2021-06

Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions

Bradwell, Hannah

http://hdl.handle.net/10026.1/17275

Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions

Scientific abstract

Objectives

Socially assistive robots (SAR) may have an important role in health and social care. Design of such SAR can be informed through detailed studies with end-users, but we also need shared understanding of SAR between developers and those influencing policy. We aimed to explore the acceptability of using SAR across a broad range of stakeholders who could influence policy and identify design considerations for developers.

Methods

We gave live demonstrations of a range of SAR rather than passive materials such as pictures, and used an acceptability model (Almere Model) as framework for analysis. Eight exhibitions involved live demonstrations and interaction with two robot animals (Paro and Miro), a humanoid (Pepper) and function-oriented telepresence robot (Padbot). 223 health and social care professionals, service users and small companies participated. Unstructured free interactions with robots were video recorded, transcribed, and content analysed. Themes were mapped onto the Almere Model of acceptability where components and design recommendations deduced.

Results

Three-quarters of attendees interacted with robots (n=167). Practical design changes identified were: (i) improved mobility for uneven floors and carpets, (ii) improved voice recognition and accent interpretation, (iii) better ease of use (mainly Pepper), (iv) enhanced robustness and battery life/autonomous charging, (v) soft, friendly aesthetics, (vi) anthropomorphic or biomorphic design (non-robotic) for friendliness and social presence, (vii) androgynous appearance.

Conclusion

Health and social care stakeholders are open to use of SAR and see potential in this field, however, practical issues such as robustness, battery life, voice/accent recognition and mobility need to be addressed.

Public Interest Summary

Robots that interact with people in health and care settings may have an important role in improving wellbeing. Detailed studies with end-users should inform SAR design for specific settings, however policy makers and robot developers must also share understanding of suitable design, for robots to be developed appropriate for health and care contexts.

We gave live demonstrations of two robot animals (Paro and Miro), a humanoid (Pepper) and telepresence robot (Padbot) at eight events with 223 health and social care professionals, service users and small companies.

Interactions with the robots were video recorded and used to assess their acceptability. Participants saw potential for robot use but identified practical concerns. These were: (i) improved mobility for uneven floors and carpets, (ii) improved voice recognition and accent interpretation, (iii) better ease of use (mainly Pepper), (iv) enhanced robustness and battery life/autonomous charging, (v) soft, friendly aesthetics, (vi) anthropomorphic or biomorphic design (non-robotic) for friendliness and social presence, (vii) androgynous appearance.

Keywords: Social robots, companion robots, acceptability, healthcare, social care, technology acceptance,

1. Introduction

Socially assistive robots: Health and social care (H&SC) faces increasing pressure [1], due to ageing populations [2] together with increases in dementia [3] and loneliness [4]. Technology [5], including socially assistive robots (SAR) [6], may help address these pressures. SAR is a subfield of robotics including social, service and rehabilitation robots. The exact definition of SAR has been debated [7, 8]. SAR sometimes possess features of humans or animals (e.g. Paro [1]), to be perceived as a social entity [6, 9], and are usually autonomous robots aimed for benefits such as companionship, effective therapy, cognitive training, social facilitation and physiological therapy [2]. However, others argue that telepresence robots (e.g. Padbot), assisting in social interaction through facilitating human-human contact should be included [7]. Despite the lack of formal definition of SAR [8, 10, 11], all SAR aid humans specifically through social interaction [12]. Various 'smart toys' (e.g. Joy for All pets) may also produce wellbeing through social interaction [13, 14]. Successful adoption however, depends on acceptability from end-users [15-17]. In this paper we adopt a compromise definition of SAR focussing on four devices; Pepper, Paro, Miro, and Padbot. Such an approach is reflective of van Wynsberghe's interpretive flexibility [18], where a robot's definition depends somewhat on context of use.

Acceptability research: There is abundant acceptability research related to SAR, offering some insight into design and implementation. Broadbent et al. [19] conducted a review of acceptability research for robots in healthcare, focusing specifically on aged care. They identified end-user characteristics influential to acceptability, such as age, needs, technology/robot experience, cognitive ability, education and culture. Influential robot features included appearance, humanness, facial design and expression, size, gender, personality and adaptability.

Odetti et al. [20] studied responses towards robotic dog AIBO by 24 people with dementia. Analysis suggested some acceptability, with the robot perceived as "*harmless, friendly, cute*" (pg 1818). Two patients provided negative responses resulting in removal of the robot. A limitation of their study was the reliance on verbal communication to establish acceptability, problematic due to the decline in communicative ability associated with dementia progression [20]. For this reason our current study explored acceptability across a range of stakeholders in H&SC, gaining opinions not only from the service users, but also those involved in their care. Assessing acceptability with only one device also provides limited insight into optimum design, as does assessing acceptability based only on observation, rather than based on a validated acceptability model.

