

# Are older people any different from younger people in the way they want to interact with robots? Scenario based survey

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## Abstract

### Background

Numerous projects, normally run by younger people, are exploring robot use by older people. But are older any different from younger people in the way they want to interact with robots? Understanding older compared to younger people's preferences will give researchers more insight into good design. We compared views on multi-modal human-robot interfaces, of older people living independently, with students and university staff.

### Methods

We showed 96 participants aged under 65 and 18 aged 65+, six videos presenting different scenarios, including interfaces both working properly and failing, for an older man interacting with a robot by speech and touch screen tablet. Participants were asked about the interfaces they might use and why, using self-completed questionnaires with mainly open-ended questions.

### Results

People over 65 were more like people under 21 than those aged 22-64 (78%, 67%, 47% respectively) in preferring speech over tablet for robot-human interaction. But reasons for doing so may differ, for example, hearing and eyesight impairment Vs speaking while hands full. Older participants were more likely (83% Vs 55%) to want a robot in the house than those under 65. Older people were as familiar with tablets and smart speakers as younger people, but less likely to use smart phones. Some younger people suggested interacting with robot via their smart phone, and while not at home. Answers to similar questions about preferences for robot interaction varied according to position in the questionnaire.

### Conclusions

User-centred design of human-robot interfaces should include open questions to understand people's preferences, should account for question wording and order in interpreting user preferences, and should include people of all age ranges to better understand interface use. Older people's technology needs have differences and similarities to the younger people who are likely carrying out the research. Our sample of older people were more like people under 21 than those aged in between in for preference of robot-human interaction, and more willing to have a robot in the home than younger people. Differences may come from a more home based lifestyle and difficulties with vision, hearing, or dexterity rather than lack of interest in technology.


**Keywords**: older people; human robot interaction; communication preferences; user-centred design.

# Background

Use of robots with older people: An ageing population is a major concern for health care in the UK as in many other countries. Given that by 2040 one in seven people will be aged over 75 [1], social robots have been proposed as assistants for older people [2]. Robots can be programmed with caring and empathetic behaviours, helping users in various tasks, or entertainment to help reduce loneliness [3].

Human-robot interaction (HRI): HRI is a challenging problem because recognizing social norms and determining socially acceptable behaviours by robots are still far from perfect [4]. To make social HRI natural it is important for robots to understand verbal and non-verbal social cues, as do humans [5]. In the last decade, HRI researchers have studied various human-inspired interaction models in social robots. For example, in Breazeal (2003), the use of robot facial expressions was investigated in communication between the Kaspar robot and an autistic child [6-7]. Natural language for HRI has been studied by others [8-9]. Smart phone/tablet based interaction has been used to enhance human-robot interaction in projects such as Maggie [10], and the widely available Pepper robot uses voice and tablet for interaction [11].

Recent and current studies: Governments and funding bodies around the world are supporting projects in care-robotics, such as HOBBIT [12], MARIO [13], ENRICHME [14], and Robot-Era [15]. Projects such as HOBBIT aim to support independent living for older people by providing physical and cognitive assistance. The goal of HOBBIT is to develop companionship between users and robots by letting them take care of each other, so that users finally accept the robot in their household [16]. The European project ENRICHME offered an intelligent robotic system that interacted with and monitored older people in a smart home environment [14]. If the robot noticed any emergency, it could contact the care assistant or family members for immediate assistance.

In the Robot-Era project, the robot offered various services to users, such as helping them with shopping, cleaning the house, laundry, ordering food, calling friends and family, and organizing events [15]. Robot-Era used three different robots (domestic, condominium, and outdoor), each developed for specific tasks. For example, users interacted with the domestic robot to order groceries. The outdoor robot went to the shop, collected the order, and brought it back to the condominium robot, who transferred it back to the domestic robot and to the user's house [15]. Users could send their commands to the robot by using a tablet computer's graphical user interface and by talking to the robot (speech recognition).

HOBBIT, focused on joint tasks between the older person and the robot, fall detection and prevention such as picking up objects and monitoring users to detect falls. The system had a multimodal user interface using graphical user interface on the attached tablet located in front of the robot, speech recognition, and a gesture recognition interface [16].

