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Perceptions of socially assistive robots: A pilot study exploring older adults' concerns

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Abstract

With growing interest in geriatric applications for socially assistive robots (SARs), further research is required to understand potential barriers of acceptance among older individuals. Much of the existing work has focused on individuals in assistive and long-term care, with fewer examinations of adults who choose to age-in-place. Additionally, limited work has examined older American's concerns regarding the use of this form of technology. Therefore, the current pilot study examined potential determinants to acceptance of SARs among independent-living older adults in the United States. This pilot study included older community-dwelling individuals from a mid-sized city in Oklahoma that participated in a larger study on SARs. Participants completed a brief survey on potential concerns related to SAR qualities and capabilities as well as measures of demographic information, psychosocial features, and technology perceptions. Participants reported primary concerns related to privacy and security and the potential for hacking. Alternatively, appearance and the ability for robots to detect sound and record conversations were non-concerns. Analyses also explored demographic, psychosocial, and technological features related to participants' extent of concern regarding SARs. In sum, the current pilot adds to the limited work on older American's perceptions of socially assistive robots. Findings provide an initial understanding of the barriers to accepting SARs' among independent-living older adults in the United States. Findings on older individuals' concerns can be used to improve design elements of SARs and inform implementation efforts to improve the likelihood that older adults use and benefit from companion robots.

Keywords Aging · Technology · Assistive technology · Consumer preferences

Social isolation, or the perceived disconnectedness amid feelings of loneliness (Cornwell & Waite, 2009), is a prevailing concern for aging adults (Holt-Lunstad, 2017; Lubben, 2018). Current estimates suggest that isolation affects more than eight million older adults (AARP, n.d.). Without monitoring or intervention, social isolation can contribute to a wide array of co-occurring infectious and chronic diseases, neuropsychological deficits, and depression in older adults (Cornwell & Waite, 2009) and can result in early mortality (Holt-Lunstad et al., 2015). Gerontologists have begun to systematically reexamine viable interventions for reducing prolonged social isolation (Cohen-Mansfield & Perach, 2015; Findlay, 2003), and smart robotic technologies are a potential therapeutic intervention for increasing sociability (Khosravi et al., 2016). As geriatric care settings integrate novel technology, socially assistive robots (SARs) will likely become a viable tool used to monitor behavior and provide companionship (Frennert & Östlund, 2014).

Researchers investigating the therapeutic effectiveness of SARs have reported positive effects involving socio-psychological improvements surrounding social connectedness

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and interpersonal communication (Bemelmans et al., 2010). Furthermore, SARs can effectively reduce physiological stress parameters that often accompany low cognitive stimulation, poor social engagement, or feelings of loneliness in old age (Bemelmans et al., 2010). For instance, engaging with the Socially Assistive Pet Robot, PARO (Shibata & Wada, 2011; Wada et al., 2007), has been shown to stimulate social interactions and reduce feelings of loneliness among older dementia care recipients (Petersen et al., 2017; Robinson et al., 2013; Yu et al., 2015). Beyond the benefits to those in long-term care facilities, human-robot interaction is a promising social framework for improving quality-of-care among older adults who age-in-place (Alves-Oliveira et al., 2015). However, much of the research on the benefits of interacting with SARs primarily focuses on the utility of SARs among those diagnosed with cognitive impairments in care facilities (Pu et al., 2019). Thus, there is a need to understand the potential benefits of SARs among non-institutionalized community-dwelling older adults.

If SARs are a viable tool for reducing social isolation and increasing connectedness among independently living older adults, research is required to identify possible barriers of technology acceptance that may contribute to whether older adults accept this technology. Gerontechnology experts contend that older adults are often less likely to adopt and continue to use novel technologies compared to other age groups, often resulting in a "digital divide" (for review, see Neves & Vetere, 2019). Origins of this phenomenon evolved from classical thinking proposed within the Knowledge Gap Hypothesis (Tichenor et al., 1970), which posits that the emergence of sophistically advanced technological tools and devices contribute to a gap among individuals who accept, adopt, and use technology and those who do not. Growth in this divergence is hypothesized as being exacerbated by three key barriers, including limited access to the economic means necessary to purchase cutting-edge technologies, low technology literacy impacting proper usage, and poor emotional regulation of psychological distress arising from situations requiring technology use. As technology continues to advance, age-based divisions in the use and adoption of information and communication technologies (ICTs), such as smartphones, tablets, computers, internet, and social networking platforms (Anderson & Perrin, 2017; Tsatsou, 2011), as well as robotic technologies (Berde, 2019) persist. Incorporating novel technologies, like SARs, into everyday life can help older individuals maintain and enhance their well-being; and thus, examining possible barriers that may prevent or discourage older adults from adopting SARs could help close this gap.