More recently, Pino et al. [21], investigated acceptance of SAR among individuals with mild cognitive impairment, informal carers, and healthy older adults using a questionnaire and focus groups. Questions were based on the Almere model, which assesses older adult's acceptance of assistive social technology [17]. Participants received PowerPoint and booklet exposure to pictures, videos and descriptions of available SAR, and one prototype robot was demonstrated. Questionnaire results suggested most participants preferred mechanical human-like robots, possessing both anthropomorphic and mechanical design features. Preferred functionalities were cognitive support, communication services, risk prevention and healthcare, and daily tasks of living support. Interestingly, participants appeared more willing to use SAR in the future than the present. This corroborated research by Wu et al. [22] who reported those with mild-cognitive impairment felt too able for robotic assistance, suggesting robots more suited those further handicapped. This apparent stigma requires further exploration with larger samples. Successful implementation of robots within H&SC depends on stakeholder acceptability and intention to use, key determinants of actual use [17]. The study was also limited by use of booklets/PowerPoints as examples of SAR, rather than direct robot interaction, limiting participant ability to assess robot capabilities, a limitation of studies [22, 23] also. In response, our study involved direct interaction with SAR, providing greater validity of participant opinions.

Further acceptability research was conducted by de Graaf et al. [24] as part of development of an acceptability model. Perhaps surprisingly, results suggested participants negatively evaluated social companionship from robots, preferring to perceive robots as serving people rather than substituting humans [24]. The sample however was selected from the general Dutch population, who perhaps have less requirement for companionship than stakeholders in H&SC, limiting generalisability of these results to our target audience.

Despite available literature on acceptability and design, a number of SAR have failed in this sector [19, 25, 26] and while detailed outcome-based studies among end-users are important they can also be time-consuming, expensive and may be made redundant if policy makers and inflencers have negative attitudes to the technology. We need, therefore, an improved understanding of acceptance or rejection across a broad range of relevant stakeholders to inform design [21, 22, 27]. Assessing acceptability may be approached in different ways and we draw upon previous research [8, 10, 16, 19, 20, 22, 26, 27].

The implementation of SAR in H&SC requires a network of people, organisations, users, scientists, engineers and designers to ensure design meets the requirements of those involved in adoption, purchasing and implementation in this sector. So acceptability research needs to engage with the 'right' stakeholders. Research such as that by De Graaf et al. [24], is informative but not so relevant to the British H&SC sector where we need to understand the views of our stakeholders, such as service providers, patients and service-user groups. [20, 27, 28].

<u>Context:</u> Our work was carried out in the context of the [name of project omitted to remove author identifiers] [29] that aimed to both develop the market for health products (including SAR) and to help develop Small to Medium Enterprises (SME's) located in Cornwall, South West England.

<u>Aims:</u> Understanding acceptability for each stakeholder group individually is the optimum approach for designing specific devices [30], however, we aimed to raise awareness of SAR and to get an initial 'broad' understanding of perceptions, acceptability and any general issues needing addressing when considering H&SC contexts. In this paper we aim to provide an overall acceptability assessment across a broad range of stakeholders in Cornwall, gathered via live demonstrations of multiple SAR rather than passive materials, together with analysis based on an acceptability model. We distil the resulting insights into consequences for future robot designs aimed at H&SC that developers may wish to consider.

2. **Methods**

2.1 Events and participants

We organised eight locality events across Cornwall UK offering real-world interactions with SAR to a broad spectrum of H&SC stakeholders who may influence policy and practice in the adoption of SAR. H&SC professionals may make purchase decisions, lead SAR interventions, and also impact perception of technology, positively and negatively [19]. H&SC students represent future healthcare professionals. Their inclusion, although often ignored, is essential to capture sustainable needs and requirements, with future professionals predicted to support an even greater burden of population disability [31]. Service users are target end-users in this context, while, SME's focused on eHealth and health technology represent current or future providers.

Researchers identified and approached current and future H&SC professionals from disciplines including domiciliary care, residential care, primary and secondary care, pharmacists, mental health, and health related charitable or formal organisations, including local Council representatives. Invitations were sent via email. Three universities with presence in the county advertised online to students. Service users were recruited through online and newspaper advertisements, support groups and public engagement events. Members of SME's relevant to health, eHealth and technology were also identified and invited via email. Participants who did not specify their category at registration were recorded as 'others.'

In total, 223 participants, 108 H&SC professionals, 34 services users, 24 students, 20 SME's and 37 'others,' were recruited using this convenience sampling.

2.2 Ethics

Favourable ethical approval was granted by the Faculty Science and Engineering Ethics Committee at the University of Plymouth.

2.3 Devices for interaction

We selected four SAR with potential application in H&SC: an expensive humanoid robot (Pepper), a telepresence robot ('Skype on Wheels') (Padbot), and two companion robot animals; Paro, a relatively expensive cuddly animal, and Miro, an entertaining floor-based robot (Fig. 1). The selected four provide examples of varied functionality, aesthetics, features and abilities for comparison and comment, rather than an exhaustive selection of SAR.

Alternative animal devices were available in our exhibitions, including the Joy for All cat and dog, Perfect Petzzz sleeping dog and a knitted hedgehog. However, data recording focused on interactions with devices that were ‘undisputed’ robots (Pepper, Paro, Miro and Padbot).