Most projects described above used multimodal user interfaces and smart environments (e.g. sensors in the home environment) for their users, so that users could choose their preferred options to communicate with systems.

Assumptions about older people: However, Frennert et al, in their 2014 review [3], studied 31 key publications in detail, identifying seven matters of concern. These concerns were: (1) the role of robots in older people's lives; (2) factors affecting older people's acceptance of robots; (3) lack of mutual inspiration in the development of robots for older people; (4) robot aesthetics; (5) ethical implications of using robots in caring for older people; (6) robotic

research methodology; and (7) technical determinism versus social construction of social robots [17]. They concluded that older people are often not present in the development of robots and that their matters of concern are not identified in the design process. Instead, they are ascribed general needs of social robots due to societal changes such as ageing demographics and demands from the healthcare industry. They argued that older people seem to be plagued with stereotypical views such as that they are lonely, frail and in need of robotic assistance. They concluded that the perceptions of older people need to be re-examined and perhaps redefined to fairly represent who they are, and that more research on older people as social robotic users was needed.

Assessing usability: There is, of course, a considerable body of work assessing the usability of robots [3, 18-20]. For example, Heerink and colleagues developed a 'toolkit' using a quantitative approach to evaluate users' acceptance of assistive social robots for elderly care environments. Such a toolkit helps to know whether a robot is acceptable for its intended audience. [21-22]

The need for this research: Our study had a more limited, but different aim, to explore preferences in mode of interaction by age. We wanted to inform the design of a robot system at the start. Like the findings of Frennert et al, [21-22] but more anecdotally, we had been in conversations that seemed to jump between the extremes (a) that older people are very different from younger people, or that (b) they are just the same. We were designing an interface for a robot system and needed evidence about older people's preferences but we wanted to know, given that robot designers and researchers were generally younger, if and in what way, older people's preferences were different from those of younger designers.

Although, most studies claim to be user-centred, researchers sometimes use closed questions with pre-defined options that do not allow respondents to explain or qualify their answers. There are few studies investigating the reasons for the choices made by users in this context [23].

We report here a study that was part of a larger project, <anonymised> [24]. The aim of <anonymised> is to develop a hierarchical system integrating an existing robotic platform with a domestic system, smart objects, a virtual community and an activity centre. <anonymised> aims to provide additional monitoring of older people, living alone and independently in their homes, who may be at risk of physical or cognitive decline. Integrating an activity centre and a virtual community in <anonymised> should promote activities and socialization through connection to peers.

# Methods

## Aim, design and setting

We aimed to understand the communication preferences for users with care robots and how preferences varied by age and use of other technologies. We designed a presentation and questionnaire and undertook a cross-sectional survey in two settings: (i) a university, (ii) a managed apartment block for older people.

## Ethical approval

We received ethical approval from the Faculty of Technology Ethical Committee (18/03/2017). All participants were given an information sheet, had the purpose explained verbally, signed a consent sheet, and were anonymous.

## Samples and data collection methods

Younger participants were recruited at a health care event for students and staff at <anonymised> University (Figure 1: left). Middle-aged participants were recruited by personal invitations over one week, data collection taking place in University offices, libraries and coffee shops. Older participants were recruited during a one-day visit at a sheltered housing block in <anonymised> (Figure 1: right) for people aged 65 and over. At this location, residents live independently in their own apartments but have a communal lounge.

From previous studies, we expected to recruit between 15-20 older people at the apartment block. An overall sample size of 95 would give 80% power to find a difference between 40% and 60% preferring one mode over the other at the 95% level so we aimed to recruit at least 95 to the sample. We recruited as many as was possible in the health care event, then recruited further staff until we were comfortably past an adequate sample size. In total we recruited 114 participants aged 18-92 via three opportunistic samples.