Recent empirical examinations suggest that technology acceptance and use among older adults may depend on one's preconceptions and preferences (Vandemeulebroucke et al., 2018). There is some indication that first impressions surrounding the appearance, comfort, and practicality of technology are essential for successful integration (Beer et al., 2012; Charness et al., 2017), whereas others contend that privacy and monitoring capabilities dictate whether clinicians can effectively implement positive therapeutic intervention (Cain et al., 2012; Goher et al., 2017). Other features such as the monetary costs (Bedaf et al., 2015; Pearce et al., 2012), data security, auditory comprehension abilities, and technological support requirements of such devices could prevent older adults from owning and using this technology at-home (Pino et al., 2015; Vandemeulebroucke et al., 2018). That being said, older adults willing to use SARs often report that such technology provides autonomy (e.g., meeting daily activities-of-living), personal safety (e.g., monitor and detect falling), cognitive assistance (e.g., memory retrieval), entertainment (e.g., listening to news or music), and companionship (e.g., prevention of feeling lonely; Vandemeulebroucke et al., 2018; Pino et al., 2015). If research can better identify characteristics that determine whether older adults adopt SAR technology, then technology developers could address these barriers and improve the likelihood that older individuals would use and benefit from this technology.

Much of the previously mentioned research on the barriers of SAR acceptance examined preferences and concerns among older adults from European countries (for review see Vandemeulebroucke et al., 2018). Concerns regarding robotic design, functionality, technical operation, and other capabilities among older Americans have received limited attention (Prakash & Rogers, 2015; Smarr et al., 2014). Consequently, it is unclear whether Americans share similar concerns that could prevent them from adopting and benefitting from SAR technology. Considering that a greater proportion of older Americans live alone compared to other countries (Ausubel, 2020), many older Americans may require and benefit from having access to social companionship provided by SARs. Therefore, it is necessary to understand what features may either encourage or prevent older individuals in the United States from accepting SAR companionship.

Current Study

The aim of this pilot study was to examine initial concerns related to the use and acceptance of SARs and identify potential determinants of robot acceptance in a sample of healthy community-dwelling older adults in the United States. Participants completed a questionnaire developed for this study that was based on documented concerns regarding the use of SARs previously examined among European older adults (Pino et al., 2015; Vandemeulebroucke et al., 2018). Our initial goal in developing the concerns measure was to document similar patterns of previously reported concerns, now among older adults in the United States, in hopes of using this data to develop a prototype SAR for future research. Unifying themes presented in previous research on older adults' concerns regarding the use of SARs (Bedaf et al., 2015; Pearce et al., 2012; Smith & Anderson, 2017; Vandemeulebroucke et al., 2018), we anticipated that older adults would report being concerned with SARs' monitoring abilities, sound detection and recording abilities, hacking potential, the safety and security of private or personal information, the extent of required technological support, user operation requirements, purchase and maintenance costs, and the potential to replace humans as care providers. Alternatively, we expected that older adults would *not* be concerned about SARs' appearance, companionship and emotion detection abilities, potential to restrict personal autonomy, increase stress, or cause risk of harm or injury to humans based on previously documented findings (Pino et al., 2015; Smarr et al., 2014; Smith & Anderson, 2017).

Finally, we examined participants' reported levels of social support, loneliness, and depression to address whether any of these features correlated with their overall concern related to SAR acceptance. If SARs are going to provide companionship in the future, it is possible that older individuals who currently feel as though they lack companionship or are more lonely or depressed may see greater opportunities for the utility of this technology compared to individuals who already have social support (for similar arguments, see Andrews et al., 2019). However, the inclusion of these variables was largely exploratory, and therefore we did not develop specific hypotheses related to these socioemotional variables. Findings from the current pilot study contribute to the relatively limited research on older American's preferences for SARs with the ultimate goal of revealing potential barriers to technology acceptance that may have implications for future development.

Methods

Participants and Procedures

A convenience sample of 51 community-dwelling older adults was collected as part of a larger study on SARs. Participants were recruited by distributing flyers, making community announcements, and snowball sampling methods at a senior life-long learning program, nutrition site, and independent-living complexes in a mid-sized community in Oklahoma. To participate, individuals needed to be 60 years-of-age or older and live independently. The current sample included 44 older adults (range: 60–92 years; $M_{age} = 74.32$ years, $SD_{age} = 8.35$ years), that were predominantly female ($n = 31$) and identified as being White/ Caucasian ($n = 36$; see Table 1 for additional sociodemographic information). During the study, all participants read and signed a university-approved institutional review board (IRB) consent form before participation.

