Older Adults Engage in Privacy Enhancing Behaviors in a Home Monitored With Robots or Cameras

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ABSTRACT
In this paper, we describe the results of an experimental study in which older adult participants interacted with three monitoring technologies designed to support older adults' ability to age in place in their own home—a camera, a stationary robot, and a mobile robot. The aim of our study was to evaluate users' perceptions of privacy and their tendencies to engage in privacy enhancing behaviors (PEBs) by comparing the three conditions. We expected participants to engage in more PEBs when they were interacting with the mobile robot, since it provided embodied cues of ongoing monitoring. Surprisingly, we found the opposite to be true—the camera was the condition in which participants performed more PEBs. We describe the results of quantitative and qualitative analyses of our survey, interview, and observational data and discuss the implications of our study for human-robot interaction, the study of privacy and technology, and the design of assistive robots for monitoring older adults.

Categories and Subject Descriptors
H.1.2. [**Models and Principles**]: User/Machine Systems – Human Factors, Software Psychology; K.4.1 [**Computers and Society**]: Public Policy Issues – Privacy, I.2.9 [**Robotics**]: Operator Interfaces.

General Terms
Design, Experimentation, Security, Human Factors.

Keywords
Aging in place, home monitoring, home, older adult, privacy, robotic applications.

1. INTRODUCTION
The need to consider and protect user privacy is regularly cited as an important benchmark for socially assistive robotic systems meant to be used in natural settings [9, 13, 19, 20]. It is therefore somewhat surprising that neither user perceptions of privacy nor their privacy behaviors have been objects of empirical research within the domain of human-robot interaction. As autonomous and teleoperated robots that can collect data on people's behaviors and allow for remote operators to monitor others become more readily available to the public (e.g. Texas, QB, CareBot), the need to study the effects of robotic technologies on user privacy is gaining in urgency. This is particularly true for currently growing application areas for monitoring and teleoperation robots, such as eldercare [2].

While human-computer interaction researchers have studied privacy issues in relation to a variety of technologies including computers, the Internet, remote controlled cameras, and geo-location devices [e.g. 3, 12], relatively little work has examined privacy perceptions among older adults (see [4, 8, 15] for exceptions). Compared to previous research on older adult behaviors and perceptions of privacy in relation to various information and communication technologies, robots are expected to provide novel possibilities for protecting and challenging user privacy due to their embodiment, mobility, and novelty for users [9, 20]. Existing research in human-computer interaction shows that people's privacy attitudes often do not match their behaviors [1]: while users might profess to having serious privacy concerns, they will disclose personal information freely in online and computer-based communication. One possible explanation is that computer-based communication is radically different from the embodied, face-to-face interaction that people are accustomed to [5]. Research in human-computer interaction, however, has not addressed the issue of embodied interaction as it pertains to privacy. Robots, which are not only embodied devices but often designed to resemble humans and/or perform human-like behaviors and functions, provide an opportunity for researchers to study whether an embodied interface will enhance user privacy protection in ways that other technologies do not.

In this paper, we study user privacy behaviors in the context of monitoring applications in the homes of older adults. Older adults comprise one of the most likely potential audiences for domestic assistive robotic technologies [10], which can enable them to age in place by providing telepresence and monitoring for caregivers, as well as various autonomous assistive services [4, 21]. Our study focuses on teleoperation and monitoring as the most likely applications to be used in the near future. We compare two types of robots—mobile and stationary—to each other and to a wall-mounted camera to explore and understand the different privacy-related affordances of these devices from the perspective of older adult users. We also use our results to expand our understanding of the psychology of privacy, particularly focusing on whether embodied and mobile devices make a difference in people's awareness of monitoring and their performance of privacy enhancing behaviors (PEBs; [5]). We first provide an overview of

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assistive robotics for older adults, privacy as it relates to monitoring technologies in general, and robots more specifically. We then describe the results of our study and their contributions to HRI and the study of technology and privacy, and provide design suggestions for robots and other monitoring technologies meant for home use.