It is well known that the perceptions of participants in robot research will be influenced by their prior exposure to robots in literature or entertainment media [25]. Others have used videos to help ground expectations [26], so we showed participants a more realistic version of the robot with both successful and failed interactions with a robot to get them to think about the reality of human robot interaction. We showed six short videos to all participants of an older man interacting with a robot (Metralabs SCITOS G5 platforms [27] using either speech or a touchscreen tablet (Figure 2). The actor was an older man (one of the authors (RJ)). Videos ranged in length from 24 seconds to 58 seconds. In all videos, the older man was trying to order food using tablet and voice, in the first two videos successfully, but then having difficulties with the interface failing, so switching modalities (videos 3-6). In the University, we had a Robot-Era robot on display (Figure 1) and in the sheltered housing, we actively demonstrated use of Pepper.

<Figures 1 and 2 about here>

## The questionnaire

After showing the videos, participants were asked to complete a questionnaire (12 questions: 7 open, 5 closed) (Appendix), asking about their choices of multimodal interface in such situations. The first six questions related to the videos of human robot interaction and the second six questions asked more general questions on their views on robots and technology. Questions about preference for voice or tablet were asked twice – first in the context of the

shown videos and second in the more general context of human robot interaction, after asking about their use of other technologies. Asking twice was a validity check on responses.

### Analysis

We compared preferences for robot interfaces via crosstabs and chi-squared or Fisher exact tests by age group, gender, work status (student, working, retired), and by current use of technology.

# Results

### Participants' choice of interaction with the robot after showing them the video

When asked just after seeing the videos, just over half (64 (56.1%)) preferred to use speech and 50 (43.9%) to use the tablet interface (Table 1). The middle working-aged group (22-64) preferred the tablet and the older and younger age groups preferred speech ($\chi^2$=6.8; 2df; p=.03). There was no difference between men and women, nor by work status, in preference for using speech or tablet.

Table 1: Preference for mode of interaction (first question) by age group

| Age groups | Interaction Preferences | | Total |
|---|---|---|---|
| | Speech | Tablet | |
| **21 and under** | 16 (66.67%) | 8 (33.33%) | 24 (100%) |
| **22-64** | 34 (47.22%) | 38 (52.78%) | 72 (100%) |
| **65 +** | 14 (77.78%) | 4 (22.22%) | 18 (100%) |
| **Total** | 64 (56.1%) | 50 (43.9%) | 114 (100%) |

Participants' reasons for their preferred mode of interaction varied; Table 2 gives examples by age group. Some participants preferred speech to avoid 'typing' but others preferred using the tablet to avoid issues of reliability with speech. Others thought that, despite the risk of failures, the speech interface was more naturally engaging than the tablet. For participants aged under 65, reasons for using speech or tablet were mostly related to engagement or reliability. University staff included a number for whom English was not their first language and they preferred tablet to speech for more reliable interaction. Five older people cited issues such as physical problems, for example, some commented that because of their trembling fingers they cannot use the tablet properly, others because of impaired hearing preferred to use the tablet. None of the younger participants cited such physical problems in using the interface. Some participants mentioned that if their hands are busy doing some work and unable to use the tablet, they would probably interact with the robot using speech.

Table 2: Examples of participants' comments supporting their preferences for speech or tablet by age

| Age Group | Example comments |
|---|---|
| ***Under 21*** | • Speech as it is easy to use if you are busy and unable to use tablet quick enough. It also means you can do it without going to the machine<br>• Speech, as may not always have hands free. However, I believe I would use a mix of both.<br>• Preferably speech, still involves some form of human interaction, tablet would be too complicated to locate area of choice. There is a greater risk of error and technical difficulties.<br>• Speech, easier to do, not involve moving, not involve understanding to use a tablet |
| ***22-64*** | • Depends. If I had my mobile next to me I would use that as it is there. If the robot was here i would use speech<br>• Tablet, speech recognition is often very poor especially with my Irish accent<br>• Tablet, quicker and avoids speech issues<br>• I would prefer to use the tablet as it would be easier, I often find my accent isn't recognised by voice operated devices |
| ***65 and over*** | • Speech but slower<br>• Tablet - could not hear robot, voice not clean<br>• Speech, I'm very slow with tablet because of dexterity<br>• Tablet because I am deaf. but possibly both |