Fig. 1 Devices available for interaction during exhibitions: Pepper, Padbot, Paro seal, Miro, Joy for All dog and cat, Perfect Petzzz breathing dog, handmade knitted hedgehog, mobile apps, Amazon Echo Spot, virtual reality equipment

Figure 2 shows a typical interaction station. Interactions with apps, virtual reality and smart speakers were often located elsewhere within the room, but were not included in this research. Miro generally roamed autonomously on the floor, whilst Pepper and Padbot were stationed on the floor with one researcher (GAN). Paro was available on a table, supported by another researcher (HB). The alternative animal devices were displayed alongside Paro.

2.4 Procedure

The eight events comprised a buffet lunch and access for 40 minutes to a technology exhibition, followed by round table discussions. This paper reports on the exhibition. Two researchers (GAN, HB) operated stations where SAR were available for participants, in groups or individually, to approach, engage and discuss. Researchers demonstrated robot abilities, allowed participant interaction and answered questions. Interactions were video recorded, audio transcribed and collated with field notes. Participant identities were not known for analysis. While numbers within stakeholder groups could be calculated from registration details, participants were anonymous in video footage and notes, thus analysis is conducted across all stakeholders, rather than between stakeholder groups. From recordings we estimate three-quarters (i.e. 160-170 people) interacted with the SAR.

2.5 Data recording equipment

Video recording equipment captured interactions between participants and robots. The camera was located at the interaction station supported by GAN, focusing on participant interactions with Pepper, Miro and Padbot. Some interactions with Paro at the second station are picked up in the periphery of data recording (Fig. 2) but field notes captured additional comments, particularly about Paro.

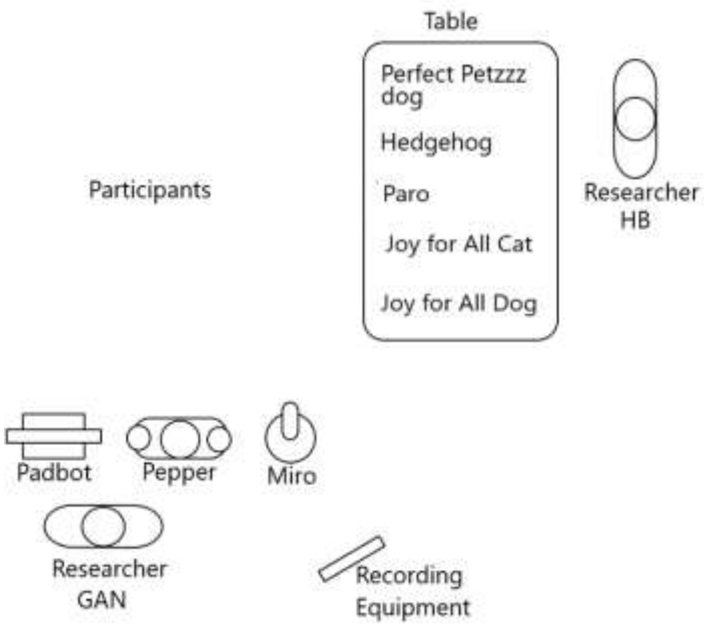

Fig. 2 Typical layout of interaction stations

2.6 Data analysis

We used the Almere model constructs for analysis of acceptability. The Almere Model, devised by Heerink et al., assesses acceptance of assistive social agent technology based on 13 constructs and was created specifically for measuring acceptance among older adults [17]. Our sample was not of older people, but the relevance of eldercare to H&SC stakeholders supported use of the Model, with the main alternative being tested only with students [32]. Our study involved observations of real-world robot interaction to assess acceptability based on unprompted opinions, so we did not use the questionnaire provided by the Almere model authors [17] but instead followed other studies [21, 27] in using the constructs as a guide.

Transcripts were collated with field notes, both of which underwent content analysis, by two researchers (GAN, HB). Content analysis was selected for inclusion of frequency of theme occurrence [33], and involves systematic coding and categorising of text [34]. As prescribed by Elo and Kyngas [35], researchers undertook data immersion, coding, grouping codes, generating categories, and reporting, with a focus on manifest content. Identified themes were analysed for relation to Almere Model constructs, to assess the degree to which collected evidence suggested acceptability. Researchers created tables displaying Almere Model constructs, related themes and evidence. From this we identified issues or design concerns among H&SC stakeholders that require addressing for implementation in this field.

3. Results

The four SAR seemed acceptable to our stakeholders as supported by the themes mapped on to the Almere constructs (Table 1). Participants saw potential in their use but raised practical issues for consideration. Below we explore this further. Additional evidence regarding each Almere construct is available in Supplementary File, Tables A-J.