2. BACKGROUND

2.1 Assistive robots for older adults

The imminent likelihood of using robots in the aid and care of older adults raises both the promise of helping people achieve their goals of independence and dignity (e.g. [12]) and concerns that robotic technologies might jeopardize the human rights of elders [25]. Based on an ethnographic study of the homes and everyday practices of older adults, [12] suggest that robotic technologies should conform to the local social ecology, support the values of independence and dignity, and also adapt to other actors in the environment to be appropriate for and helpful to older adults. Other researchers mention the possibility that using monitoring robots will deprive elders of much needed social interaction, infringe on their privacy, and cause loss of freedom and autonomy as robotic systems start making decisions and taking actions in the homes of elders [25]. [23] also suggest that the availability of robots will inevitably decrease older adults' access to the human touch, an often forgotten but necessary component of car. They also caution that robots as monitors and telepresence devices may have a negative impact on the relationship between caregivers and receivers as both parties come to rely on technology more and more. More research on specific applications and in different contexts of use is necessary for developing appropriate design guidelines and practices for assistive robots for older adults.

2.2 Privacy in human-computer interaction

While it is beyond the scope of this paper to review the literature related to privacy in HCI in its entirety (for a review see [14]), we do want to highlight one particularly relevant issue we are interested in exploring in this study: the finding that privacy attitudes often do not match privacy behaviors (e.g., [1]). For example, in the context of e-commerce online disclosure of personal information while interacting with an e-commerce site did not match privacy preferences users had previously stated [24].

[2] offered a number of possible explanations as to why this mismatch may occur including limited information, self-control problems and bounded rationality. However, another possibility is simply *awareness*. Awareness in this case includes awareness of what information is being exposed and to whom it is being exposed (see [5]). Because information and communication technologies do not offer the rich social experience that interacting with other humans offers, differences in privacy behaviors may be explained by lack of cues about to whom information is being transmitted as well as the amount and content of information. Put simply, peoples' stated attitudes about privacy may differ from their behaviors because they are not fully aware of what information they are revealing and to whom. While some recent work has been done to provide more cues to people as they make privacy decisions (e.g, [6]), this explanation remains underexplored. Notably, in terms of this study, if this explanation is correct, there is great potential for robots to represent feedback and provide awareness to users better than other information and communication technologies because of their embodied nature.

2.3 Privacy in human-robot interaction

HRI scholars (Kahn et al 2007, Feil-Seifer et al 2007) emphasize privacy as an important benchmark in the design of "increasingly humanlike" and assistive robots. [16] suggest that the presence of robots might affect a user's sense of privacy, particularly in relation to the robot's ability to monitor and collect information about the individual. [11] propose that robots differ from other pervasive technologies because users can see when robots are observing them and send them away or avoid them, thus potentially providing more possibilities for protecting user privacy (p. 430). Robotic embodiment has already been identified and studied as an important factor in assistive applications for older adults [18], providing the user with a more naturalistic interaction interface and encouraging the development of a relationship with the technology. In a user study with 12 older adults, Beer and Takayama [3] cite that the concern for privacy is the second highest category mentioned by elders and suggest that features allowing users to refuse monitoring when they want could address some of these concerns. [17] also suggest that privacy-oriented design is important for robots that operate in everyday human environments, pointing out that users may not be aware of the sensory capabilities of robots and that they would like to be informed of times when they are being recorded or monitored.

2.4 Overview of the Study

In this study we sought to evaluate the possibility privacy in computer-based communication, specifically a camera, is different from privacy when using embodied monitoring devices (i.e., robots). To accomplish this we conducted an experiment. To elicit privacy concern ethically, we generated a scenario where each older adult participant was told they should plan a surprise party for a caregiver who was monitoring them using a monitoring device. Further details of the experiment are described below.

3. METHODS

3.1 Participants

Participants were 18 older adults between the ages of 69 and 88 recruited from a local retirement community through posted advertisements and by word of mouth. There were 11 women and 7 men and all participants lived independently. See Table 1 for detailed demographic information.

Table 1. Demographic information for participants

	Overall (N=18)	Camera (n=6)	Stationary Robot (n=6)	Mobile Robot (n=6)
Age				
Mean	81	82	80	80
SD	(5.5)	(7.1)	(3.0)	(6.1)
Race				
White	100%	100%	100%	100%
Gender				
Female	61%	50%	50%	83%
Male	39%	50%	50%	17%
Income				
$30- 49k	6%	17%	0%	0%
$50- $74k	33%	0%	33%	67%
>$75k	56%	83%	50%	33%
Prefer not to answer	6%	0%	17%	0%
Education				
Some College	17%	0%	17%	33%
College	83%	100%	83%	67%

Living Situation				
Alone	56%	50%	67%	50%
W/Spouse	39%	50%	33%	33%
W/Family	6%	0%	0%	17%
Marital Status				
Married	39%	50%	33%	33%
Widowed	55%	50%	50%	67%
Never Married	6%	0%	17%	0%

3.2 Design

The study was a between subjects design. Participants were randomly assigned to one of the three possible monitoring devices: camera, stationary robot, and mobile robot.