## Participants' choice of interacting with the robot after asking about other devices

Participants were asked a second time for their personal preferences of interacting with a robot, after asking them about their use of personal devices and not in response to our videos. By framing the question slightly differently and in a slightly different context we were able to test the robustness of their views about interfaces. Again, this was an open-ended question. Most people (68/114) suggested at least two modalities of interaction (e.g. voice and tablet, tablet and other). Only 7 people suggested interacting by tablet alone and 39 voice alone. Table 3 shows modalities suggested (either singly or in combination) by age group. Most people (97/114) included voice as a means of communication either alone (39) or in combination, whereas only about half (62/114) mentioned tablet either on its own or in combination with another modality.

Nine people aged under 65 mentioned possible use of mobile phone as a means of interaction particularly when out of the house: *…through pictures or contacting through mobile phones (If not at home and you want the heating on ready or you want to make sure door is locked if you're out somewhere*". Remote access to the robot was suggested by another although not mentioning phone and when within the house: *…why does speech have to be on the robot, it could be in each room of the house in the background to command the robot.* Other responses picked up on the suggested use of subtitles in an earlier question. *"Subtitles would help, as for some such as elderly may find it difficult to understand what the robot is saying."* Other suggestions included making gestures or touching the robot (as opposed to a screen). Reasons for participants' choices included 'situational' and voice being hands free: *I think voice command is good if you are busy doing other things however personally I would use a tablet or phone most of the time*.

Table 3: Participants' preferences to interact with the robot, by age group.

| Age group | Interface | Total |
|---|---|---|

| | Tablet | Voice | Phone | |
|---|---|---|---|---|
| 21 and under | 14 (58.3%) | 22 (91.7%) | 5 (20.8%) | 24 |
| 22-64 | 44 (61.1%) | 62 (86.1%) | 4 (5.6%) | 72 |
| 65+ | 4 (22.2%) | 13 (72.2%) | 0 (0.0%) | 18 |
| Total participants | 62 | 97 | 9 | 114 |

(Participants answered in free text and may have suggested several forms of interface that they would use.)

## Comparison between first and second question on robot interaction

The questionnaire asked for preference between voice and tablet in two parts of the questionnaire (Q1 and Q9). Fewer people seemed to prefer tablet in responding to the second question (Table 4). Only 28 people remained with their binary choice earlier in the questionnaire: 23 who remained voice only and 5 who remained tablet only. Five people changed from only voice to tablet and 21 changed from only tablet to voice.

Table 4: Comparison of the responses between two similar questions of preferences to communicating with a robot

| **Second question (Q9), after answering questions about other devices** | **First question (Q1), asked after watching videos** | | **Total** |
|---|---|---|---|
| | **Speech Preferred** | **Tablet Preferred** | |
| **Tablet only (or tablet and laptop or desktop)** | 5 (7.8%) | 3 (6.0%) | 8 (7%) |
| **Voice or voice and phone (not tablet)** | 23 (36.0%) | 21 (42.0%) | 44 (38.6%) |
| **Voice & Tablet** | 29 (58.0%) | 21 (42.0%) | 50 (43.9%) |
| **Voice Tablet or phone** | 2 (3.1%) | 1 (2.0%) | 3 (2.6%) |
| **Did not answer** | 5 (7.8%) | 4 (8.0%) | 9 (7.9%) |
| **Total** | 64 (56.1%) | 50 (43.9%) | 114 (100%) |

## Preference for type of voice

Most participants did not directly answer a question about what type of voice the robot should have but instead indicated that there should be choice. Example of responses include: "*should have a program where you can choose whether to have male or female voices. and to be more caring and polite.", "should have both female and male so user can decide, would be more personal if the robot was to use your name*", "*I think being able to acknowledge the users*

*name and general manners would be better. it makes it better to communicate and would make a better companion for someone*." Among the 41.6% who chose male or female, most (30/36) favoured a female voice. Younger people were more likely to want to have control over the voice options ($\chi^2$=49.07, 4df; p = .006).