Table 1 Sociodemographic Characteristics of Participants

	n (%)
Age (*M*=74. 32 years, *SD*=8.35 years)	
60s	13 (29.5)
70s	20 (45.5)
80s	9 (20.5)
90s	2 (4.5)
Gender	
Male	13 (29.5)
Female	31 (70.5)
Race	
White/ Caucasian	36 (81.82)
Black/ African American	4 (9.09)
American Indian	1 (2.27)
Asian/ Asian American	1 (2.27)
Native/ Pacific Islander	1 (2.27)
Alaskan Native	1 (2.27)
Marital Status	
Never married	4 (9.1)
Married	21 (47.7)
Divorced	4 (9.1)
Widowed	15 (34.1)
Education	
Some high school	1 (2.27)
High school diploma	7 (15.9)
Some college	8 (18.2)
Associate arts degree	4 (9.1)
College degree	4 (9.1)
Graduate degree	10 (22.7)
Ph.D./ Doctoral degree	10 (22.7)
Self-Reported Health	
Poor	1 (2.27)
Fair	10 (22.7)
Good	26 (59.1)
Excellent	7 (15.9)

Based on 44 participants

Participants then completed a series of paper-and-pencil surveys that included a demographics measure and several standardized questionnaires. At the completion of the session, all participants were debriefed and thanked for their participation.

Measures

Robot Concerns Measure

The Robot Concerns measure was developed to directly examine possible concerns about features of SAR technology.

The 15 items on this measure were adapted from previously reported concerns (i.e., monitoring abilities; the potential for SARs to replace humans as care providers; sound detection and recording abilities; hacking potential; safety and security of private or personal information; purchase costs; repair and maintenance costs; extent of required technological support; user operation requirements) and non-concerns (i.e., the potential for SARs to increase stress; size, color, and appearance; emotion detection abilities; companionship abilities; potential for SARs to restrict personal autonomy; risk of harm or injury to humans due to SARs) related to the use of SAR technology. Participants reported whether they were concerned (Yes/No) about each of the items on this measure. Overall, the Robot Concerns Measure was reliable ($\alpha = .86$), as were the subscales for the hypothesized concerns ($\alpha = .79$) and non-concerns ($\alpha = .73$).

Perceptions of Social Robots Questionnaire

The Perceptions of Social Robots Questionnaire (PSRQ), originally developed by Nomura et al. (2007), addressed participants' current feelings towards SARs across 5-items. Compared to the Robot Concerns measure, the PSRQ addressed participants' general emotions about SARs rather than focusing on specific concerns. Participants responded using a 5-point Likert-type scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*) on questions related to positive (e.g., "*I find guidance provided by robots effective.*") and negative (e.g., "*I feel anxiety about the possible widespread application of robots to perform tasks in the near future.*") feelings towards robots. Overall, the PSRQ was reliable ($\alpha = .73$), as were the subscales for positive ($\alpha = .79$) and negative ($\alpha = .73$) feelings towards SARs. Higher PSRQ scores indicated more positive views on SARs.

Technology Readiness Index

The Technology Readiness Index (TRI; Parasuraman, 2000) was included to measure participants' perceptions of technology as a potential explanatory factor related to overall levels of concern and feelings towards SARs. This 10-item measure addressed perceptions of security achieved through technology (e.g., "*I do not consider it safe to do any kind of financial business online.*"), interest in technology (e.g., "*I like computer programs that allow me to tailor things to fit my own needs.*"), and technological expertise (e.g., "*Other people come to me for advice on new technologies.*"). Participants responded using a 1 (*Strongly disagree*) to 5 (*Strongly agree*) Likert-type scale. Overall, the TRI was reliable ($\alpha = .74$). Higher scores on the TRI indicated more positive views on technology.

Social Provisions Scale

To examine the relationship between participants' self-reported levels of social support and their concerns about SARS, the 12-item Social Provisions Scale (SPS; Cutrona & Russell, 1987) was administered. Participants evaluated aspects of their social relations using a 4-point Likert-type scale from 1 (*strongly disagree*) to 4 (*strongly agree*). Sample items include questions on perceptions of social support (e.g., "*There are people I can depend on to help me if I really need it.*"; "*There are people who enjoy the same social activities I do.*"). We found the SPS to be somewhat reliable ($\alpha = .65$). Higher SPS scores represented greater perceptions of social support.

UCLA Loneliness Scale

To examine the relationship between participants' subjective feelings of social isolation and loneliness and their concerns about SARS, participants completed the 20-item UCLA Loneliness Scale (Russell, 1996). Participants rated various statements (e.g., "*I have nobody to talk to*"; "*I feel completely alone*"; "*I lack companionship*") in terms of how often that statement reflects their feelings, using a 1 (*I often feel this way*) to 4 (*I rarely feel this way*) Likert-type scale. Overall, the UCLA Loneliness Scale was reliable ($\alpha = .88$) and lower scale scores represented greater feelings of loneliness.

Geriatric Depression Scale

To examine the relationship between participants' self-reported depressive symptoms and their concerns about SARS, participants completed the Geriatric Depression Scale (GDS; Yesavage et al., 1982). The GDS asked participants to rate 30 items related to depressive symptoms (e.g., *"Do you often feel helpless?*"; "*Do you enjoy getting up in the morning?*") using dichotomous Yes/No responding. Overall, the GDS was reliable ($\alpha = .81$) and higher GDS scores represented greater endorsement of depressive symptoms.