The main objective of the study was *to evaluate users' perceptions of privacy of three types of monitoring technologies designed to support older adults' ability to age in place in their own home.* To accomplish this, we focused on the following research questions and hypotheses:

RQ1: Will older adults' level of comfort with household activities change when they assume that they would be monitored?

- H_0: $|\Delta CHA| = 0$
- H_1: $|\Delta CHA| \neq 0$

RQ2: Which activities would be considered more comfortable to be performed while being monitored and which activities would be considered less comfortable?

- Exploratory/descriptive (no specific activities hypothesized)

RQ3: Will older adults' level of comfort with household activities change differentially by device type?

- H_0: $|\Delta CHA|$ camera = $|\Delta CHA|$ stationary robot = $|\Delta CHA|$ mobile robot
- H_1: $|\Delta CHA|$ camera < $|\Delta CHA|$ stationary robot < $|\Delta CHA|$ mobile robot

RQ4: Will the proportion of older adults who engage in privacy enhancing behaviors (PEBs) differ by type of monitoring device?

- H_0: # of PEBs camera = stationary robot = mobile robot
- H_1: # of PEBs camera < stationary robot < mobile robot

RQ5: What types of PEBs do older adults utilize to maintain privacy while being monitored?

- Exploratory/descriptive (no specific behaviors hypothesized)

3.3 Materials

3.3.1 Questionnaires

Participants filled out four questionnaires at the beginning of the study: a demographics questionnaire, the Privacy Attitudes Questionnaire (PAQ; a modified Westin segmentation index), the Negative Attitudes towards Robots (NARS; [20]), and the modified comfort with household activities (CHA) questionnaire. The demographics questionnaire enquired about participants' age, gender, household income, etc. The PAQ enquired about participants' general privacy attitudes. The NARS measures people's existing attitudes towards robots, and the modified CHA assessed general levels of comfort performing activities within a home environment. We developed the modified CHA using Frye and Dornisch's [13] disclosure topics as the basis of our questionnaire items.

After participants had interacted with the monitoring technology, we administered two post-test questionnaires: The Collected Robot Scales and the modified CHA. The Collected Robot Scales were used to assess the perceptions of our participants on the home monitoring technologies they encountered. It was constructed by combining the "Godspeed Scale" [2], which includes measures of animacy, anthropomorphism, likeability, perceived intelligence, and perceived safety and Nonaka et al's (2004) 6-level scale for "fear," "surprise," "disgust," and "unpleasantness."

The same modified CHA (described above) was used in the post-test, however, this time, participants were asked to fill in the modified CHA considering the device they were exposed to during the study was present in their home. Change scores were calculated for each question on the CHA such that the post-CHA score was subtracted from the pre-CHA score.

3.3.2 *Interview*

A verbal semi-structured interview was used to gathered information about the participant's perceptions. The interview covered topics such as users' reasons for (or reasons for *not*) performing privacy enhancing behaviors, comfort with tasks, perceptions of invasiveness of devices, and overall impressions of the home monitoring technologies. One area of specific interest was PEBs. Each participant was asked if they engaged in any PEBs while performing the tasks assigned for the study. If the participant answered yes, the interviewer asked what type of behaviors the participant performed. If the participant answered no, the interviewer followed up to determine why no PEBs were employed. Next, researchers asked each participant how they thought the monitoring technology they experienced worked, how comfortable participants were performing the tasks, and to report any previous experience with monitoring technologies. In addition, participants were asked to describe situations when use of monitoring devices would be appropriate and or inappropriate and whether or not participants would use a monitoring technology such as the one they had interacted with in their home.

3.3.3 Scenario and tasks

To be able to observe participants performing tasks that would be appropriate in the home environment and give them an opportunity to engage in PEBs, we asked participants to imagine a scenario in which they were preparing a surprise birthday party for their caregiver. Participants were given a task list to complete in planning the fictional surprise birthday party; they were also asked to record completed tasks on the list. The tasks, in order of performance, included making a phone call to confirm a guest's attendance, blowing up a balloon, hanging a "Happy Birthday" banner, answering the door to receive a flower delivery, placing flowers in a vase, icing a cupcake, using sanitary wipes to clean their hands, putting on a tee shirt, and evaluating their appearance in a mirror.

