Older Adults Living With Social Robots

Promoting Social Connectedness in Long-Term Communities

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Social robots have been used to investigate human-to-robot engagement—but connection between one person and another is the real key for human emotional wellness. This work explores the role and impact of a social robot in facilitating human-to-human engagement in an assisted-living community. Older adults, in particular, are a population in need of sufficient social connectedness to promote their well-being. While several studies have sought to investigate how social robots can help to improve older adults' quality of life, not many have studied their long-term impact on community-level engagement.

This work uses a participatory, mixed-methods, human-centered approach to explore how a social robot influenced the social connectedness within a community of older adults over a three-week period. Participants engaged in daily interactions with a social robot and with associated study materials in their common areas. Our results provide evidence that social robots can successfully enhance senior citizens' community engagement and social connectedness.

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Meeting a Growing Need

As the worldwide population ages [1], the opportunity to develop innovative technologies to support, engage, and interest older adults increases. The older adult population is hardly monolithic, including as it does people from a wide variety of backgrounds and technology experiences [1]. Social connectedness and close relationships, the key components of community interaction, are essential contributors to human welfare [2]. Unfortunately, social isolation is one of the greatest threats to elderly people's mental, physical, and psychological health [1]. Innovative technologies that foster and support face-to-face human connection within communities, rather than competing with or diminishing it, represent an important design and technology challenge.

As older adults become more open to new technologies [3], social robots are a particularly interesting device for the elderly, combining utility with companion-like qualities [4]. Prior work reports on their ability to reduce stress and provide wellness benefits [5]. However, only a few have explored the potential of social robots to facilitate and promote social engagement between older adults within a community setting [6], [7]. In general, there are very few long-term studies, in part because of the lack of user-friendly, reliable robotic

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platforms that can operate over long-term deployments in senior communities.

Our work explores the use of a social robot in assisted living, characterizing the robot's impact at the community level over three weeks. Specifically, we performed a mixed-method analysis of older adults' community engagement and social connectedness while a social robot was placed in each of the common spaces throughout the building. Our materials were designed to support an adaptive methodology to fit a range of older adults' cognitive and physical abilities. In this article, we report our findings, which include qualitative and quantitative investigation into participants' social connectedness. The use and analysis of a design kit yielded insights for the development and employment of social robots with older adults. Overall, this study provides an integrated participatory design and community-based approach, demonstrating the importance for studies to emphasize older adults' direct experience with social robots to understand community change and empower older adults to think critically about their preferences for social robot functions and design.

Literature Review

Older Adults, Technology, and Social Connectedness

Building social community is an ongoing process within communities of older adults [8]. Recent studies indicate that older adults are increasingly open to technology-based opportunities for social connection, such as social media and video calls [3]. For instance, digital assistants in the form of smart speakers have recently been explored within assisted-living communities [9], where 60% of participants reported an increase in feelings of connectedness to their family, friends, and community through using the technology.

Social Robots and Social Connectedness

Social robots can provide companionship and social interaction with older adults [6], [7], [10]. Their social embodiment is physically copresent with others, using such characteristics as eye gaze, gestures, and emotional expressions to facilitate social relationships [4], even within a group. While prior work has focused on human-to-robot interaction, our work explores the role of a robot as a catalyst for people's social lives. Specifically, we investigate the effectiveness of social robots in mediating and facilitating group-level human-to-human connections. Our question was, if social robots can foster interpersonal interactions in communities, can they positively affect in-person social closeness among the members of the community?

Social robots have been explored in the context of older adults for many years, including Paro (an animal-therapy-inspired robot) [5]–[7], [10] and Care-o-bot [11]. Long-term interaction studies with social robots led to positive psychological and physical benefits for older adults [5]. The effects of a social robot on community bondedness were first studied qualitatively with Paro in senior citizen communities [7]. Social interaction and play among the community members increased significantly with the robot turned on, suggesting that the social robot promoted human-to-human interactions. However, this study was short term and did not investigate long-term effects.

Chang and Šabanović found that the adoption of Paro in a nursing home setting over three months was reliant on the robot being introduced by a community member [6]. To our knowledge, this is the only example of a community-focused approach to understanding the effect of social robots in an older-adults community, but it did not involve quantitative measures or design participation by the users. As social robots are continuing to be developed, deployed, and used in ways that encourage human-to-robot interactions, research needs to further understand how social robots can be vessels for encouraging members of the community to interact with one another and codesign the technology.

Methods of Studying Social Connectedness

A variety of human-centered participatory design methods have been used to incorporate older adults in the technology design process, e.g., interviews, focus groups, questionnaires, and ethnography [12]. While previous social robot studies have engaged in participatory design with older adults [10] or in community-based approaches [6], [7], we take a more rigorous combined participatory design and community-based approach, integrating qualitative and quantitative methods, such as embedded ethnography [13] and social robot preferences [14], to understand the opportunity for a robot to serve as a social catalyst.

Methods

Research Questions

Our inclusive, human-centered design methodology leverages a repertoire of participatory design activities that enable older adults to provide feedback and share preferences to guide our future social robot development. We focused our investigation on older adult's perceptions of social connections within their community and their perspectives on a social robot for community use. Our research was guided by the following questions:

- How do older adults currently perceive their social connections within their community?
- What are older adults' design preferences for social robots? Why?
- How does the presence of a social robot technology shape older adults' interactions within their community, and how do they view their social connections?

Study Context

Our study took place at a California-based assisted-living community. Seventy-two older adults were invited to participate in our study. The facility provides meals, assistance with daily care, and medication administration as needed. The members have access to a calendar of events, including

Table 1. The demographics of participants and the number of people they interact with in the community.