Analytical Procedures

To address older adults' perceptions of SARs and identify potential barriers to technology adoption, we primarily examined the data using Observation Oriented Modeling (OOM). Rather than focusing on population parameters, OOM is a person-centered analytical approach that assesses each individual response to determine how many participants matched the hypothesized patterns of concerns and non-concerns regarding the use of SARs (for recent examples, see Gatobu et al., 2016; Grice et al., 2020). We believe that this approach provides compelling evidence of how many people share the hypothesized concerns and non-concerns more so than does examining the population parameters, especially considering the small sample size of the current pilot study and the ultimate goal of addressing barriers to technology acceptance among individuals. The resulting statistics from OOM analysis include a Percent Correct Classification (PCC) index, indicative of the percentage of participants whose responses match the predicted pattern, as well as a *c*-value, or chance value. The chance value uses a series of randomized trials to determine the probability of obtaining the resulting PCC value. For these analyses, we set the number of randomized trials equal to 1000. The percentages of participants who matched expectations are reported in Table 2 as PCC values with accompanying probability values (*chance*-values, or *c*-values; 1000 trials each) from randomization tests (see Grice, 2011). All other analyses were conducted using IBM/SPSS Statistics 24.0. For analytic purposes, we set the statistical significance threshold at $\alpha = .05$.

Results

Initial Data Cleaning and Scale Analytics

Seven participants were removed from analyses based on incomplete responses on the Robot Concerns measure. No significant differences were observed when comparing participants that were retained and excluded based on age, sex, race, education, marital status, or overall health ($ps > .05$). One participant was retained despite having missing data on the UCLA Loneliness scale to help bolster the sample-size. Their data was not assessed in analyses that included the UCLA Loneliness scale.

One of our primary interests was in participants' reports on the Robot Concerns measure. For that reason, we examined the interitem correlations among the hypothesized concerns and non-concerns (see Tables 3 and 4). Regarding the hypothesized concerns, all items correlated with at least two other hypothesized concerns. The strongest observed relationships were between concerns related to purchase and maintenance costs ($r(43) = .64, p < .001$) as well as between the concern for safety and security of private or personal information and SAR's hacking potential ($r(43) = .60$, $p < .001$). Related to non-concerns, all items correlated with at least one other hypothesized non-concerns. The strongest observed relationships were between the non-concern of companionship abilities and a SAR's ability to increase stress ($r(43) = .53$, $p < .001$) as well as between the non-concern of emotion detection abilities and companionship abilities ($r(43) = .50$, $p < .001$).

Participants' total number of 'Yes' responses on the Robot Concern measure were totaled such that higher scores indicated greater levels of concern. Overall, participants reported an average of 7.36 concerns ($SD = 4.12$) regarding the use of SARs on the Robot Concerns measure. The number of reported concerns did not differ between males ($M = 7.92$, $SD = 3.66$) and females ($M = 7.13$, $SD = 4.33$; $t(42) = .58$,

Table 2 Participant Perceptions of Socially Assistive Robots

	Response Frequencies		PCC	*c*-value
	Concerned	Not Concerned		
Hypothesized Potential Concerns				
Safety and security of private or personal information	34	10	77.27	.001
Hacking potential	31	13	70.45	.004
Repair and maintenance costs	28	16	63.64	.05
Extent of required technological support	27	17	61.36	.08
User operation requirements	25	19	56.82	.21
Purchase costs	24	20	54.55	.31
Potential to replace humans as care providers	21	24	47.73	.67
Monitoring abilities	19	25	43.18	.88
Sound detection and recording abilities	15	29	34.09	.99
Hypothesized Non-Concerns				
Size, color, and appearance	3	41	93.18	< .001
Potential to increase stress	16	28	63.64	.04
Risk of harm or injury to humans	17	27	61.36	.08
Potential to restrict personal autonomy	17	27	61.36	.09
Companionship abilities	23	21	47.73	.65
Emotion detection abilities	24	20	45.45	.76

PCC indicates percent of participants correctly classified. *c*-value represents a probability value of obtaining the PCC based on 1000 random iterations of the data

Table 3 Interitem Correlations Among the Hypothesized Concerns on the Robot Concerns Measure

	1.	2.	3.	4.	5.	6.	7.	8.
1. Safety and security of private or personal information								
2. Hacking potential	.60***							
3. Purchase costs	.38*	.11						
4. Repair and maintenance costs	.38**	.13	.64***					
5. Extent of required technological support	.46***	.31*	.40**	.57***				
6. User operation requirements	.29	.04	.22	.39*	.53***			
7. Potential to replace humans as care providers	.30*	.22	.32*	.16	.29	.19		
8. Monitoring abilities	.36*	.36*	.06	−.01	.32*	.20	.55***	
9. Sound detection and recording abilities	.27	.15	.08	.25	.37*	.24	.27	.34*

*p <. 05; **p < .01; ***p < .001

p = .566). Tables 5 and 6 depict the overall means, ranges, and correlations of the Robot Concerns measure, PSRQ, TRI, SPS, UCLA Loneliness Scale, GDS, and select demographic variables. Participants' total number of concerns negatively correlated with scores on the PSRQ ($r(42) = -.40$, $p = .007$), TRI ($r(42) = -.37$, $p = .015$), and GDS ($r(42) = -.40$, $p = .034$). No other significant relationships between total concerns and the other variables emerged.