3.3.4 Monitoring Technologies

Participants interacted with one of three types of monitoring technology participants during the study — a wall-mounted camera, a stationary robot, and a mobile robot. The camera was chosen because of its ubiquity and familiarity to users, the stationary robot was basically a camera mounted on a robotic body, while the mobile robot provided the kind of interaction one

might expect from a monitoring robot, following the participant around the experimental space.

The wall-mounted camera was an Axis 215 PTZ camera, whereas the stationary and mobile robots used the same robotic platform with a webcam mounted on top. However, the stationary robot and the mobile robot exhibited different behaviors. The robot we used is an off-the-shelf Videre model mobile platform, shown in Figure 1. The robot is approximately 40cm by 41cm by 15cm and is regularly used in university lab research with human subjects. In the stationary condition, the robot was placed in the room and did not move from its spot throughout the study. In the mobile robot condition, a research assistant teleoperated the robot to move around the room, generally trailing the participant as they moved around the space.

Figure 1. Robotic platform used in stationary and mobile conditions, wall-mounted pan-tilt-zoom camera.

3.3.5 Recording apparatus

We used a GoPro HD camera to visually capture participants' behavior throughout the study. Verbal data was collected using a digital voice recorder.

3.4 Procedure

The study took place at the R-House Living Lab at Indiana University, a five-room house used for research on human-robot interaction and the design of domestic interactive technologies. Once participants arrived at the R-House, researchers obtained informed consent. Participants were then asked to fill out the pre-test questionnaires and were randomly assigned to one of three monitoring device conditions: camera, stationary robot, or mobile robot. Next, participants were asked to give us the name of someone who could be a caregiver to them, should the need arise. Afterwards, participants were introduced to the monitoring technology to which they had been randomly assigned.

Next, participants were given a scenario that described a fictional surprise birthday party for the caregiver they imagined and asked to prepare for that surprise party by performing the tasks on a list provided for the purpose (see section 3.3.3 for a more thorough description of the tasks). The research assistant performing the study then left the room and observed the participants via camera until all tasks were completed or 30 minutes had passed. Afterwards, the research assistant returned to the room, conducted a semi-structured interview and administered the two post-test questionnaires. At the conclusion of the study, participants were debriefed as to the purpose of the study and remunerated $20 for their time. The entire study took approximately 1½ hours.

4. RESULTS

In the following section we discuss findings from each of the 5 research questions outlined in section 3.2.

4.1 Comfort with Household Activities

The first thing we were interested in was to understand how general comfort performing household activities would change in a non-monitored versus monitored home. To determine the difference in comfort with household activities between a non-monitored home and a monitored home we calculated the difference between the pre- and post-CHA score for each household activity (ΔCHA).

Overall 15 household activities changed by at least a quarter of a point (note that a positive change score indicates a *decrease* in comfort when in a home with a monitoring device).

Table 2. Activities where participant comfort decreased

	Participants (N=18) Mean ΔCHA (SD)
Engage in sexual activity with a partner	3.4 (2.6)
Engage in physical contact with an intimate partner	1.9 (3.3)
Take a shower	1.3 (2.1)
Engage in sexual activity by myself	1.2 (2.8)
Practice personal hygiene	0.8 (2.1)
Take a bath	0.8 (2.2)
Do personal finances (pay bills, write checks)	0.7 (1.6)
Have friends over	0.3 (1.2)
Blow my nose	0.3 (0.8)

There were 9 activities where comfort with performing decreased with the addition of a monitoring device in the home (see Table 2) and 6 activities where comfort increased (see Table 3).

Table 3. Activities where participant comfort increased.

	Participants (N=18) Mean ΔCHA (SD)
Engage in a argument	-.72 (2.2)
Exercise	-.56 (1.6)
Dance around the house	-0.5 (2.0)
Drink alcohol	-.33 (1.6)
Express my political views	-.33 (1.3)
Watch any movie	-.39 (1.2)

In addition we were interested in understanding whether level of comfort changed differently based on the type of monitoring device (camera, stationary robot, or mobile robot).

A one-way ANOVA was used to test for differences in change scores by monitoring device type. The change score for two household activities differed significantly by device type (ps < .05; see Table 4). None of the other change scores significantly differed by device type (ps > .05).