## Robots for household use in the future

Older people were more likely to want a robot for their household compared to those aged under 65 (83.3% Vs 55.2%; $\chi^2$=4.98; 1df; p=.026). The most popular use of a household robot was for household tasks (43 out of 146 responses, 29.45%), like vacuum cleaning the floor, and personal tasks, like reminding them to take their medicine. Some (mostly younger) people suggested robots could help communicate with other people, organize email etc. Some participants were concerned about the price that made them unsure of owning a robot.

## Current device use

All 24 participants under 21 used a smart phone but only 7 (43.75%) of those over 65 (Table 5). Similarly, most people under 65 used a personal computer but only 9 aged over 65. Tablet computers, on the other hand were used just as much by older people as by other age groups. The middle-aged groups were less likely than younger and older age groups to have tried smart speakers like Amazon Echo or Google Home. There were big differences by age in the number of devices used; nobody under the age of 21 had used just one device whereas nearly half those aged 65+ used just the one device ($\chi^2$= 75.11, 4df; p < .001).

Table 5: The use of technological devices by age group

| Devices | 21 & under | 22-64 | 65+ | Total |
|---|---|---|---|---|
| **Personal Computer** | 23 (95.83%) | 71 (95.95%) | 9 (56.25%) | 103 (91.15%) |
| **Tablet** | 15 (62.50%) | 50 (67.57%) | 10 (62.50%) | 75 (66.37%) |
| **Smart Phone** | 24 (100%) | 69 (93.24%) | 7 (43.75%) | 100 (88.5%) |
| **Amazon Echo or Google Home** | 4 (16.67%) | 4 (5.41%) | 2 (12.50%) | 10 (8.85%) |
| **Total people** | 24 (100%) | 72 (100%) | 17 (100%) | 113 (100%) |

Note: one participant did not respond so analysis is based on 113.

## Voice commands on current devices and preference for robot interaction

Most smart phones, tablets, and modern computers have the option of voice commands, so we asked participants if they knew if their devices had voice technology. The majority (63%) said they did but a quarter did not know including a large proportion (30%) of working age participants. Just under half (51, 45.5%) used voice commands either frequently or sometimes. There was no difference between age group. Those who currently use voice were

neither more nor less likely to prefer voice for human-robot interaction. Reasons for not using voice included: simple 'habit' (*I've never felt the need, I don't come across situations where I think 'I wish I had Siri' plus id get frustrated when it took misinterpreted what I was asking);* problems with the technology *(Really poor technology to understand voices, voice is one of the most complex subjects on earth and I don't believe effective voice communication with machines will ever exist):* and concerns about privacy *(I usually use my phone in public so don't want to speak online. I have grown up without voice automated items so I often don't think of it. Sometimes it can't understand my accent.).* On the other hand users of voice found it *(faster than using typing and encourages more natural communication)* and (it's easier to use and if you are busy Siri knows your voice so you do not even have to touch the device.)

# Discussion

Attitudes to technology and preferences in human-robot interaction are changing all the time. We aimed to understand how communication preferences in interacting with care robots varied by age, as young and middle-aged robot designers often make assumptions about older people. Our study was to inform the early stage of design of a new robot system so we were asking questions based on scenarios rather than exploring or observing interactions with an actual system. However, this meant we could try to standardise the experience and context of the questions we asked. We did this by creating a video of someone interacting with a robot; to provide realism the interaction sometimes worked and sometimes failed. Finally, in our questionnaire we asked similar questions in different ways after introducing other ideas that may influence preferences for human-robot interfaces.

The preferences of our sample of older people (aged from 65 to over 90) were more like people under 21 than those aged 22-64, in preferring speech over tablet for robot-human interaction. Older people were more willing to have a robot in the home and just as familiar with tablets and smart speakers. Others have found that older people are the most inclined to believe that robotics can contribute something to their personal happiness and are the most positive in believing that robots can help regain independence in situations where they can no longer fulfill daily tasks [28].