Table 1: Content analysis themes mapped on to Almere Model Components

Almere Model Components	Themes (frequency)
Attitude towards technology	Likeability (24) Aesthetics (24) Intelligence (7)
Perceived usefulness	Comparison to known products (17) Mobility (13)

	Potential use (77)
Perceived ease of use	Ease of use (55)
Perceived enjoyment	Enjoyment (15)
	Humour (151)
Trust	Usability (18)
Intention to use	Ownership (17)
	Potential use (77)
Perceived adaptiveness	Adaption (5)
Anxiety	Fear (16)
	Damage (3)
Social presence	Anthropomorphism (17)
	Gendering (89)
	Objectifying (35)
Perceived Sociability	Friendliness (15)

Table 1 demonstrates mapping of themes onto Almere Model constructs. Frequencies represent the number of comments made providing evidence for each theme. Some constructs received more support than others. Perceived enjoyment was most well supported, followed by social presence and perceived usefulness. Trust, perceived sociability and perceived adaptiveness received the lowest counts of evidence (below the Median of 55 total counts per construct). Designs considering methods of enhancing Trust of SAR could be an area for future research, as could considering adaptiveness of SAR to different needs. Anxiety also received comparatively low counts of evidence; however, as a negative construct, this is a positive result for perceptions of the SAR. Results are detailed further below.

Attitude towards technology

This Almere construct refers to positive or negative feelings towards application of SAR, including making life more interesting, and being a good idea [17]. Our content analysis related themes were likeability, aesthetics and intelligence (Table A). The themes demonstrate predominantly positive attitudes towards the robots and their use, including aesthetics being *"friendly,"* responsiveness being *"clever,"* and evidence for likability. Many participants referred to 'loving' the robots, *"I love him [Miro],"* within seconds of beginning their interaction. Evidence for the intelligence theme in particular suggests SAR were perceived as 'a good idea.' The gaze following of Paro and Pepper was felt beneficial for companionship, *"it's brilliant, for a companion, I feel like he's looking right at me."* One participant suggested she *"would visit [hospital] just to see"* Pepper, thus supporting potential for robots making life more interesting. However, some negative attitudes were evidenced through the aesthetics theme, some participants desired a soft shell, warm feeling and less robotic appearance to Pepper; *"change how hard it is, like if it was softer*." Only one participant reported robots should be recognisably robotic.

Perceived usefulness

This construct is belief the system would be assistive, measured through participants feeling SAR would be useful to them [17]. Overall, our evidence supported this construct well (Table B) through participants identifying many potential uses for SAR and comparing robots to known products. Spontaneously discussed potential uses included; telehealth, delivering exercise classes and supporting physiotherapy, social support, reducing loneliness/isolation, maintaining independence, providing entertainment, and medication or mindfulness reminders.

Limitations noted included Pepper's voice recognition with negative comparisons to other devices; *"it can't understand me, the Xbox has to learn me as well because I have a regional dialect*." This was a recurring concern as the limitations around voice recognition and accents could impair *Perceived Usefulness* in H&SC settings. Another limitation was mobility, with concerns around flooring irregularities in H&SC environments such as care homes, where carpets, rugs or steps may be more common than in hospital settings. Mobile SAR such as Padbot, Miro and Pepper could thus benefit from adaptation with *"bigger wheels"* for example, as suggested by one participant.

Therefore, although strong support was found for *Perceived Usefulness*, current limitations on voice recognition and mobility require practical improvements for successful implementation in a variety of

H&SC contexts. These limitations were absent for Paro (who is portable but not mobile or verbal), and thus animal-based SAR may be more readily applicable

Perceived ease of use

This construct is the degree to which one believes use would be free of effort. More detailed evidence (Table C) suggests good support for this construct, *"that's nice and easy [Miro's app]*"; however concerns arose for Pepper, with participants commenting on the quantity of menu options and requirement for training; *"how long does it take [to] learn, […] oh it's a bit too scary [...], do you need quite a lot of training*?" Generally, however, participants observed basic demonstrations (turn device on, use linked app), and then appeared comfortable and equipped enough to use robots with ease. This is a positive contributor towards acceptability.

Perceived enjoyment

Perceived Enjoyment refers to feelings of joy/pleasure associated with SAR use [17]. Themes which linked with this construct were enjoyment and humour (including laughing in response to SAR), due to the pleasure evidenced in both themes (Table D). All SAR provoked laughter and giggling during interactions, *"I think he's [Pepper] wonderful actually [laughs] he makes you laugh*." Evidence demonstrates clear enjoyment, pleasure and joy; *"he [Pepper] just cheered me up*," thus strongly supporting this construct.

Trust

Our theme of usability (Table E) related to the Almere construct of Trust, defined as belief a system performs with personal integrity and reliability. Numerous questions were raised suggesting required *Trust* improvements, including battery life, *"if it [Paro] died, it could be unsettling for care home residents,"* further to accent interpretation, and internet connection. Due to concerns on battery life, "*standby"* modes and autonomous charging at *"homing stations"* were suggestions made to enhance reliability and therefore *Trust* in the system.

Intention to use

Our related theme to this construct was ownership (Table F), mainly representing occasions when participants mentioned taking/acquiring a robot for personal or occupational use, therefore representing *Intention to Use; "we could have him [Paro] in the staffroom," "now I have to take it [Miro] home*." Incidences were limited, however, referring back to *Potential Uses* could provide further support for this construct, as participants suggesting applications for robots could indicate an intention to use, should they have been able to.