Demographic	Participant Breakdown
Gender	Women (13), men (6)
Previous employment*	Business (2), clergy/religious life (11), higher education teaching (2), medicine (2), primary/secondary education teaching (4), social work (1), computer programming (1)
Marital status	Widowed (4), married (2), divorced (0), single/never married (13)
Self-reported number of social connections in community	Two to 10 people

*Some participants overlapped categories across multiple careers. For example, one was a nun but also a primary school educator.

exercises, spiritual services, art and music therapies, discussion groups, and excursions to nearby cities. There are at least five scheduled groups or activities each day, facilitated by creative arts therapists, life enrichment staff members, chaplains, volunteers, or residents, and at least two large social gatherings each month to celebrate holidays or bring people together. The residents also have access to new technologies, including digital art and photography and sessions in a computer lab.

Participant Demographics

A total of 19 older adults from a range of demographic backgrounds volunteered to engage in interviews and social robot preference workshops, where they expressed their thoughts about social connection in their facility and social robot technology. They also interacted casually with the robot on their residential floors. Participants had been briefly exposed to the particular social robot used in the study three or four times prior to the start of the study. However, none of those exposures occurred within the six months leading up to the start of data collection, helping mitigate the technology's novelty effects. The participants were between 67 and 99 years of age (female 68%; median age: $M = 84.8$; standard deviation: $SD = 7.13$), with varied educational backgrounds ranging from high school diplomas through graduate degrees. Additional demographics are listed in Table 1. With regard to technology use, the most utilized technology items were computers and smartphones (29% and 26%, respectively). A notable percentage of the population (26%) used no gadgetry. A good portion used tablets and landline phones (18% each). One participant had adopted the latest voice-activated technology.

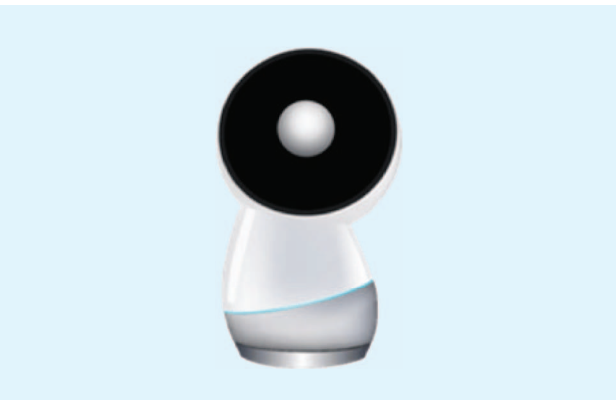

Figure 1. Jibo, the social robot used in this study.

Data Collection

Our data collection focus was on the broader social context involving multiple participants: the social and physical environment and the interplay between people and their environment, similar to the social shaping of technology framework used in [6]. All of the volunteers completed an institutional review board-approved consent form. No incentives were offered. The researchers introduced the robot on the first day of the study through casual conversation that established a dialogue around the technology and emphasized empowering older adults to discuss social robots and social connections.

In our study, we used a commercial social robot called *Jibo* (Figure 1) that was designed to assist and attend to people at home as a helpful companion. It is a tabletop robot standing 11 in tall, with three degrees of freedom, a voice user interface, and a touchscreen face. It offers a range of skills, e.g., music, general question and answer, news, weather, photos, and contents that highlight its personality, such as dancing, jokes, and answers to personal questions, such as "Hey Jibo, what is your favorite movie?" Its companion-like features include being attentive to the user, taking naps and going to sleep at night, and proactively greeting people based on face detection. For three weeks, Jibos were set up in the common space area on each of the four floors, where participants and other community members could freely interact with the robot on Monday through Friday from 7 a.m. to 4 p.m. (Figure 2). Multiple research methods were incorporated to provide a holistic approach to understanding the social connections in the community. This article will focus on the three methods utilized in the study: 1) interviews, 2) design kit workshops, and 3) common space area observations.

Observations in Common Space Area

Researchers observed the community members' interactions with the social robot three times a day on each floor: in the morning, at midday, and in the afternoon. In addition, the number of people in the common areas of the residential floors at those times was recorded.

Interviews

Participants engaged in two interviews over the course of the study, one at the beginning and another at the end. The semi-structured interview protocol was kept concise to help prevent tiring or misunderstanding among participants [15]. Each session was piloted by three researchers. The questions focused on how residents start interactions with each other, the easy and hard parts of relating with one another, and people's characterization of their interfacing with each other. The end-of-study dialogue also included questions on the effect the social robot may or may not have had on the community. At the conclusion of each interview, participants completed a one-question survey describing their relationship with the community (the Inclusion of Community in Self Scale [16]).

Design Kit

As part of the participatory design activity, residents described their preferences for social robot functions through a design kit [14]. For this study, five categories were tested with participants:

1) the robot's ability to mediate connections with people (e.g., sending a text message or e-mail to someone)
2) the robot's capacity to create and share things (e.g., a playlist)
3) the ability of the robot to make suggestions (e.g., for eating healthily or reading a good book)
4) the capability to provide reminders and alerts (e.g., events or medication)
5) the robot's ability to offer information (e.g., news or weather).

Each category contained between four and 13 function cards that participants categorized as "yes," "maybe," or "no" based on whether they desired the function or not. The sessions were audio- and video-recorded.