Primary Analyses

Participant responses for each of the 15 possible concerns on the Robot Concerns Measure were analyzed using concatenated pattern analyses using Observation Oriented Modeling (see Table 2). Participants were hypothesized to express concerns for nine of the fifteen items on the Robot Concerns Measure. They were not expected to express concerns about the remaining six items. Results indicated that a majority of participant responses were consistent with the expected concerns. For instance, 34 of the 44 participants reported they would be concerned about the safety and security of private or personal information when using a SAR (PCC = 77.27; c-value = .001). Additionally, 31 participants reported they would be concerned about the hacking potential of SARs (PCC = 70.45, c-value = .004). A slight majority of participants also reported being concerned about potential repair and maintenance costs (PCC = 63.64, c-value = .05) and about the extent of technological support required to operate a SAR (PCC = 61.36, c-value = .08) as hypothesized. In comparison, we found that the majority of participants did not fit the hypothesized patterns among the remaining potential concerns. Specifically, only about half of the sample was concerned about purchase costs (PCC = 54.55, c-value = .31) and user operation requirements (PCC = 56.82, c-value = .21). Even fewer participants fit the hypothesized patterns related to SARs' sound detection and recoding abilities, monitoring abilities, and the potential for SARs to replace humans as care providers (PCCs <50%, see Table 2).

Mixed results were likewise observed among the hypothesized non-concerns. The outcome most consistent with the hypothesized pattern was related to appearance; specifically, 41 of the 44 participants indicated they would not be concerned with the appearance of a SAR (PCC = 93.18, c-value < .001). Thus, the appearance and cosmetic design features of SARs appear to be a ubiquitous non-concern among the current sample of older adults. A slight majority of participants indicated that they also would not be concerned about the potential for SARs to increase stress (PCC = 63.64, c-value = .04), to restrict personal autonomy (PCC = 61.36, c-value = .09), or to pose a risk of harm or injury to humans (PCC = 61.36, c-value = .08) as anticipated. However, few participants matched the hypothesized patterns related to SARs' emotion detection abilities or companionship abilities (PCCs <50%, see Table 2).

Table 4 Interitem Correlations Among the Hypothesized Non-Concerns on the Robot Concerns Measure

	1.	2.	3.	4.	5.
1. Size, color, and appearance					
2. Potential to increase stress	.36*				
3. Risk of harm or injury to humans	.16	.47***			
4. Potential to restrict personal autonomy	−.03	.37*	.14		
5. Companionship abilities	.26	.53***	.29	.38**	
6. Emotion detection abilities	.07	.41**	.27	.26	.50***

*p <. 05; **p < .01; ***p < .001

Table 5 Reported Means Related to Participants' Overall Concerns Regarding Socially Assistive Robots, Technology Beliefs and Perceptions, and Well-being

Variable	*n*	*M* (*SD*)	Range
1. Robot Concerns	44	7.36 (4.12)	0–15
2. TRI	44	28.98 (7.12)	5–50
3. PSRQ	44	15.91 (3.91)	5–25
4. SPS	44	41.02 (4.08)	4–48
5. UCLA Loneliness	43	34.42 (7.93)	20–80
6. GDS	44	4.95 (4.27)	0–30

M(*SD*) denotes Mean(Standard Deviation). TRI = Technology Readiness Index; PSRQ = Perceptions of Social Robots Questionnaire; SPS = Social Provisions Scale; GDS = Geriatric Depression Scale

Finally, all 15 items from the Robot Concerns Measure were analyzed using the concatenated pattern analysis in OOM to determine the number of participants who matched the hypothesized patterns across all expected concerns and non-concerns. The analysis indicated that none of the participants perfectly matched the hypothesized patterns (PCC = 0.00, *c*-value = 1.00). That being said, 22 participants closely matched the hypothesized patterns with total response PCC values between 60.00% and 86.67% across all concerns and non-concerns. Of these participants, all but one participant indicated that they would be concerned about privacy and security threats and maintenances costs. Most of the participants also indicated that they would be concerned about the technological support required to operate a SAR ($n = 19$), the potential for hacking ($n = 19$), and the purchase costs ($n = 18$). Many of these participants also indicated that they would not be concerned about appearance ($n = 19$). We examined whether there were significant group differences between participants with greater PCC values (i.e., 60% and above) compared to those with lower PCC values using independent samples *t*-tests (see Table 7). On average, the group of participants with PCC values greater than 60% reported significantly more concerns related SARs ($M = 9.45$, $SD = 3.04$) than the group of participants with PCC values below 60% ($M = 5.27$, $SD = 4.05$; $t(38.94) = -3.88$, $p < .001$, $d = 1.17$). However, no significant differences on scores from the TRI ($t(35.92) = 0.70$, $p = .49$), PSRQ ($t(42) = 0.31$, $p = .76$), SPS ($t(42) = -0.33$, $p = .74$), loneliness (UCLA Loneliness Scale; $t(35.21) = -1.12$, $p = .27$), or GDS emerged ($t(42) = 0.21$, $p = .49$). The two groups were also demographically similar (see Table 7); however, the group of participants that were more consistent with hypothesized patterns was slightly more educated. Additionally, 77% ($n = 10$) of the males matched the expected pattern of responses across the 15 items on the Robots Concern Measure with a PCC value of at least 60%. This is compared to 39% ($n = 12$) of females.