Perceived adaptiveness

This Almere construct is the perceived ability of a system to adapt to a user's needs. Our theme of adaptation, although only present on five occasions, provided some evidence of participants querying adapting SAR to meet specific requirements (Table G), such as Pepper being adapted *"for somebody with dementia," "do you program it to what the persons needs are?"* Interestingly, such queries related only to Pepper, perhaps perceived as more easily adaptable due to the tablet and available apps.

Anxiety

This construct relates to systems evoking anxious or emotional reactions. Our related themes, damage and fear occurred three and 16 times respectively (Table 1). Damage was felt relevant, as fear of damaging a device would likely provoke a negative response, *"[gentle touch] I didn't want to be too.. you know [Pepper]*." The evidence for damage related only to Pepper (Table H), perhaps due to participant anxiety on damaging a device perceived as expensive. Methods of reducing fear of damage may require further consideration for implementation in H&SC [17]. Paro was praised for feeling *"robust"* with the padding and fur, perhaps providing confidence in use and reducing *Anxiety* related to potential damage. Evidence for the theme of fear was also limited only to Pepper, *"it's worrying to have a conversation with a robot [Pepper]."* Whilst the majority of participants interacted with robots without displaying any anxiety, multiple incidences of fear were recorded for a few individual participants. Some evidence demonstrates preconceptions of robots, driven by media representation; *"what springs to mind is that sci-fi movie, taking over the planet, going rogue [...] making mistakes [Pepper]."* The damage and fear themes demonstrate possible barriers to acceptability of SAR for H&SC stakeholders. However, on balance, evidence for these themes is less prevalent than other themes. Nevertheless, the points raised should still be considered to reduce *Anxiety* and improve acceptability further.

Social presence

This relates to the experience of sensing a social entity when interacting with a system. Our theme supporting this construct was anthropomorphism, and the related theme of gendering/objectifying (Table I). Evidence of anthropomorphizing suggests participants attributed feelings to robots, even empathising with devices, *"are you having a bad day? [Miro]*." This supports participants feeling they were in the company of a social entity [17], as would participant tendency towards gendering robots, *"she must be a girl with those eyelashes [Paro]*." There were 89 occasions of gendering, compared to 35 counts of objectifying. Viewing the robots as objects could provide evidence against *Social Presence*, whilst projecting a gender could suggest the robot is perceived as a being rather than a thing [23], therefore capable of social presence. Interestingly, all evidence for *Social Presence* was directed towards SAR with anthropomorphic or biomorphic design (Pepper, Miro, Paro), whilst Padbot received no evidence for anthropomorphism or gendering.

Perceived sociability

Finally, this construct refers to perceived system ability to perform sociable behavior, measured through participants' beliefs that robots would be pleasant to interact with, talk to and be nice, further to feeling understood by the device. Our related theme was friendliness (Table J), including evidence of SAR perceived as nice, with a positive regard for sociable device interactivity, *"he's very polite [Pepper]*." Participants often interacted in a manner indicative of believing the robot understood them, talking to them, commanding Paro and Miro, and engaging SAR as you would a living entity, *"be a good boy [Miro]*." The evidence also somewhat supports Pepper being a pleasant conversational partner, even considering conversational issues, participants appeared to find language mistakes endearing rather than frustrating. The amusement gained suggests the available SAR were pleasant to interact with, although again evidence was lacking for Padbot.

4. Discussion

Acceptability of social robotics among stakeholders

Based on the interactions of 160-170 stakeholders, the four SAR appear generally acceptable to H&SC policy makers and implementers, future implementers (students) and end-users. The variety of suggested potential applications demonstrates an open attitude for implementation of SAR in H&SC and strong potential for further robot development. This contrasts with the limited appreciation of social companionship reported by de Graaf et al. [24] that may be a reflection of their use of a general population sample. Our stakeholders suggested medication and mindfulness reminders, social support, reducing loneliness, maintaining independence, and entertainment as applications in line with the work of Pino et al. [21]. Telehealth, exercise and physiotherapy were additional uses seen in our study not noted in Pino's study. However, there were issues raised that designers and developers need to consider for general applicability to H&SC.

Design considerations

Our results would support use of soft, friendly aesthetics like Paro rather than 'robotic' aesthetics. Pino et al. [21] reported mechanical human-like robots to be preferred, with both anthropomorphic and mechanical features. In contrast, soft/furry animal aesthetics were felt most desirable for older people based on a review by Broadbent et al. [19]. The participants in our study generally desired less robotic aesthetics, contrasting Pino et al. [21] with only one participant suggesting SAR should clearly resemble robots. This difference may be explained by our larger sample, wider range of stakeholders, and/or more hands on interaction. Furthermore, evidence for the construct of *Fear* was limited only to plastic-robotic Pepper, perhaps due to media representations of humanoids. Broadbent et al. [19] suggested robot exposure most prominently comes from media depictions such as films and television. Support for this explanation arose in the current research. Softer aesthetics may thus receive a better reception in H&SC.

This study also supports use of anthropomorphic or biomorphic features to increase social presence. Broadbent et al. [19] noted robot appearance was important for acceptability, and de Graaf et al. [24] reported improving sociability as a key aim. Our study suggests including soft, friendly anthropomorphic and biomorphic design features would be desirable for aesthetic and tactile acceptance, distancing design from media influenced schemas of rogue mechanical humanoids.