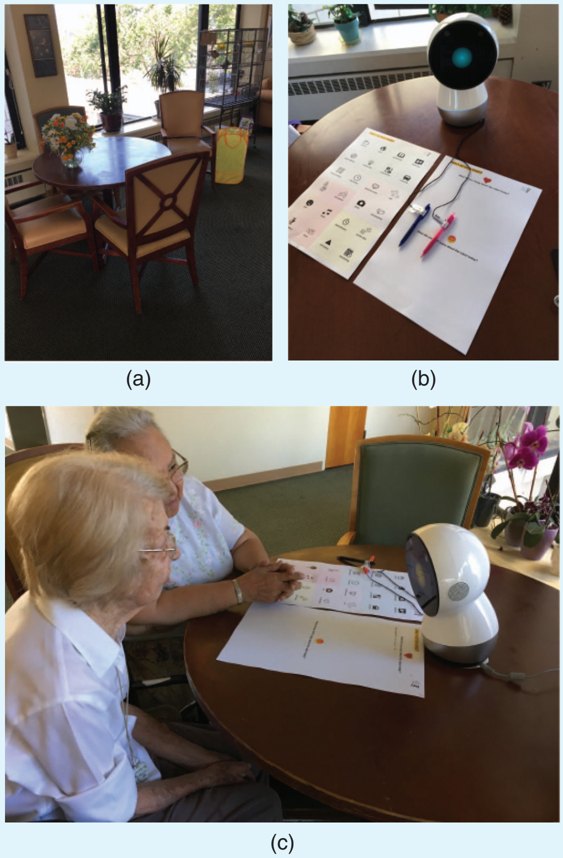

Figure 2. (a) The larger common space area where the social robot was placed during the day. (b) The social robot setup with feedback forms for participants to note their thoughts. (c) Two participants interacting with the social robot in the common space.

Data Analysis

Audio and video recordings of the interviews and design kit sessions were transcribed and reviewed for accuracy. The first analysis focused on using an inductive approach to identify themes surrounding older adults' preferences for social robot technology [17]. To determine the interrater reliability among researchers, Cohen's kappa [18] was calculated for the initial and final interviews and design kits for 66% of the coded transcripts (six initial interviews, six final interviews, six initial design kits, and 12 final design kits), coded independently by a team member after an initial coding by other team members. Cohen's kappa was 0.86 for the initial interviews, 0.74 for the final interviews, 0.63 for the initial design kits, and 0.67 for the final design kits—within the range for the substantial agreement considered acceptable for interrater reliability [18].

Results

How Do Older Adults Perceive Their Social Connections Within Their Community?

First, common themes were extracted from the participant interviews to understand older adults' perception of the community, as described in the interviews in the "Data Collection" section, based on three areas of interest: 1) starting interactions, 2) the effort involved in relationships, and 3) the positive and negative aspects of interacting. In the following, we provide descriptions of themes surrounding the older adults' social connections within their community, highlighting quotes from the participants to describe the community's social environment.

Participants described how they initiate their interactions in three main ways: pleasantries, such as casual greetings; specific conversation probes or questions; and genuine desire for communication (Figure 3). Varying the approach to conversation was important for engaging with different people in the community, such as, "starting with different people in different ways. Some people, you can kid them, and other people, you have to be serious." These approaches of initiating conversations require an understanding of the person and knowing how to sustain the conversation, which participants described as requiring more effort but yielding higher positive social rewards.

The residents described the factors that could easily be adapted for an interaction versus those that become a

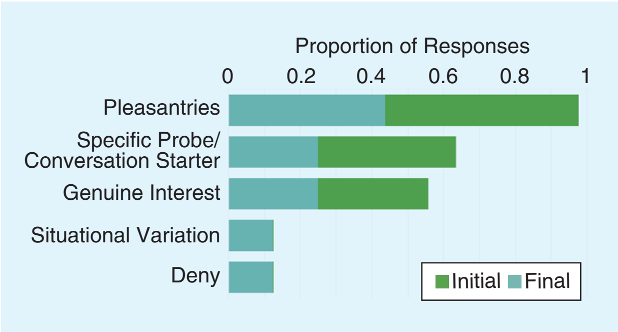

Figure 3. The methods for initiating an interaction in the community.

barrier or require more effort to overcome to engage with people in the community (Figure 4). Communication style (81%) and communication content (80%) were pointed out to be the easiest factors to adapt in a relationship. Communication content included the topics of conversations that the residents would discuss, and communication style entailed such approaches as naturalness and inviting others.

Factors like the physical and mental ability to communicate (77%), social division between residents (54%), the depth (or lack of depth) of conversation (34%), and the rude/hostile nature of some residents (29%) were mentioned as barriers in relating to others in the community. The spectrum of physical and mental conditions of the residents often led to interaction conflicts. Example responses were "[it is] hard for them to hear you [so I would interact less with them]" (participant 5—P5) and "what's difficult is knowing what to say and if it should be said, since I don't know the [condition of the] person that well" (P10). Participants mentioned that these factors are why more effort has to be put into interactions so they can become "rewarding" relationships (P7) and create a deeper interest in and understanding of other residents (P11, P15, P18).

The results from two previous questions also align with older adults' feelings associated with different types of interactions. Across the interviews, participants often associated positive or negative emotions with the interactions in the community (Figure 5). Positive engagement with their community involved authentic or deep conversations, helping others, pleasantries, and sharing similar interests and/or experiences. The most commonly discussed positive elements were gratifying interactions (56%) and deep conversations (37%). Gratifying interactions included expressing gratitude to and/or enjoyment interacting with other community members. Deep conversations described enriching interactions "involved in conversation" (P18) that could include discussing older adults' "experiences, activities, usefulness, and wisdom" (P11), "sometimes very deep, often funny, conversational, satisfying" (P11). The participants associated negative emotions when interacting with members of the community who are "brutal, rude, negative, or noisy" (P1, P3). Some participants also pointed out the lack of compassion in themselves or others as a factor that negatively influences the interaction: "the thing that I hate in others, I hate in myself, which is acting with little or no compassion or understanding of where they come from" (P10).