Our study was in line with national statistics [29] that older people are less likely to use smart phones. This may reflect a more home based lifestyle and difficulties with hearing or dexterity rather than lack of interest in technology. Our older participants were very willing to use new technologies but, for example, some older people preferred to use tablets because of poor hearing while other preferred voice because of poor eyesight.

If questionnaires are to be used as part of user-centred design, it is important to include open questions to understand why people prefer one interface to another and to have validity checks. Our study demonstrated the well-known impact of question order, wording, and context on how respondents answer questionnaires [30-32]. The wording of our first question, even though using an open rather than check box response mainly elicited a binary choice of voice or tablet. The wording used on the second occasion we asked, coming after questions about the use of other interfaces such as Siri, encouraged a more nuanced response.

Various studies [33-35] show the effects of ageing towards people's preferences on low pitch and very high pitch voices so we asked about the type of voice that robots should have. Our participants had no strong preference for male or female voice for the robot but wanted to be able to choose. Younger people were more likely to want to have such control. Tay et al had

found that preference for the gender of robot voices is likely to align with the stereotype for that particular robot role [36].

Whether participants use speech in their own desktops, laptops, or mobiles or not, many wanted to communicate with robots by using speech commands. The reason could be that the personal robots have a full physical embodiment that would help participants to perceive them as physically present, leading to a general wish of communicating via voice as if they were talking with another person [37-38]. While security was an issue for some users in using speech options on mobile, such as Siri and Cortana, younger participants appeared not to have such concerns communicating with the robot using speech at home. Most people wanted to control the way robots will communicate with them, for example, to choose from different voices and to call them by their names.

In conclusion, our findings have implications for the field of social robot companions for healthcare and social care. For example, the study shows that the provision of multimodal systems (speech, tablet) for human-robot interaction is beneficial both to satisfy individual preferences related to expertise and ease in using technologies, as well as age-related preferences for accepting robots in people's own homes. Another important lesson learned is the involvement of users and stakeholders in the early stages of the systems design. The method used here directly engaged with the typical population of users, at different ages. Further extension of such an approach might want to consider direct engagement with other stakeholders, such as family doctors and the national health system, social services, carers and family members. Moreover, an important future step is the testing of social robot platforms with elderly users in their home or care settings, to better gauge, and manage, the sometimes high expectation of the users and caregivers and the relatively limited capabilities of current social robotic systems.

## Limitations

Our data in the three main age categories were collected in slightly different ways and so the views offered may have been influenced by our method of data collection. The older people all had a Pepper demonstrated to them to give them an idea of what a modern robot could do, prior to showing the standard video. Many University students and staff had seen demonstrations of Pepper at various times but we cannot guarantee that they had seen examples of 'modern robots' other than the robot in the video. Our study is also somewhat limited by the relatively small number of older people from one retirement block. Although, of course the statistical tests we used are perfectly valid for unequal numbers of older and younger people, the study would have been stronger with a larger sample of older people from more than one location.

## Abbreviations

None

## Figures

Figure 1: Left hand side: three participants at the <anonymised> University health care event. Right hand side: Participants completing the questionnaire at the older people's residence.

Figure 2: The user communicating with the robot using speech (top) and tablet computer (bottom).

# Declarations

- Ethics approval and consent to participate: We received ethical approval from the Faculty of Technology Ethical Committee (18/03/2017). All participants were given an information sheet, had the purpose explained verbally, signed a consent sheet, and were anonymous.
- Consent for publication: All authors have approved the manuscript. Participants included in the photos have given consent for their use.
- Availability of data and material: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.•
- Competing interests: none
- Funding: <removed to anonymise> were funded by the <anonymised> project.
- Authors' contributions: This sub project of <anonymised> was designed by RJ, MB, MR. Data collection was carried out by <removed to anonymise>.
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# References

1. Government Office for Science. Future of an ageing population. Foresight report looking at the challenges and opportunities of an ageing society 2016. https://www.gov.uk/government/publications/future-of-an-ageing-population. Accessed 5 October 2017.

2. Broekens J, Heerink M, Rosendal H (2009) Assistive social robots in elderly care: a review. Gerontechnology. doi:10.4017/gt.2009.08.02.002.00.