Sparrow [36] suggested previously that animal aesthetics were misguided and unethical, requiring deceit and delusion. However, we saw no ethical concerns on deceit raised. Although this indication does not provide sufficient comment on robot-ethics, our evidence would suggest rather than being misguided, adopting anthropomorphic or biomorphic design, further to soft shells, could enhance acceptability. Our results also suggest anthropomorphic or biomorphic design enhanced social presence, with no evidence for *Perceived Sociability* seen for the only SAR lacking such features (Padbot).

Additionally, adopting an androgynous design may avoid gender stereotype expectations. Previously the Broadbent et al. [19] review suggested there is insufficient research to suggest an optimum gender for a robot. However as noted by Søraa [37], applying a gender can be necessary to discuss the device. Our study suggests maintaining androgynous design may be advantageous, allowing participants to assign a gender of their choosing, due to the considerable debates on gender for our demonstrated SAR. Further support for androgynous design comes from research finding robots projecting ‘uncommon’ gender roles elicited more basic responses from users through perceptions of lesser knowledge than their gender role allowed, for example a female mechanic being perceived as less skilled than a male [38]. Androgynous robot designs could therefore decrease misconceptions on robot ability resultant of social stereotypes on gender norms. This consideration could be particularly important when considering H&SC contexts, due to potential gender norms of doctors, nurses and carers [39].

A further consideration noted was for improved voice recognition and accent interpretation, with issues raised regarding conversational fluency, accent interpretation and noisy environments. Pending advancements in voice recognition software, a potential solution is using other human-robot interfaces. Successful human-robot interaction would be key in ensuring usefulness of robots in H&SC. While technical issues appeared endearing to participants here, issues faced during real-world implementation would likely cause frustration. Another considerations likely to become relevant in real-world H&SC settings is improved mobility for uneven floors, carpets and rugs, particularly for SAR to be implemented across a range of H&SC contexts. Design considerations to account for varied and uneven floor surfaces seems a feasible alteration to improve acceptability specifically for this sector.

This study also identified importance of better perceived robustness of devices, to alleviate fear of damage. Devices might also aim for a long battery life or autonomous charging, as suggested by our stakeholders, to remove potential distress of a device 'dying.' Autonomous charging may also support ease of use. Generally, our evidence supports ease of use for the robots demonstrated, particularly for Paro and Miro, however some concern was shown towards usability of Pepper, with the quantity of options on the tablet appearing overwhelming for some. Options could be streamlined on app-based SAR dependant on intended setting to improve perceived ease of use. Improvements in verbal communication would also reduce the need for tablet based interaction with multiple apps.

Although the above recommendations are based on stakeholders' perceptions of the example robots, they provide important insight for designers into requirements of future robot developments. The data has identified potential uses that developers may target robots at, design flaws in current robots to avoid, and improvements to be included to ensure usability specific to H&SC contexts. As identified previously by Broadbent et al. [19] features of the end-user will also affect acceptability, including; age, needs, technology/robot experience, cognitive ability, education and culture. It may also be appropriate for future research to explore how well recommended features translate across different types of SAR, for example, research may explore if the preferential soft-fur embodiment is appropriate on a telepresence robot further to a robot pet. There were incidences of our participants requesting Pepper felt 'warm' or 'softer' to touch, thus this could be an interesting study.

Strengths

Our study addressed previous methodological limitations including; i) passive materials rather than live robot demonstration, ii) general observations without basis on acceptability model, iii) limited stakeholders included in small samples and iv) assessing acceptability with only one device. We gathered opinions from a larger number and wider range of participants than previous studies. Previous research has focused individually on end-users [20], or primarily carers [28], with other stakeholder groups such as students of relevant disciplines and related businesses appearing underrepresented. The physical demonstration of various types of SAR is a further strength of our study, allowing more comprehensive attitude formation from participants than acceptability research focused on only one type of SAR, such as an animaloid [20]. Finally, the live demonstration and hands-on interaction participants gained with the robots created more informed opinions and attitudes than demonstrations of robots through PowerPoints or booklets [21, 23].

Limitations

The two external factors in the Almere model that impact acceptability and use, social influence and facilitating conditions, could not be included within our technology exhibition context. Heerink et al. [17] also acknowledge moderating factors absent from the model, specifically age, gender, voluntariness and computer experience. These factors likely influence real-world implementation and demonstrate the need for further research. It would have additionally been interesting to assess design recommendations from each stakeholder group separately, and for stakeholders of different ages, however this was not possible with the data we collected. Although this limits understanding of design specific to each stakeholder group, robots first need designing for acceptability to service providers, purchasers and decision makers before they can enter real-world use. This paper thus provides insight for a foundation design of SAR aimed at H&SC settings, such as care homes and hospitals, where implementation faces unique and specific challenges.