Table 4. ANOVA of ΔCHA

	Device Type				
	Camera *Mean* (SD)	Stationary Robot *Mean* (SD)	Mobile Robot *Mean* (SD)	F	*p*
Alcohol	0 (0)	.67 (1.37)	-1.67 (1.86)	4.88	.023
Sex	5 (1.55)	4.67 (1.37)	.50 (1.76)	15.36	.001

4.1.1 Alcohol

Bonferroni adjusted post-hoc comparisons of the three device types indicate that participants in the mobile robot group increased their comfort level with respect to consuming alcohol in a home containing the mobile robot whereas the Camera or Stationary Robot had very little change in their reported comfort with consuming alcohol, p = .025. There was no significant difference between the Camera and Stationary Robot (ps < .14).

4.1.2 Sex

Bonferroni adjusted post-hoc comparisons of the three device types indicate that participants in the mobile robot group changed their comfort level very little with respect to engaging in sexual activity with a partner in a home containing the mobile robot whereas participants in the Camera and Stationary Robot conditions reported significantly *more* concern, p = .001. Comparisons between the Camera and Stationary Robot were not statistically different (ps < .99).

4.2 Privacy Enhancing Behaviors

Privacy enhancing behaviors are behaviors that people engage in to avoid, modify, or alleviate privacy concerns [5]. We were interested whether PEBs differed by monitor type, what PEBs older adults would engage in, how frequently older adults engaged in PEBs, and to understand older adults PEB perceptions.

4.2.1 Privacy Enhancing Behaviors by Monitoring Type

The first thing we wanted to understand was whether or not there were differences in privacy enhancing behaviors by monitoring device type. Because our sample size was not large enough to use a chi-square test (requires minimum expected cell count of 5; we had expected cell counts of 3), we used a Fisher's exact test. Fisher's exact test is most appropriately used with a 2 x 2 contingency table, so we pooled participants into "robot" and "camera" conditions for this analysis (however, see Table 5 for the percentage of participants who engaged in PEBs by monitoring device type).

Table 5. Privacy enhancing behavior by monitoring type

PEB	Camera (n=6)	Stationary robot (n=6)	Mobile robot (n=6)
Yes	67%	17%	17%
No	33%	83%	83%

Applying Fisher's exact test, the proportion of participants in the camera condition who engaged in PEBs is significantly more than the proportion of participants who engaged in PEBs in the robot conditions (p = .057). While 67% of the participants in the camera condition engaged in PEBs only 17% of participants in the robot condition engaged in PEBs. Participants in the camera condition were significantly more likely to engage in a PEB than participants in the robot condition.

4.2.2 Quantity of Privacy Enhancing Behaviors

In addition to examining the presence of PEBs, we also wanted to understand, for participants who *did* engage in privacy behaviors, how often they engaged in PEBs over the course of the study.

Overall, 6 of 18 participants engaged in PEBs during the session. However, there was a range in the *quantity* of PEBs per session. While most participants engaged in between 1 - 5 PEB per session, 2 participants (one in the camera and one in the mobile robot condition) displayed 12 PEBs each.

4.2.3 Quality of Privacy Enhancing Behaviors

To understand the range of behaviors participants used to enhance privacy while being monitored we examined the video of each participant during the session. PEBs included:

- covering up camera with an object (e.g. painting, scotch tape)
- turning camera in opposite direction (on robot)
- censoring speech during phone calls
- setting the party up in a different room
- moving their bodies out of sight of camera (to another room, behind furniture)
- turning their back towards the camera
- covering chest to hide "happy birthday" printed t-shirt (see Figure 2 for screenshot of participant hiding the contents of her t-shirt)
- obscuring objects with their body and/or other objects in the room (see Figure 3 for screenshot of participant hiding flowers behind her back)
- walking backwards

Figure 2. PEB: Flowers Behind Back

Figure 3. PEB: Arms Covering Chest

In addition to objective observable behaviors, we were also interested in participants subjective self-report of their PEBs. When we asked participants about whether they engaged in any PEBs, many participants reported specific PEBs. In the quotes below, participants who were in the camera condition are identified by 'cXX', those in the stationary robot condition by 'srXX', and those in the mobile robot condition by 'mrXX.'