Discussion and Implications

The purpose of this pilot study was to examine the concerns that community-dwelling adults in the United States have regarding the use of SARs. This study adds to the limited investigations into older American's preferences and concerns related to SARs (Prakash & Rogers, 2015; Smarr et al., 2014). Several findings emerged within the results. In general, the older adults in this pilot study seemed mildly concerned about SARs, such that the average number of reported concerns was approximately 7 out of the 15 possible concerns. Interestingly, the reported number of concerns did not significantly differ by gender and was not correlated with any other demographic

Table 6 Correlations Among Participants' Reported Overall Concerns Regarding Socially Assistive Robots, Technology Beliefs and Perceptions, Well-being, and Demographic Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Robot Concerns											
2. PSRQ	−.40**										
3. TRI	−.37**	.25									
4. SPS	.19	.26	.14								
5. UCLA Loneliness	.03	.07	−.20	−.65***							
6. GDS	.32*	−.15	−.33*	−.38*	.49**						
7. Sex	−.09	−.08	.03	.31*	−.38*	−.26					
8. Age	.03	−.02	−.09	.08	−.28	−.08	−.02				
9. Race	.06	.04	−.06	.23	−.29	−.11	.24	−.03			
10. Education	.20	.12	.04	.27	.07	−.16	−.26	.08	−.21		
11. Marital Status	.09	−.31*	−.10	.00	−.12	.02	.28	.42**	.04	−.15	
12. Overall Health	−.18	.19	.25	.10	−.22	−.44**	.11	−.01	.04	.16	−.25

TRI = Technology Readiness Index; PSRQ = Perceptions of Social Robots Questionnaire; SPS = Social Provisions Scale; GDS = Geriatric Depression Scale. Numbers in parentheses are Cronbach's alpha values; *$p <. 05$; **$p < .01$; ***$p < .001$

Table 7 Demographic Comparison Between Participants with Percent Correctly Classified (PCC) values below and above 60% Based on the Hypothesized Concerns and Non-Concerns

	Ps with PCC<60%	Ps with PCC>60%
Demographics		
Age – *M* (*SD*)	73.95 years (8.19 years)	74.68 years (8.68 years)
Gender		
Male	3	10
Female	19	12
Race		
White/ Caucasian	19	17
Black/ African American	1	3
American Indian	0	1
Asian/ Asian American	1	0
Native/ Pacific Islander	1	0
Alaskan Native	0	1
Marital Status		
Never married	2	2
Married	9	12
Divorced	2	2
Widowed	9	6
Education		
Some high school	1	2
High school diploma	4	1
Some college	5	3
Associate arts degree	3	1
College degree	2	2
Graduate degree	4	6
Ph.D./ Doctoral degree	3	7
Self-Reported Health		
Poor	0	1
Fair	6	4
Good	11	15
Excellent	5	2
Psychosocial Variables	*M* (*SD*)	*M* (*SD*)
TRI	29.72 (8.51)	28.22 (5.49)
PSRQ	16.09 (3.79)	15.73 (4.11)
SPS	40.82 (3.80)	41.22 (4.42)
UCLA Loneliness Scale	33.05 (5.84)	35.73 (9.47)
GDS	4.50 (3.47)	5.41 (4.98)

PCC indicates percent of participants correctly classified. *M*(*SD*) denotes Mean(Standard Deviation). TRI = Technology Readiness Index; PSRQ = Perceptions of Social Robots Questionnaire; SPS = Social Provisions Scale; GDS = Geriatric Depression Scale

variables (i.e., age, race, education, marital status, overall health). In contrast, we found that more positive feelings towards SARs were negatively correlated with participants' total number of concerns. This finding corresponds with the general sentiment that older individuals who feel positively about SARs should feel less concerned about adopting this technology. More so, it provides some initial validation of the Robot Concerns measure. Additionally, the negative relationship between technology beliefs and overall reported concerns similarly indicates that older individuals who are more familiar with or comfortable using technology tended to report fewer overall concerns regarding the adoption of SARs. We also found that older adults that endorsed more depressive symptoms were more likely to report greater concerns. It is possible that this result is an artifact of depressive thinking or low motivation to respond; however, this claim requires further empirical examination.