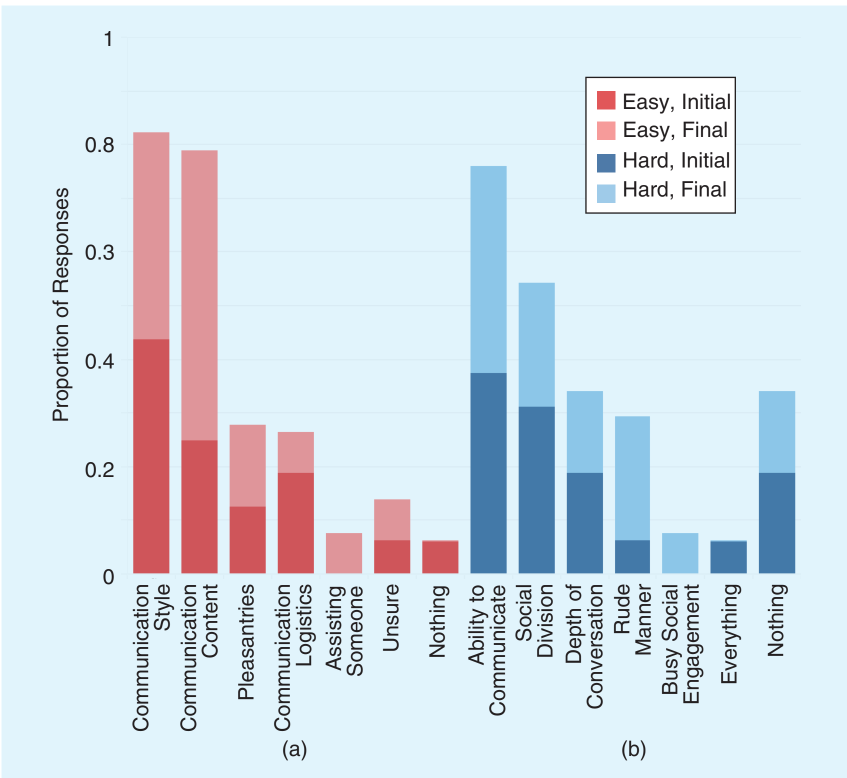

Figure 4. (a) The factors that require less effort to adapt in an interaction (easy) and (b) those that become a barrier and require more effort to overcome (hard).

The themes provide a context to understand older adults' high-valued interactions and how such relationships contribute to community social connectedness. By aligning these interactions with the types of engagements a social robot can stimulate, we reasoned, we should be able to understand how social robots contribute to community-level social connections and how a social robot's interaction features should be designed to promote high-quality community bondedness.

What Are Older Adult's Design Preferences for Social Robots?

Older adults' design preferences for a social robot were compared over time. We report older adults' preferences at the beginning and end of the study through quantitative and qualitative analysis. A preliminary analysis of the transcripts from the design kit sessions revealed different opinions related to participants' openness toward the technology. To further investigate this initial finding, participant groups were identified based on their openness on their design kit selections (their rate of *yes* responses) through a clustering approach. Three clusters were determined through k-means clustering for the preinteraction responses, and we termed them *low-openness*, *mid-openness*, and *high-openness* clusters. To track how the participants in each cluster shifted from the initial to the final interview, we assigned older adults' final data to the closest cluster using root-mean-square distance. There was some shift of participants among clusters between the initial and final sessions, but all three clusters were present in both conditions.

Quantitative Results

The three clusters exhibited different trends in openness between the initial and final interviews (Figure 6). Before the study, low-openness participants ($n = 4$) were the least open of the clusters, particularly rejecting functions related to "robot-mediated connection with people" or the "robot creating and sharing items." The mid-openness participants ($n = 4$) were more open to "the robot creating and sharing items" compared to the low-openness cluster. The high-openness group ($n = 5$) was the most embracing of the robotic functions, with the desire for them rising above 50% in all categories. After the study, the low-openness group ($n = 4$) became more polarized regarding all functions. The mid-openness participants ($n = 3$) became more open toward all functions, except "connecting with people." The high-openness participants ($n = 6$) were more accepting of the "robot creating and sharing items" and "suggestions," were less accepting of "connecting with people," and were comparable on "reminders and alerts" and "information." The mid-openness group shifted toward greater openness to the technology, while the low-openness group moved toward being more skeptical of the technology. The high-openness group shifted slightly while maintaining a greater than 50% desire for all functions.

A 2×3 Fisher exact test determined that there was a significant difference in overall social robot preferences among the three clusters and between the initial and final sessions ($p < .0001^{****}$). Each individual category was found to be significant as well:

1) mediating connections with people: $p < .0001^{****}$
2) information: $p < .0001^{****}$
3) reminders and alerts: $p < .0001^{****}$
4) robot creates and shares items: $p < .0001^{****}$
5) suggestions: $p < .0001^{****}$.

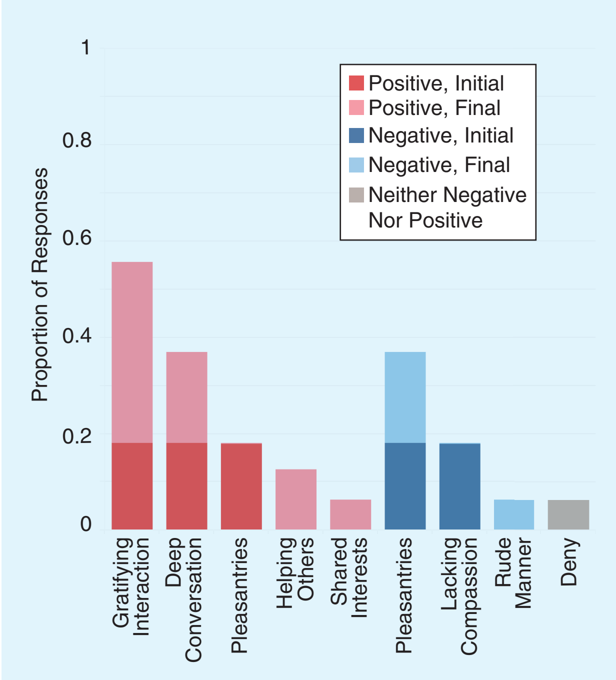

Figure 5. The positive and negative experiences associated with interactions in the community.