3. Frennert S (2016) Older people meet robots: Three case studies on the domestication of robots in everyday life. Doctoral dissertation, Lund University, Lund, Sweden.

4. Lu DV, Smart WD (2011) Human-robot interactions as theatre. *RO-MAN-11*, pp 473-478. doi: 10.1109/ROMAN.2011.6005241.

5. Pantic M, Cowie R, D'Errico F, Heylen DKJ, Mehu M, Pelachaud C et al (2011) Social Signal Processing: The Research Agenda. In: Moeslund T., Hilton A., Krüger V., Sigal L. (eds) Visual Analysis of Humans. Springer, London. https://doi.org/10.1007/978-0-85729-997-0_26

6. Breazeal C (2003) Emotion and sociable humanoid robots. International Journal of Human-Computer Studies 59, pp119–155.

7. Dautenhahn K (2007) Socially intelligent robots: dimensions of human–robot interaction. Philos Trans R Soc Lond B Biol Sci.362, pp 679–704.

8. Brick T, Scheutz M, (2007) Incremental natural language processing for HRI. *2nd ACM/IEEE International Conference on Human-Robot Interaction (HRI),* Arlington, VA, pp 263-270.

9. Bastianelli E, Castellucci G, Croce D, Basili R, Nardiet D, (2014) Effective and Robust Natural Language Understanding for Human Robot Interaction. Frontiers in Artificial Intelligence and Applications 263, DOI: 10.3233/978-1-61499-419-0-57.

10. Salchis AM, Barber R, Khamis MA., Malfaz M, Gorostiza FJ., Pacheco R et al (2006) Maggie: A Robotic Platform for Human-Robot Social Interaction. Robotics, Automation and Mech. doi:1-4244-0025-2/06.

11. SoftBank Robotics: Who is Pepper? https://www.ald.softbankrobotics.com/en/robots/pepper (2017). Accessed 5 October 2017.

12. HOBBIT Project Website: HOBBIT – The mutual care robot. http://hobbit.acin.tuwien.ac.at/ (2017). Accessed 5 October 2017.

13. MARIO Project. http://www.mario-project.eu/portal/ (2017). Accessed 5 October 2017

14. Enrich me – Our approach. http://www.enrichme.eu/wordpress/about/our-approach/ (2017). Accessed 5 October 2017.

15. Robot-Era. http://www.robot-era.eu/robotera/index.php. Accessed 5 October 2017.

16. Fischinger D, Einramhof P, Papoutsakis K, Wohlkinger W, Mayer P, Panek P et al (2016) Hobbit, a care robot supporting independent living at home: First prototype and lessons learned. Robotics and Autonomous Systems. ISSN:0921-8890.

17. Frennert S, Östlund B (2014) Seven matters of concern of social robots and older people. International Journal of Social Robotics 6(2), pp 299-310.

18. Dorsten AM, Sifford KS, Bharucha A, Mecca LP, Wactlar H (2009) Ethical perspectives on emerging assistive technologies: insights from focus groups with stakeholders in long-term care facilities. J Empir Res Hum Res Ethics 4(1), pp 25-36. doi: 10.1525/jer.2009.4.1.25

19. Pino M, Boulay M, Jouen F, Rigaud AS (2015) “Are We Ready for Robots That Care for Us?" Attitudes and Opinions of Older Adults Towards Socially Assistive Robots. Frontiers in Aging Neuroscience 7. doi: 10.3389/fnagi.2015.00141

20. Wu YH, Fassert C, Rigaud AS (2012) Designing robots for the elderly: Appearance issue and beyond. Archives of Gerontology and Geriatrics 54(1), pp 121-126. doi: 10.1016/j.archger.2011.02.003.

21. Heerink MB, Krose V, Evers B, Wielinga (2010) Assessing Acceptance of Assistive Social Agent Technology by Older Adults: the Almere Model. International Journal of Social Robotics 2 (4), pp 361-75. doi: 10.1007/s12369-010-0068-5.