The most notable findings were those obtained through OOM analyses that addressed the hypothesized concerns and non-concerns. Of the hypothesized concerns, data security and privacy were the leading concerns regarding SARs among the current sample of older Americans. Specifically, a majority of the older adults in the current pilot study reported that they would be concerned about the privacy and security of their personal information when using a SAR, as well as the potential for the SAR to be hacked. Vandemeulebroucke et al. (2018) documented similar concerns in a recent meta-analysis. They posited that concerns related to hacking and security threats might be a result of older adults perceiving SARs as monitoring devices that may ultimately pose a threat to their autonomy (see also Pino et al., 2015). Interestingly, older Americans do not seem to share this concern, as many report seeing SARs as a tool to enhance independent living (Smith & Anderson, 2017). Similarly, less than half of the participants in the current sample were concerned about SARs' monitoring abilities, and over 60% of participants were not concerned that SARs would restrict their autonomy. It is possible that the observed hacking and privacy concerns may reflect a general apprehension about technology security (Heinz et al., 2013) rather than a fear that this technology would use monitoring features to restrict autonomy. Correlational findings from the current study may support this notion, as having more negative views about technology and less knowledge about SARs was correlated with reporting a greater number of concerns. In other words, these findings may be indicative of the digital divide, in which older individuals with limited technological knowledge may be more apprehensive about adopting novel technologies like SARs.

Beyond hacking and safety and security threats, many older adults in the pilot study indicated that they were concerned about repair and maintenance costs as well as the extent of technical support required to operate a SAR. These concerns are consistent with the current beliefs among researchers and practitioners related to barriers to adoption (Bedaf et al., 2015; Pearce et al., 2012; Pino et al., 2015; Vandemeulebroucke et al., 2018). Taken together, the current findings on older Americans' concerns related to SARs have important implications for future technological development and healthcare providers. As the field of social robotics progresses, those interested in SAR development and intervention efforts among independent-living older adults should focus on developing features that would protect privacy and be able to communicate these features to older individuals. Similarly, it is essential to develop equipment that is user friendly for older adults at an affordable cost. Finally, technology developers and care providers need to be able to convey these features to older adults. Doing so will likely reduce older adults' concerns and thereby increase the likelihood that they would adopt this form of technology and experience the anticipated psychosocial benefits.

In contrast to participants' expressed concerns, an overwhelming majority (93.18%) of older adults reported that the appearance of SARs was not a concern. This finding differs from previous investigations (Pino et al., 2015; Prakash & Rogers, 2015; Wu et al., 2012; Wu et al., 2014), in which participants shared opinions on whether SARs should appear more or less human-like. Similar to existing sentiments among Americans (Smarr et al., 2014), participants may have been more concerned about the functionality of a SAR rather than its physical appearance. It is also possible that participants did not have initial concerns regarding the appearance of SARs when asked about it in the hypothetical but may express different thoughts when seriously considering adopting this technology. Other studies have documented the desire for customizing the appearance and function of SARs (e.g., Beer et al., 2012; de Graaf et al., 2015; Pino et al., 2015), which was not represented in the current study's line of questioning. This limitation should be addressed in future studies to better understand older Americans' preferences for customization (Smarr et al., 2014) and whether this impacts their willingness to adopt this form of technology. If older Americans want to be more involved with designing their own robots to not just serve a social purpose but also to create functionality within their daily lives, they may experience stronger interaction benefits because their needs are more specifically met. At the same time, this could have significant implications for the monetary costs of the technology if expensive customization is required for older individuals to be receptive to SARs.

Interestingly, individuals in this pilot study were divided on several of the examined potential concerns and non-concerns. Many older adults reported that they were concerned about purchase and maintenance costs, user operation requirements, and the potential for SARs to replace humans as care providers; however, there was a relatively similar number of participants who were not concerned about these features. Future research should continue to examine these possible concerns among older adults, as they may be significant barriers of acceptance of SARs for certain older Americans, such as low-income families and those with limited access to support. Furthermore, about half of the sample was concerned about SARs' companionship and emotion detection abilities. The divide in participants' concerns related to social features may represent that older Americans are generally unaware of SAR technology (Smith & Anderson, 2017), and thus, many of them were not concerned about social functioning. As previously mentioned, it also might indicate that older Americans are more interested in robots serving physical functions to assist with actions of daily life (Smarr et al., 2014) more so than companionship. In a related study with young and middle adults, Spence et al. (2014) examined participants' initial expectations of interacting with a SAR and found participants were more uncertain of interacting with a robot compared to a human and had lower expectations of liking their conversational partner and feeling a social presence if they were to interact with a robot compared to a human. The current findings on older adults' perceptions of SARs' social features may provide corroborating evidence that people generally doubt the social benefits that SARs can offer. Older adults may move beyond this hesitation if given opportunities to interact with SARs (see Spence et al., 2014 for similar argument), especially within the context of their own home. This could help older adults who age-in-place and experience social isolation not only be more receptive to the technology but also improve their socioemotional well-being. Future studies should further examine this notion and test whether initial concerns about SAR's social capabilities change after repeated exposure to this technology.