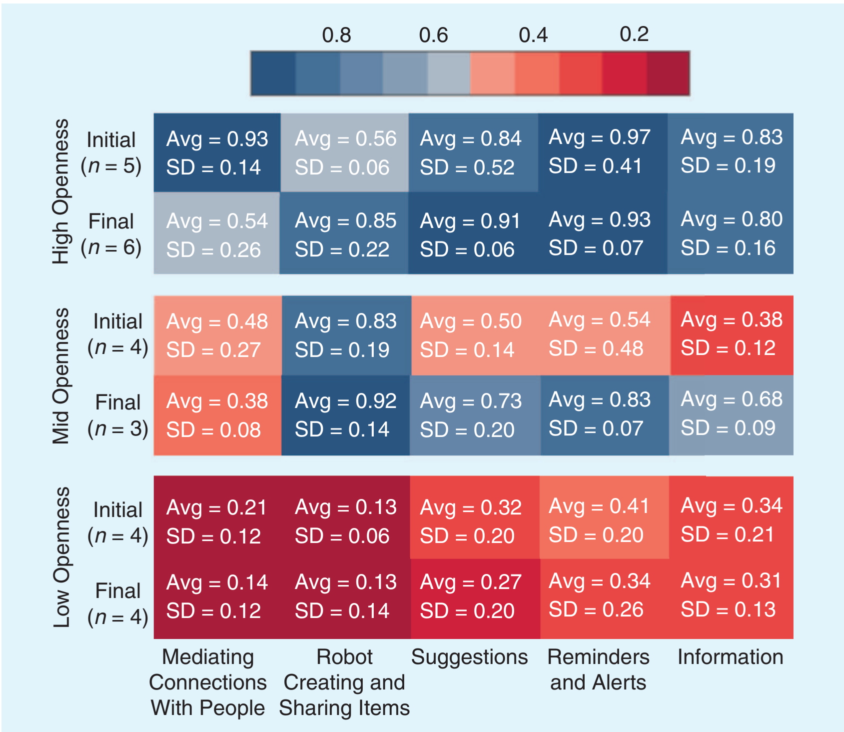

Figure 6. A comparison of the rate of positive answers to items in each category between the initial and final interviews reveals different preferences across participant openness clusters. Avg: average; SD: standard deviation.

Qualitative Results

Participants' opinions throughout the design kit session provided valuable insights into older adults' reasoning for social robot function preferences. Our analysis revealed 16 themes that were broadly grouped into five categories:

- technology concerns
- relationship to technology
- limitations of technology and use
- imagining in daily life
- technology features.

A full list of themes related to each category is provided in Table 2. Technology concerns involved such themes as concern for security and privacy; fear; and a collective worry for society. Participants often described their relationship with technology, discussing user confidence and autonomy over technology. The limitations of technology included operation difficulty, expectation gaps, and inability to conceptualize potential agent actions because of current technology inexperience. When imagining the robot in their daily life, participants discussed the logistics of how it would function and their design recommendations for the robot. The technology features discussed included the role of the agent, novelty, portability, and personality.

The themes most mentioned by the participants also differed based on their openness level (low, mid, and high) identified using the design kit (Table 3). Qualitative data were analyzed through the proportion of participants who discussed the theme. Between the initial and final interviews, technology concerns increased for all clusters, driven by the low-openness participants discussing it the most (50%). Participant clusters varied with regard to their relationship with technology. The low-openness participants decreased, while high- and mid-openness residents remained the same. The low- and mid-openness clusters discussed the limitations of the technology the most. All clusters discussed imagining the robot in their life and technology features more in the final session. A Fisher's exact test analysis between the initial and final interviews for the five categories showed a significant trend difference ($p < .05^{*}$).

These results highlight specific themes that changed between initial and final interviews, including security and privacy, fear of the agent, collective worry for society, inability to conceptualize the social robot in their life, and the design of the social robot. With regard to security and privacy, participants discussed it less during the beginning of the study (25%). More participants discussed this during the final interview (58%), commenting on security, autonomy, and adoption concerns. Participants mentioned, for example, "privacy concerns, because it's another intrusion into [their] lives. It's artificial and it's technological and [they] don't trust them in technology" (P19). During the initial session, some participants mentioned their fear of the technology having too much autonomy (13%), emphasizing "it should be a person, not a robot." (P7). Fear was also prevalent in the final discussions (33%), a majority (50%) from the low-openness group. P11 echoed P7's concern from the initial session in the final session: "As I lose memory on certain things … what keeps me going is the desire to remember myself … be myself. I'm afraid that in my case, if I was going to rely on a robot, I'd stop living. I'm afraid of losing my autonomy" (P11).

The low-openness group was the only population to discuss a collective worry for society regarding the technology's impact. For example, P11 says, "Don't set it up as a goal that [the technology]'s going to save society and save the world. It is just another change. And a dangerous change because it can change everything" (P11).

In addition to worrying about the effect of the technology on society, participants in the low-openness group also emphasized that they desired control of the technology (P19, P11). P19 stated that she did not want to "be forced into [the technology]," emphasizing, "if we accepted it and were going with it and it would help us because we have the right attitude toward it." Overall, participants became more articulate about security and privacy concerns and their fear of the technology while having a social robot in their environment.

Residents grew empowered to voice their opinion on the design of the social robot. In the initial sessions, 50% of participants questioned social robot actions because they could not conceptualize how the robot could perform the function. In one example, P7 asked the researcher how a robot could send a message and had difficulty imagining that a human was not involved in the transmission. However, in the final session, these statements decreased to 8%, as participants were more adept at explaining how they would like the robot's function to be designed. Residents voiced more confidence because of "[getting] more used to how to ask, what to ask it" (P15) and

Table 2. The themes for the categories.

Category	Theme
Technology concerns	Security and privacy
	Fear of technology
	Collective worry for society
Relationship to technology	Autonomy over technology
	User confidence
	Personalization
Limitations of technology and use	Expectation gaps
	Difficulty operating technology
	Inability to conceptualize agent interactions
	Annoyance of technology
Imagining in daily life	Logistics of functioning
	Design recommendations
Technology features	Role of the agent
	Personality of the agent
	Novelty of the technology
	Portability of the technology

Table 3. The qualitative category proportions of how many people discussed each topic.