A limitation of the current study is the short interaction period, only 40 minutes at each event. It is possible there was a novelty effect present during these initial interactions [10, 36]. Research has suggested acceptance measured over longer periods of use allows for familiarisation and more informed attitudes towards the device, more predictive of actual use [17, 19]. It is possible some variables may have a large effect on acceptability initially, but could have less impact following use over a longer period of time [20]. For this reason, some of the factors identified in the current research as impairing acceptability may not be an issue following real-world implementation and use, such as the theme of fear, which may have partially resulted from unfamiliarity with robots, and would thus ease over time. It is also possible additional barriers could arise unwitnessed during short interactions, or that factors facilitating acceptance short-term are less relevant during real-world use. Furthermore, the evidence found in the transcripts supporting the concept of *Trust* is somewhat limited, and perhaps would be better established through interventional studies in real-world H&SC contexts. The group-interaction dynamics during exhibition could also have impacted results, through influences such as social desirability, conformity and collective effect. This method did however allow for data among a larger sample than much previous work in this area.

Conclusion

Our results suggest key stakeholders in the H&SC sector are open to the use of SAR in their field, as demonstrated by evidence in support of components of the Almere model of acceptability that was obtained from live interactions of a large sample of stakeholders with example SAR, furthering previous research by responding to methodological limitations. The variety of potential uses identified particularly suggests participants saw potential for devices in this field. However, to be of most use, the general view suggests further design considerations were required. Improvements that could help ensure usefulness included: (i) improved mobility for uneven floors and carpets, (ii) improved voice recognition and accent interpretation, (iii) better ease of use (some concern for Pepper's usability), (iv) enhanced robustness and battery life or autonomous charging, (v) soft, friendly aesthetics (eg. like Paro), (vi) anthropomorphic or biomorphic design (non-robotic) to improve friendliness and social presence, (vii) androgynous appearance. The design considerations suggested need to be further explored in more detailed studies with end-users.

Compliance with Ethical Standards

The authors declare that they have no conflict of interest.

References

[1] Moyle W, Jones C, Murfield J, Thalib L, Beattie E, Shum D, Draper B. Using a therapeutic companion robot for dementia symptoms in long-term care: reflections from a cluster-RCT. Aging & mental health. 2019;23(3):329-336.

[2] Abdi J, Al-Hindawi A, Ng T, Vizcaychipi MP. Scoping review on the use of socially assistive robot technology in elderly care. BMJ Open. 2018;8(2).

[3] World Health Organisation. Dementia Fact Sheet. World Health Organisation; 2019. Available from: https://www.who.int/news-room/fact-sheets/detail/dementia.

[4] Valtorta N, Hanratty B. Loneliness, isolation and the health of older adults: do we need a new research agenda? J R Soc Med. 2012;105(12):518-22.

[5] Maguire D, Evans, H., Honeyman, M., Omojomolo, D. Digital change in health and social care: The King's Fund; 2018. Available from: https://www.kingsfund.org.uk/publications/digital-change-health-social-care.

[6] Broekens J, Heerink M, Rosendal H. Assistive social robots in elderly care: A review. Gerontechnology. 2009;8(2):94-103.

[7] Moyle W, Arnautovska U, Ownsworth T, Jones C. Potential of telepresence robots to enhance social connectedness in older adults with dementia: an integrative review of feasibility. International Psychogeriatrics. 2017;29(12):1951-64.

[8] Frennert SÖ, B. Review: Seven Matters of Concern of Social Robotics and Older People. International Journal of Social Robotics. 2014;6(2):299-310.

[9] Pu L, Moyle W, Jones C, Todorovic M. The Effectiveness of Social Robots for Older Adults: A Systematic Review and Meta-Analysis of Randomized Controlled Studies. The Gerontologist. 2019;59(1):e37-e51.

[10] Kachouie R, Sedighadeli S, Khosla R, Chu M-T. Socially Assistive Robots in Elderly Care: A Mixed-Method Systematic Literature Review. International Journal of Human-Computer Interaction. 2014;30(5):369-93.

[11] Bemelmans R, Gelderblom GJ, Jonker P, de Witte L. Socially assistive robots in elderly care: a systematic review into effects and effectiveness. Journal of the American Medical Directors Association. 2012;13(2):114-20.

[12] Feil-Seifer D, Matarić M. Defining Socially Assistive Robotics. Proceedings of the 2005 IEEE International Conference on Rehabilitation Robotics; 2005: 465-8.

[13] Bradwell HL, Winnington, R., Thill, S., Jones, R. B., editor Longitudinal diary data: Six months real-world implementation of affordable companion robots for older people in supported living. Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction (HRI ’20 Companion); 2020: 23-26 March 2020; Cambridge, UK.

[14] Picking R, Pike J. Exploring the effects of interaction with a robot cat for dementia sufferers and their carers. Internet Technologies and Applications (ITA); 2017; Wrexham, UK: IEEE.

[15] Fink J. Anthropomorphism and Human Likeness in the Design of Robots and Human-Robot Interaction, In: Ge S.S., Khatib O., Cabibihan JJ., Simmons R., Williams MA. (eds) Social Robotics. ICSR 2012. Lecture Notes in Computer Science, vol 7621. Springer, Berlin, Heidelberg.