22. Heerink M, Krose B, Evers V, Wielinga B (2009) Measuring acceptance of an assistive social robot: a suggested toolkit. The 18th IEEE International Symposium on Robot and Human Interactive Communication, Vols 1 and 2, DOI: 10.1109/ROMAN.2009.5326320.

23. Wallen F (2017) Comparing voice and touch interactions for Smartphone radio and podcast application. Found on: https://kth.diva-portal.org/smash/get/diva2:1119305/FULLTEXT01.pdf. Accessed 5 October 2017

24. <removed to anonymised>

25. Broadbent E, Kuo IH, Lee YI, Rabindran J, Kerse N, Stafford R *e*t al (2010) Attitudes and reactions to a healthcare robot. Telemed J E Health. doi:10.1089/tmj.2009.0171

26. Minae KM, Jung MF, Knepper RA (2016) Human Expectations of Social Robots. In: Proceeding HRI '16 The Eleventh ACM/IEEE International Conference on Human Robot Interaction. pp 463-464. ISBN: 978-1-4673-8370-7

27. DiNuevo A, Broz F, Wang N, Belpaeme T, Cangelosi A, Jones R et al (2017) The multi-modal interface of Robot-Era multi-robot services tailored for the elderly. Intelligent Service Robotics. doi:10.1007/s1137

28. Arras KO, Cerqui D (2005) Do we want to share our lives and bodies with robots? A 2000-people survey. Technical Report 0605-001. Autonomous Systems Lab Swiss Federal Institute of Technology, EPFL. Found at: www2.informatik.uni-freiburg.de/~arras/papers/arrasTR05.pdf. Accessed 10 February 2018

29. Office for National Statistics. Internet access – households and individuals: 2016. 5. Mobile or smartphones are the most popular devices used by adults to access the internet. Found at: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2016#mobile-or-smartphones-are-the-most-popular-devices-used-by-adults-to-access-the-internet . Accessed 12 February 2018

30. Brink MD, Schreckenberg D, Vienneau C, Cajochen JM, Wunderli N, Probst-Hensch, et al (2016) Effects of Scale, Question Location, Order of Response Alternatives, and Season on Self-Reported Noise Annoyance Using ICBEN Scales: A Field Experiment. International Journal of Environmental Research and Public Health 13 (11). doi: 10.3390/ijerph13111163

31. Lee S. McClain C, Webster N, Han S (2016). Question order sensitivity of subjective well-being measures: focus on life satisfaction, self-rated health, and subjective life expectancy in survey instruments. Quality of Life Research 25 (10), pp 2497-510. doi: 10.1007/s11136-016-1304-8

32. Siminski P (2008). Order effects in batteries of questions. Quality & Quantity 42 (4) pp 477-90. doi: 10.1007/s11135-006-9054-2

33. Re DE, O'Connor JJM, Bennett PJ, Feinberg DR (2012) Preferences for Very Low and Very High Voice Pitch in Humans. PLoS ONE. doi:10.1371/journal.pone.0032719

34. Pichora-Fuller MK, Singh G (2006) Effects of Age on Auditory and Cognitive Processing: Implications for Hearing Aid Fitting and Audiologic Rehabilitation. Trends Amplif. doi: 10.1177/108471380601000103

35. Liu H, Wang EQ, Chen Z, Liu P, Larson CR, Huang D (2010) Effect of tonal native language on voice fundamental frequency responses to pitch feedback perturbations during sustained vocalizations. J Acoust Soc Am. pp 3739–3746.

36. Tay B, Jung BY, Park T ( 2014) When stereotypes meet robots: The double-edge sword of robot gender and personality in human-robot interaction. Computers in Human Behavior 38, pp 75-84. doi: 10.1016/j.chb.2014.05.014

37. Wainer J, Feil-seifer DJ, Shell DA, Mataric MJ (2006) The role of physical embodiment in human-robot interaction. Robot and Human Interactive Communication. doi:10.1109/

38. Dautenhahn K, Ogden B, Quick T (2002) From embodied to socially embedded agents - Implications for interaction-aware robots. Cognitive Systems Research. Doi:10.1016/S1389-0417(02)00050-5

Figure

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Figure

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