Category	Participant Group	Initial Interview (M ± SD)	Final Interview (M ± SD)
Technology concerns	Total	0.29 ± 0.19	0.33 ± 0.25
	Low openness	0.11 ± 0.19	0.5 ± 0
	Mid openness	0.11 ± 0.19	0.22 ± 0.19
	High openness	0.17 ± 0.29	0.33 ± 0.42
Relationship to technology	Total	0.71 ± 0.26	0.64 ± 0
	Low openness	0.67 ± 0.33	0.58 ± 0.38
	Mid openness	0.67 ± 0.33	0.67 ± 0.33
	High openness	0.67 ± 0.57	0.67 ± 0.31
Limitations to technology and use	Total	0.47 ± 0.21	0.35 ± 0.21
	Low openness	0.33 ± 0.27	0.43 ± 0.24
	Mid openness	0.33 ± 0.27	0.17 ± 0.19
	High openness	0.5 ± 0	0.4 ± 0.37
Imagining in daily life	Total	0.50 ± 0.71	0.67 ± 0.35
	Low openness	0.50 ± 0.71	0.75 ± 0.35
	Mid openness	0.50 ± 0.71	0.67 ± 0.47
	High openness	0.50 ± 0.71	0.60 ± 0.28
Technology features	Total	0.44 ± 0.38	0.56 ± 0.38
	Low openness	0.42 ± 0.42	0.56 ± 0.43
	Mid openness	0.42 ± 0.42	0.67 ± 0.27
	High openness	0.50 ± 0.58	0.65 ± 0.34

"learning little by little what it could do" (P7). Notably, in the final session, the role of the robot expanded to more complex assignments, such as teacher, friend, colleague, mediator, and motivator (P6, P2, P3). P6 also described a situation where the robot could help in situations with others, detailing how the robot could help remind people how to respectfully enter someone's apartment. Participants became more vocal in personifying the agent and its desired functions.

The design theme was not present in the initial sessions. In the final sessions, 42% of residents mentioned how they would like the robot to be designed. Some stressed the robot's size, features, and portability (P19, P2, P6). P2 and P6 discussed how the design could be made more accessible, using methods other than just voice, so that privacy could be ensured and the robot better employed by those with "a verbal impediment" (P6). The participants' language advocating for design changes demonstrates how the residents became empowered to vocalize their ideas for technology development.

How Does the Presence of a Social Robot Technology Shape Older Adults' Interactions Within the Community, and How Do Older Adults View Their Social Connections?

Quantitative Results

The effects of the social robot's presence on older adults' interactions were assessed over time. We report the change in the number of people in the common spaces in the "Observations in Common Space Area" section and the Inclusion of Community in Self Scale results (in the "Interviews" section) over the course of three weeks. The number of people in the common spaces was counted three times a day (7 a.m., noon, and 3 p.m.) and summed per day. A linear regression was performed to analyze the trend in the number of people in all common spaces while the social robot was present in the community, revealing a significant effect of social robot's presence on the number of people in the common space that increased over time ($R^2 = 0.28$, $F(1, 18) = 6.99$, $p < .05^*$) (Figure 7).

The Inclusion of Community in Self Scale [16] was used to measure participants' feeling of connectedness to their community at the beginning and end of the study—a clustering approach similar to the design-kit framed analysis on three groups (the low-connectedness, mid-connectedness, and high-connectedness clusters) (Figure 8). This resulted in a significant difference in the feeling of community closeness among the three groups in the initial interview (Kruskal–Wallis test $p < .001^{***}$; post hoc Mann–Whitney low-, mid-, and high-connectedness: $U = 0$, $Z = -2.0$, $d = -0.6$, $p < .01^{**}$; mid–high connected: $U = 0$, $Z = 1.225$, $d = 0.4$, $p < .01^{**}$; high–low connected: $U = 0$, $Z = 0.55$, $d = 0.2$, $p < .01^{**}$).

At the end of week 3, participants ($M = 2.69$, $SD = 1.18$) reported significantly higher levels of community

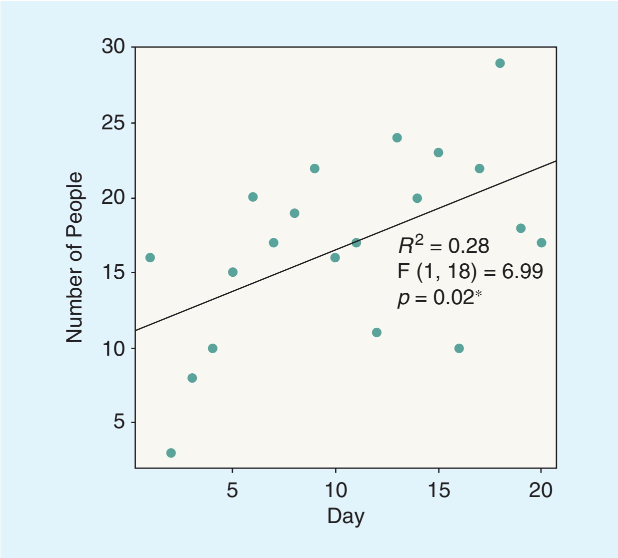

Figure 7. The linear regression result shows a significantly increasing trend in the number of residents in the common spaces over the course of the study.