For example, participants described how they tried to "hide" (mr025) from or "stay out of line" (c024) of the monitoring device. Similarly, others described how they occluded what they were doing using their body and objects in the room:

> *"I stood with my back to camera so they couldn't see the number I was dialing…. The next task was to blow up the balloon so I got behind the chair... I left the balloon behind the chair until I had tape to put it under the camera"(c24)*

> *"[I]… did everything [in the conference room] that I could including hanging the banner. And when I came in here with the shirt I tried to keep my back faced this way." (c7)*

Three participants also reported censoring what they said on the phone to avoid letting the caregiver hear about the birthday party:

> *"I was pretty oblique... I avoided saying when it was or what it was about." (c24)*

> *"I just said she could come over… [instead of mentioning birthday plans]." (c20)*

> *"I figured she [my caregiver] wouldn't have any idea who it [party guest] was so it wouldn't make any difference because I would certainly be calling other people at other times… I didn't say anything… about the party"(c7)*

5. DISCUSSION

5.1 Comfort with Household Activities

5.1.1 Change in Level of Comfort

There were 9 activities where comfort with performing household activities decreased with the addition of a monitoring device in the home and 6 activities where comfort increased. Upon reflection, many of the activities where comfort decreased were activities that could be thought of as sensitive or private. For example, the 4 activities with the greatest decrease in comfort level were related to being nude and 3 of the 4 were related to intimate activities.

On the other hand, many of the activities where comfort increased may be thought of as potentially dangerous activities. For example, engaging in an argument could raise one's blood pressure, while engaging in exercise or dancing around the house could result in a fall.

The evidence from the change in CHA scores indicates that participants understood the functionality of the monitoring systems, had privacy concerns about being watched while performing some activities (e.g., showering), but reported that they would be *more* comfortable performing some potentially dangerous activities in a home containing monitoring devices.

5.1.2 Change in Level of Comfort by Device Type

We were also interested in understanding whether level of comfort with household activities changed differently based on the type of monitoring device (camera, stationary robot, or mobile robot). We found that the change score for two household activities (consuming alcohol and engaging in sexual activity with a partner) differed significantly by device type.

Participants in the mobile robot condition reported increased comfort with respect to consuming alcohol while participants in the other two conditions changed their comfort level very little. One possible explanation for the increased comfort with the mobile robot rather than either the stationary robot or camera is that participants may have thought that the mobile robot could find them should they need assistance if they had too much to drink. Thus, the mobile robot could be thought of as helpful and therefore make older adults feel more comfortable.

As for the idea of engaging in sexual activity with a partner, participants comfort levels in the mobile robot condition changed very little from their initial comfort score to the score taken while considering engaging in the activity with the monitoring device present, whereas participants in the camera and stationary robot conditions reported significantly *more* concern when considering engaging in the activity with the monitoring device present. One possible explanation for this is that participants in the mobile robot condition may have thought they could "shoo" or tell the robot to leave the room should they decide to engage in such activity, or perhaps the person controlling the robot would decide to leave of their own accord.

5.2 Privacy Enhancing Behaviors

Overall we found that older adults in each of the three monitoring conditions engaged in PEBs. The quantity of PEBs participants expressed ranged from 1 PEB to 12 PEBs over the course of the session. PEBs were varied and included covering up the camera with an object, censoring speech during phone calls and covering up the chest to hide the "happy birthday" printed t-shirt. In addition to these objective, observable behaviors, participants also described the PEBs they exhibited in their own words. In general, they told us they changed their behavior to hide from the

monitoring device so that their caregiver would not see them preparing for the party.

Taken together, this triangulated evidence from both objective and subjective sources suggests that *older adults will change their behavior in the home if they are concerned about their privacy due to in-home monitoring.* A number of researchers have suggested that monitoring devices, especially cameras, are associated with privacy concerns, however, the evidence reported here is the first behavioral study to demonstrate that privacy concerns lead older adults to change behavior in a home environment when they are monitored by a variety of monitoring devices, including embodied robots.

In addition to examining whether older adults would change their behavior due to privacy concerns, we also examined how these behaviors differed by type of monitoring device. We expected participants in the mobile robot conditions to engage in *more* PEBs than participants in the stationary robot condition, and participants in the camera condition to engage in *fewer* PEBs than in either of the robot conditions. We expected this because the embodied presence of robots in the user's environment could make users more aware of being observed (e.g., [11]) and thus more likely to take actions to preserve their privacy. The results of this study, which show that more participants engaged in PEBs when being monitored by a camera, may be interpreted as evidence that is counter to the suggestion that users would be more aware of being observed. However, an alternative explanation is related to existing research on tele-operation and the elderly [17], which suggests that users may not be familiar with the capabilities of robots and therefore may not be aware of when they are being monitored. In contrast, people may already be quite familiar with cameras and may have already developed privacy enhancing behaviors and practices. Admittedly, in the case of our study, the robots also had visibly attached cameras, but users' lack of familiarity with robotic technologies may have trumped their recognition of the function of the mounted cameras.