Finally, no participants perfectly matched the pattern of hypothesized concerns and non-concerns regarding the use and acceptance of SARs. That being said, half of the sample matched between 60% to 80% of the hypothesized pattern. Although we acknowledge our pilot study's small sample size, this is still a striking finding. Half of the participants expressing a majority of the prevailing concerns and non-concerns about adopting SARs further demonstrates that many of the existing sentiments among researchers and practitioners about possible barriers to SAR technology acceptance were observed among the current sample of older Americans. This was particularly true for concerns related to privacy and security threats, hacking, user operation concerns, and purchase costs. Further research is required to examine whether these concerns are more widely held among most older Americans. We also observed that the group of participants who better matched the hypothesized patterns of concerns and non-concerns (PCC values above 60%) were slightly more educated than the group of participants who did not match the hypothesized patterns as well. Of the limited number of males in the study, most males matched the hypothesized pattern. Thus, there may be certain demographic attributes that contribute to older adults' concerns related to SARs. Further research is required to test this hypothesis. Additionally, although we did not observe any significant differences between the two groups of participants with PCC values above and below 60% in terms of technology beliefs, perceptions of SARs, social support, loneliness, or geriatric depression, there may be other psychosocial features that are indicative of whether older individuals are concerned about certain features of SARs. Future research should try to identify attributes linked to common concerns regarding SARs to possibly develop person-centered educational programming to ultimately increase the likelihood that individuals adopt and benefit from SARs as anticipated.

Limitations and Future Directions

One limitation of the current study relates to the validity and reliability of the included measures. For instance, we developed the Robot Concerns measure simply based on previous reports of possible concerns regarding the use and acceptance of robotic technology (Pino et al., 2015; Vandemeulebroucke et al., 2018). We did find some strong interitem correlations between many of the hypothesized concerns and non-concerns, respectively. Yet, further work is required to create a more sophisticated scale that could more accurately address participants' level of concern. For instance, if participants had been given the opportunity to respond using a Likert-type scale, then we could tap into the extent of older adults' concerns or non-concerns related to features of SARs. Additionally, we found that the SPS had rather low reliability ($\alpha = .65$). This may, in part, be due to the small sample included in the current pilot study. Future work should seek to replicate our findings among a larger sample to improve the reliability of this measure and address possible implications of social support on older adults' concerns related to SARs. At the same time, the SPS was not a central variable of interest but instead was included to determine whether initial levels of social support affected participants' overall concerns. Finally, since the onset of the current pilot, alternative measures on technology readiness, such as the TRI 2.0 (Parasuraman & Colby, 2015), have been developed and are widely used in research. Although the TRI administered in the current pilot study demonstrated sufficient reliability, our findings should be replicated using more recent measures of technology readiness to better understand the relationship between older adults' familiarity with technology and concerns related to adopting SARs. Due to the nature of the current pilot study, we were unable to address these possible limitations. However, future work can build from the current study and possibly tap into more nuanced features of older adults' concerns regarding the use and acceptance of SARs.

Another limitation of the current study was that we did not examine participants' familiarity with SAR technology prior to testing. It is possible that participants in the current sample had experience with varying degrees of smart technology that could have impacted their responses on the Robot Concerns measure and PSRQ. It would also be interesting to examine whether experience with common smart devices, like Siri or Alexa, affects older adults' openness to more advanced robotic technologies. More so, it is important to note that the current findings are based on convenience sampling, which may mean that the current findings do not generalize to *all* older adults. Similarly, the current sample was also fairly well educated, which may have influenced their receptiveness to novel forms of technology. That being said, the findings presented here are part of a pilot study on SARs and thus require additional research to address whether the findings presented here are representative of the majority of older adults in the United States.

Conclusions

The current pilot study sheds light on the concerns regarding the use and acceptance of SARs among healthy, independent-living older individuals. It is our hope that this pilot study initiates a much-needed discussion on applications for SARs within community-dwelling older adults in the United States and how to address concerns that may prevent older adults from accepting this form of technology and experiencing the anticipated benefits.

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Data Availability The datasets generated during and/or analyzed during the current study are not publicly available because data include some identifiable features. However, the data are available from the corresponding author on reasonable request.

Declarations

Ethics Approval All procedures were approved by the Oklahoma State University Institutional Review Board (IRB). Participants in the current pilot study signed an IRB approved informed consent prior to participation.

Consent for Publication All of the authors have given consent for the publication of this manuscript.

Conflicts of Interest/ Competing Interests On behalf of all authors, the corresponding author states that there is no conflict of interest.

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