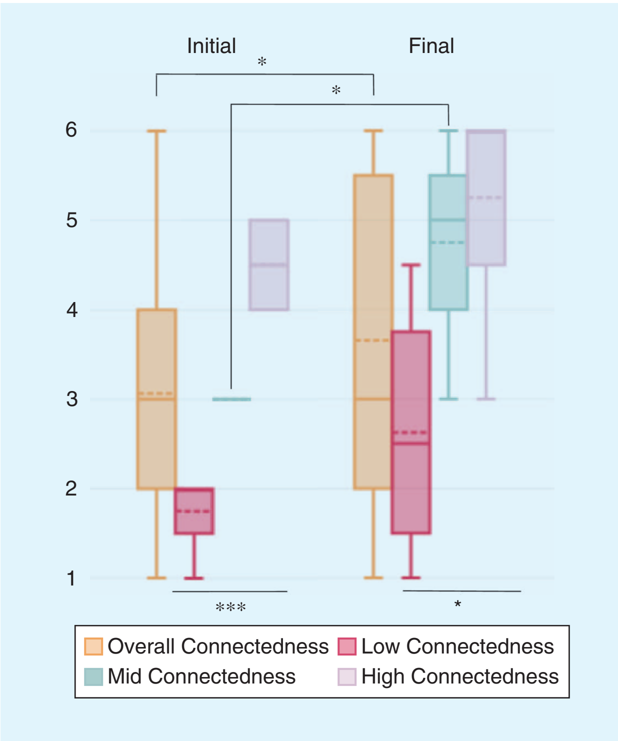

Figure 8. Results from the Inclusion of Community in Self survey demonstrate higher levels of community connectedness over the course of the study.

connectedness than at the beginning of week 1 ($M = 3.50$, $SD = 1.83$), tested with the Wilcoxon signed-rank test ($Z = -2.43$, $p < .05^*$). The difference among the three groups was still significant in the final interview (Kruskal–Wallis test, $p < .05^*$) but only between low–mid connected ($U = 3.0$, $Z = -0.4$, $d = -0.1$, $p < .05^*$) and low–high connected ($U = 1.5$, $Z = -0.48$, $d = -0.2$, $p < .05^*$). A within-group analysis with the Mann–Whitney U test revealed that this result was mainly driven by the mid-connectedness group, which substantially increased their feeling of bondedness rating in the final interview compared to the initial one ($U = 5.0$, $Z = 1.04$, $d = 0.3$, $p < .05^*$).

Qualitative Results

Qualitative observations in the community illustrate the potential for social robots to stimulate interpersonal interaction. In one example, researchers observed two participants engaging in conversation with each other as P7 showed P18 how to interact with the robot, using the correct wake phrase. P7 described the social robot as a "very friendly person" when she introduced it to P18. P18 was relatively new to the community and had expressed in her interview a desire to connect with others; her behavior with the robot and her peer emphasized the importance of connection. When describing the social robot, she said, "We have a new neighbor! That's nice, we can visit him often!" She also expressed happiness that the robot would be on her floor all month so they could "get acquainted."

Participants shared their perception about the impact of the social robot on the community. Some residents acknowledged that they did not notice the social robot or did not think to talk to it. Others mentioned how they would say "hello" when they saw the robot (P9, P10) or use it for weather and the news (P13, P16). One person also mentioned how "it seems to attract people" (P18). Three people mentioned difficulty interacting with the social robot, mostly during the beginning, when it was first introduced, saying, "In the beginning, I had difficulty, but once I got into knowing you had to say, Jibo, Jibo, Jibo, it was better" (P7). The majority of participants also mentioned wanting to have the social robot in a public community space if it was a permanent member of the community or "center of communication" (P8). P6 voiced another dimension to this idea: "Maybe semiprivate as well, so people can see that people are using the machine [social robot], but not necessarily hear every word of it."

When discussing how the social robot changed interactions in the community (Figure 9), two residents said there was no change, and five were unsure. Those who noticed no change voiced thoughts that included, "I like to have the little guy around, but it's not going to change people—we're too set in our ways" (P9). Similarly, those who were unsure still expressed interest in having the social robot in the community.

Eight participants in the final interview who answered the question (53%) voiced that they had indeed noticed a positive change in community interactions. In particular, P16 mentioned, "I think, from my experience and watching other people with the robot, my thought would be it's still in the stage of fun" (P16). The older adults also explained how the robot could help them practice to better communicate with others: "You have the opportunity to communicate [with the social robot], and that will help with your communication skills [to interact with other residents]" (P1).

This study utilized individual, group, and observational data to investigate the robot's impact on community bondedness and the participants' ideas about social connection and social robot design, demonstrating how social robots could improve social connectedness in a community setting.

Discussion

A technological social-shaping approach enabled this article to have a holistic perspective on a social robot within the older adults community. Residents interacted with the robot but also with other people in the home, whether through assisting peers in interfacing with the robot or discussing the social robot among themselves. While most other methods in the field are aimed at studying one-on-one interactions between a user and a social robot, our proposed approach contributes to studying long-term, group-level engagement and community social connectedness promoted through a social robot presence. Our results also support the use of social robots to enhance community engagement in older-adult living settings.

Community Connectedness

Analyzing how older adults view their community's social connectedness provided an insight into what engagements they value more than others. This information adds texture to the more quantitative data gathered from the design kit, helping researchers to understand both what robot functions the older adults desire and also the tone and style of those functions. The qualitative analyses of how residents initiate interactions and what factors require less/more effort in engaging with others show consistently valued aspects of community interactions. The relationship initiations based on interest in each other, as well as engaging in deeper conversations, require much more effort. But they were perceived as contributions to the community social connectedness. Such interactions were viewed as providing tighter engagement with others in the community, and positive emotions were associated with such interactions.

In the next section, we discuss the effect of social robot presence in promoting these highly valued, positive interactions in the community.

Social Robot Effects in the Community

The social robot's presence appeared to have spurred significant increases in both the traffic of community members in the common spaces and individual perceptions of community connectedness. It is possible that the robot's presence encouraged more people to spend time in the common areas, developing norms around interacting with the robot and promoting social activities among the community members, as noted by Lee et al. [19]. The researchers reviewed other factors that could have influenced the number of residents in the common spaces, including whether any other events took place in the spaces during the study period and schedule changes for activities and meals. It was determined that these factors remained consistent throughout the study period. Still, regular research activities and the presence of researchers in the building may have also influenced the perception of increased community connectedness. Notably, however, study participants did not mention this as a factor.