To evaluate these explanations we examined the post-session interview data to understand how participants explained why they *did not* engage in PEBs. Users provided a variety of reasons for not engaging in PEBs. One reason, mentioned by four participants (sr12, sr10, sr12, mr21), was that they assumed the monitoring caregiver was in a position from which they would not be able to observe them at the time they were preparing for the party. In the words of one participant: *"I figured she would be on her way over and wouldn't be able to see it anyway…"* (mr21) Another participant explained that the activity they engaged in would not be recognizable as preparation for a surprise party: "*I thought he might see me working. But I didn't think he would catch on.*" (sr17) mentioned they were not bothered by the idea that the person might see what they were doing, *"Anyway I wouldn't be embarrassed if he saw me doing that."*

Many participants (c9, sr19, c22) reported that it never occurred to them to engage in PEBs: "*No. I didn't think of it."* (*sr 19); "It never occurred to me." (c9).* One reason given for this was that participants were too engrossed in following the task-related directions to worry about being monitored; "*No. I didn't know I was supposed to, I was just following directions," (c22)*.

Some participants also questioned the technology's capabilities to monitor them: *"It wasn't at the right place, it didn't have the capability" (mr18).* One participant also mentioned not minding the robot *"It was moving around and for some reason or other it never bothered me. I paid no attention to it. As if it wasn't there" (mr013).* Such comments suggested participants' perceptions of the affordances of the robot—it was relatively low to the ground, while the stationary camera was mounted in one corner of the room next to the ceiling affording a wider angle of view. This explanation is particularly reasonable for the stationary robot, which did not give any indication of monitoring the person. However, the mobile robot followed the participants around the space as they did the tasks, giving them an ostensible indication of that the monitoring function was indeed working.

Our interpretation that participants may not be familiar with robots, and therefore less wary of their monitoring capabilities, was not born out by the interview data. When asked what they thought the monitoring technologies were doing, participants had some reasonable ideas for all three conditions. For the camera, they mentioned that it could "*see me instantly like a TV, 24/7" (08), "I'm assuming it just took a picture of me or could spot the motion" (020), "It would probably pick up audio from anywhere in the room even if I was out of eyesight or camera sight" (sc24).* The stationary robot was described similarly, as similar to Skype (012sr), or a *"remote TV and speaker type system" (011sr),* while participants describing the mobile robot focused on its responses to their movements: "*The motion attracts it every time" (mr06), "I felt like it was kind of following me around" (mr018).* More research is needed to figure out why participants did not respond by engaging in privacy enhancing behaviors while being monitored by the robot when they expressed understanding of its basic functions. One alternative explanation we will continue to explore is that participants in both robot conditions believed their caregiver might not have been monitoring them during the time they were to complete the tasks.

6. CONCLUSIONS

This paper presented the results from an experimental study of the privacy-related behaviors and perceptions of older adults participants interacting with three types of monitoring technology: a camera, a stationary robot (with camera), and a mobile robot (with camera). We were particularly interested in seeing how older adults reacted to the two robots in comparison to the camera, as there has been little empirical research on privacy behaviors in the context of human-robot interaction. While HCI researchers have investigated privacy with respect to many technologies (e.g., mobile, cameras, internet, social networking) our work is the first to consider the notion of embodied and interactive monitoring technologies, such as robots. The literature in HRI has so far not delved into empirical research on privacy behaviors around robots, but one of the expectations researchers have put forth is that robots might enable users to protect their privacy more effectively, since they are physically larger than cameras, their movements are obvious to users and they can be asked to move out of the room, and thus evaded when desired.

Our study specifically addressed this area at the intersection of HRI and HCI, looking at embodiment in respect to privacy. We hypothesized that an embodied, mobile monitoring technology would increase participants' use of PEBs, but we found the opposite to be true—fewer participants engaged in PEBs around robots. While we discussed potential explanations for this finding, more research is needed to evaluate these and other explanations. In the future, we propose to do more research to find out why this is the case, as we were only able to get a partial understanding from user comments in final interviews.

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