[16] Klamer T, Allouch SB. Acceptance and use of a social robot by elderly users in a domestic environment. In: 4th International Conference on Pervasive Computing Technologies for Healthcare; 2010: 1-8, Munich.

[17] Heerink M, Krose, B., Vanessa, E., Wielinga, B. Assessing Acceptance of Assistive Social Agent Technology: The Almere Model. International Journal of Social Robotics. 2010;2:361-75.

[18] van Wynsberghe A. Designing Robots for Care: Care Centered Value-Sensitive Design. Science and Engineering Ethics. 2013;19(2):407-33.

[19] Broadbent E, Stafford R, Macdonald B. Acceptance of Healthcare Robots for the Older Population: Review and Future Directions; International Journal of Social Robotics. 2009;1(4):319-30.

[20] Odetti L, Anerdi G, Barbieri MP, Mazzei D, Rizza E, Dario P, Rodriguez G, Micera S. Preliminary experiments on the acceptability of animaloid companion robots by older people with early dementia. Proceedings of the 29th Annual International Conference of the IEEE EMBS; 2007; Lyon, France.

[21] Pino M, Boulay M, Jouen F, Rigaud AS. "Are we ready for robots that care for us?" Attitudes and opinions of older adults toward socially assistive robots. Front Aging Neurosci. 2015;7:141.

[22] Wu Y-H, Wrobel J, Cornuet M, Kerhervé H, Damnée S, Rigaud A-S. Acceptance of an assistive robot in older adults: a mixed-method study of human–robot interaction over a 1-month period in the Living Lab setting. Clinical Interventions in Aging. 2014;9:801-11. (check)

[23] Jung MM, van der Leij L, Kelders SM. An Exploration of the Benefits of an Animallike Robot Companion with More Advanced Touch Interaction Capabilities for Dementia Care. Frontiers in ICT. 2017;4:1-11.

[24] de Graaf MMA, Ben Allouch S, van Dijk JAGM. Why Would I Use This in My Home? A Model of Domestic Social Robot Acceptance. Human–Computer Interaction. 2017;34(2):115-73.

[25] Hoffman, G. Anki, Jibo and Kuri: What we can learn from social robots that didn't make it. IEEE Spectrum. 2019. Available from: https://spectrum.ieee.org/automaton/robotics/home-robots/anki-jibo-and-kuri-what-we-can-learn-from-social-robotics-failures

[26] Forlizzi J, Disalvo C, Gemperle F. Assistive Robotics and an Ecology of Elders Living Independently in Their Homes. Human-Computer Interaction. 2004;19:25-59.

[27] Whelan, S., Murphy, K., Barrett, E. et al. Factors Affecting the Acceptability of Social Robots by Older Adults Including People with Dementia or Cognitive Impairment: A Literature Review. Int J of Soc Robotics. 2018; 10;643–668.

[28] Heerink M, Albo-Canals, J., Valenti-Soler, M., Martinez-Martin, P., Zondag, J., Smits, C., Anisuzzaman, S. Exploring Requirements and Alternative Pet Robots for Robot Assisted Therapy with Older Adults with Dementia. Proceedings of the 5th International Conference on Social Robotics; Bristol, UK. 2013; 104-15.

[29] Removed to ommit author identifiers.

[30] Bradwell HL, Edwards KJ, Winnington R, Thill S, Jones RB. Companion robots for older people: importance of user-centred design demonstrated through observations and focus groups comparing preferences of older people and roboticists in South West England. BMJ Open. 2019;9(9):e032468.

[31] Guzman-Castillo M, Ahmadi-Abhari S, Bandosz P, Capewell S, Steptoe A, Singh-Manoux A, et al. Forecasted trends in disability and life expectancy in England and Wales up to 2025: a modelling study. The Lancet Public Health. 2017;2(7):e307-e13.

[32] Shin D, Choo H. Modeling the acceptance of socially interactive robotics: Social presence in human-robot interaction. Interaction studies. 2011;12(3):430-460.

[33] Vaismoradi M, Turunen H, Bondas T. Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. Nursing & Health Sciences. 2013;15(3):398-405.

[34] Mayring P. Qualitative Content Analysis. Forum: Qualitative Social Research. 2000;1(2):1438-5627.

[35] Elo S, Kyngäs H. The qualitative content analysis process. Journal of Advanced Nursing. 2008;62(1):107-15.

[36] Sparrow RS, L. In the hands of machines? The future of aged care. Minds and Machines. 2006;16(2):141-61.

[37] Søraa RA. Mechanical genders: how do humans gender robots? Gender, Technology and Development. 2017;21(1-2):99-115.

[38] Powers, A., Kramer, A.D.I., Lim, S., Kuo, J., Lee, S-L. & Kiesler, S. (2005). Eliciting information from people with a gendered humanoid robot. ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005. Nashville, TN, USA; 2005; 158-163.

[39] Stephens, T., Spevak, R., Christabel, L.R. & Hirshfield, L.E. Drawing Doctors vs. Nurses: Gendered Perceptions of Health Professionals. Journal of the Indiana Academy of the Social Sciences, 2016:19(1), 28-42.