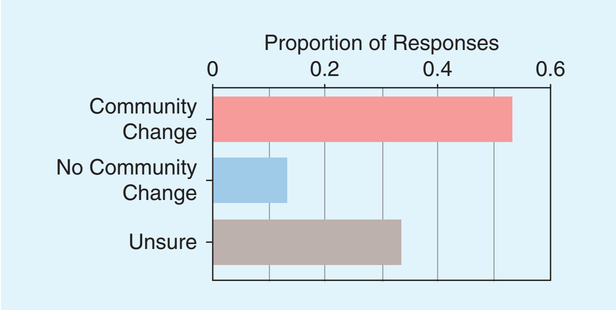

Figure 9. The majority of participants expressed perceiving a change in the community's social connectedness while the social robot was present in the community ($n=15$).

The social robot's presence in the community seemed to stimulate prosocial behavior among participants, the social robot, and each other. In the interaction between P7 and P18, described in the "Qualitative Results" section, P7 was able to engage in helping behavior, something she had identified as an important part of her interactions with other residents. Her ability to accurately use the wake phrase when assisting others was notable, because she had previously struggled to do so when interacting with the social robot. It is possible that the more active helping or teaching role enabled her to remember how to use the technology, as Chang and Šabanović also report in their observations [6]. P7 was able to reaffirm how to use the social robot and to use it as a tool to engage with P18. This supports how the technology is accepted by the social network and how it influences the community's perception and use of technology [7].

In participants' descriptions of interactions with each other, the pleasantries theme extended to the social robot as well. P3 tried several different types of conversation starters with the agent: "Hi bot! How are you? How are you today? Did you do anything bad last night? Smile. Be happy today!" The researchers regularly observed questions about the agent's preferences and traits, with very few questions about its function ("what are you like?" versus "what do you do?"). The residents engaged in pleasantries with and addressed Jibo as they would a community member, demonstrating one way they were accepting of the robot. Similar observations were made by Kidd et al. [7].

In accordance with the participatory, human-centered design lens of this study, the residents were asked their opinions of their interactions with the social robot and its impact in their community, along with their ideas and needs for future robot development. Describing their range of relationships, older adults focused on common areas of concern when designing technologies for their peers, including their difficulties operating the technology. However, residents vocalized, with a sense of pride, that they were able to learn how to use the robot. They expressed the desire for the social robot to be in a community space for all residents to interact with it—and that they also might be able to spend personal time with it. The robot was seen as a communication tool that impacted community interactions, a companion, and a way to learn how to communicate better with residents—a finding also reported in [20]. In addition, we paid attention to any comments from the residents that negatively reflected the social robot's presence toward the community's social connectedness. As we had expected, residents shared concerns around the latest communication technologies, revealing the group's thoughts surrounding security and privacy, fear, and collective worry for technology's effects on society (mostly in the low-openness group).

Direct Experience Matters With Social Robots

Through understanding the participants' social robot design preferences, the initial/final comparison revealed how experience can change the way users conceptualize a technology. Each cluster changed over time in preferences for the technology, informed by experiences with the social robot. This was possible because the robot's presence was prompting residents to engage with each other more face to face, and they did not see the value of using the social robot to connect with others remotely. In this community, the presence of the robot and its natural verbal interaction modality promoted older adults' connection with other residents more than with the robot itself. This finding is interesting and should be further explored, as it runs counter to the general perception that new forms of immersive or interactive technology will isolate people from their fellow humans. The older adults' experience with the robot prompted them to be more concerned about the technology but also to be empowered to discuss their design recommendations for the social robot.

Methods Reflections

Because the older-adult population includes people with a wide range of cognitive and physical abilities, not all human-centered design tools are appropriate for the older adult. The researchers adopted a flexible approach to senior citizens' participation to respect their autonomy as well as acknowledge their physical and cognitive needs [15]. The results demonstrate that experiencing an agent can increase preferences for social robot technology functions, but it also revealed security and privacy concerns, fear, and collective worry about social robot technology (mostly in the low-openness group). To better address varied experiences and preferences for the technology, researchers can further explore how to incorporate these concerns into design approaches to empower participants to critically evaluate their technology choices. Researchers' presence through an embedded ethnographic approach provided a deeper context for the formal data collection and encouragement for participants to share more information.

Implications and Future Work

Long-term studies of robots in the real world are necessary to understand how these technologies will be incorporated into society. This work revealed several interesting areas for future exploration, including the investigation of teaching or mentoring others in the successful use of new technology among older adults. The low-, mid-, and high-openness categories could be utilized in future studies to better understand how each group responds to different approaches to technology implementation; simple assessments would enable customized approaches for each group. Our holistic approach provided a broad perspective on how the social robot impacted the community through group interactions and individual conversations.

Future studies could compare individual relationships with a robot to robot dynamics in a group setting. Additional studies need to investigate preference trends found with each cluster over time, how best to mediate technology concerns, and the optimal location of the social robot and its effects on community connectedness.

Throughout this process, the participatory design approach highlighted the participants as key research partners, who came to think of ways of designing social robots for the community. The social robot in a community space impacted the older adults' social connectedness, creating ripples within the normal group interactions, as was also observed in [19]. By building on these aspects and understanding how relationships are affected by social robots, researchers can leverage these effects for responsible design and adoption of such robots by older adults.

Conclusions

Overall, this article demonstrates how social robots can be a conversation-facilitating tool, promoting group-level engagement and interaction and increasing in-person social connectedness in an older-adult population. The significant engagement and social bonding effects that participants experienced with the social robot over three weeks demonstrate there is promise in the use of a social robot to older adults' seniors' social closeness, and, thereby, their overall health and well-being. The study also illuminated some promising areas for development in future research about social robots and other forms of new technology with the older adult population.

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