [53] have developed self-reflexive ways to examine their pre-existing assumptions and biases not only to understand participants on their own terms, but also to be aware of the power relationship between researchers and users and to reflect those in their methods of collaboration. The PD process allowed us to gradually equalize the footing of researchers and participants in robot design over several sessions, making users more confident about their ability to contribute to design and researchers more conscious of different perspectives on robot capabilities, usefulness, and challenges.

5. LIMITATIONS

We worked with a unique group of relatively isolated rural participants of lower socio-economic status, so we do not expect their designs to generalize to all older adults. Instead, we see the process of relationship building and mutual learning during social robot design as the generalizable component of our work. We also acknowledge that participants in such studies might be more positive towards robots and the design process due to their relationship with the researchers, and we strived to take this into account in our project design by covering similar issues in multiple workshops and including therapists' views as well. We hope our study contributes to methodological discussions on PD for HRI and the roles of users in the robot design process.

6. CONCLUSIONS

In recent years, the robotics community has focused on the concept of co-robotics to develop robots that can co-exist with humans in everyday contexts [54-56]. The concept of co-robotics values the possibility of robots as mutual learners, expecting more advanced sociality of robots, within various everyday use contexts. Our research seeks to make a contribution to the efforts of the HRI community to explore possibilities for the co-existence of robots in diverse human environments, and in particular to develop participatory methods for designing robots and the social contexts needed to support their successful use. It accomplishes this by bringing up foundational issues and providing a space from which to question assumptions about sociality in HRI that have been long taken for granted. It also describes several methodological steps to include participants in the design of robots in more substantial ways, and to focus the conceptualization and design of robots on a common view of the world created by designers and participants through mutual learning and collaboration.

Additionally, we explicitly reflect on the power dynamics of designing and implementing robots in eldercare. As we learned more about the lives of our patients/users/co-designers, we began to see the many ways in which their situations necessitated bending their lives to the requirements of the health-related social service system. They had learned to enter a "patient" culture, to become, among other things, patient patients. It struck us that this culture afforded many forms of dependency, and perhaps this dependency was itself a major impediment to their being able to enter more fully into the co-designer role that we encouraged them to take. Hence, it may be the case that doing PD with similar groups and individuals may require co-identification, and perhaps even co-implementation, of a more activist, anti-dependency culture. Such a process necessitates a long term commitment for researchers, participants, and the institutions they are part of, as an integral part of social robotics research and design.

7. ACKNOWLEDGMENTS

We thank our participants for their time and invaluable insights, as well as the staff of Centerstone Indiana for their help in implementing our study. We are also grateful to IUB's Center on Real Experiences with Public Health Information Technology program for funding this research.

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