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# 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.

Bradwell, Hannah

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University of Plymouth

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# BMJ Open

## Companion robots for older people: the importance of user-centred design demonstrated through observations and focus groups comparing preferences of older people and roboticists in South West England.

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Complete List of Authors:	Bradwell, Hannah; University of Plymouth, Faculty of Health and Human Sciences Edwards, Katie; University of Plymouth, Faculty of Health and Human Sciences Winnington, Rhona; Auckland University of Technology Thill, Serge; Radboud University Donders Institute for Brain Cognition and Behaviour Jones, Ray; Plymouth University, Faculty of Health, Education, and Society
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4 demonstrated through observations and focus groups comparing preferences of  
5 older people and roboticists in South West England.  
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12 **Authors:** Bradwell, H. L<sup>1\*</sup>, Edwards, K. J<sup>1.</sup>, Winington, R<sup>1,2.</sup>, Thill, S<sup>3.</sup> and Jones, R.  
13 B<sup>1.</sup>  
14  
15

16  
17 <sup>1</sup> Faculty of Health and Human Sciences, University of Plymouth, Plymouth, Devon,  
18 UK  
19

20  
21  
22 <sup>2</sup> Auckland University of Technology, 90 Akorange Drive, Northcote, Auckland, NZ.  
23

24  
25 <sup>3</sup> Donders Institute for Brain, Cognition, and Behaviour, Radboud University,  
26 Nijmegen 6525 HR, The Netherlands  
27  
28  
29

30  
31  
32 \* Corresponding author: hannah.bradwell@plymouth.ac.uk, Academic Office (S06)  
33 Knowledge Spa, Royal Cornwall Hospital Treliske, Truro, Cornwall, UK, TR1 3HD,  
34 tel: 07975927341  
35  
36

37  
38  
39 katie.edwards@plymouth.ac.uk, rhona.winington@aut.ac.nz, s.thill@donders.ru.nl,  
40 ray.jones@plymouth.ac.uk  
41  
42  
43  
44  
45

46 Orcid Numbers:

47  
48 H. Bradwell: 0000-0002-9103-1069  
49

50 K. Edwards: 0000-0001-6212-6010  
51

52 R. Jones: 0000-0002-2963-3421  
53

54 S. Thill: 0000-0003-1177-4119  
55

56 R. Winington: 0000-0002-6504-2856  
57  
58  
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## Abstract

### Objectives:

Companion robots, such as Paro, may reduce agitation and depression for older people with dementia. However, contradictory research outcomes suggest robot design is not always optimal. While many researchers suggest user-centred design is important, there is little evidence on the difference this might make. Here, we aimed to assess its importance by comparing companion robot design perceptions between older people (end-users) and roboticists (developers).

### Design

Older people and roboticists interacted with 8 companion robots or alternatives at two separate events in groups of 2-4 people. Interactions were recorded, participants' comments and observations were transcribed and content analysed. Subsequently, each group participated in focus groups on perceptions of companion robot design. Discussions were recorded, transcribed and content analysed.

### Participants and Settings

Seventeen older people (5 male, 12 female, ages 60-99) at a supported living retirement complex, and 18 roboticists (10 male, 8 female, ages 24-37) at a research centre away-day.

### Results

We found significant differences in design preferences between older people and roboticists. Older people desired soft, furry, interactive animals that were familiar and realistic, while unfamiliar forms were perceived as infantilising. By contrast, most roboticists eschewed familiar and realistic design, thinking

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3 unfamiliar forms better suited older people. Older people also expressed desire  
4 for features not seen as important by developers. A large difference was seen  
5 in attitude towards ability to talk: 12/17 (71%) older people but only 2/18 (11%)  
6 roboticists requested speech. Older people responded positively towards life-  
7 simulation features, eye contact, robot personalisation and obeying commands,  
8 features undervalued by roboticists. These differences were reflected in  
9 preferred device, with “Joy for All” cat chosen most often by older people, while  
10 roboticists most often chose Paro.  
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## 21 **Conclusions**

22  
23 The observed mis-alignment of opinion between end-users and developers on  
24 desirable design features of companion robots demonstrates the need for user-  
25 centred design during development.  
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32 **Keywords:** Social robots, companion robots, acceptability, Paro, dementia,  
33 older people, gerontology, healthcare, social care, user-centered design  
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## 39 **Strengths and limitations of this study**

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- Novel direct comparison between older people (end-users) and roboticists (developers).
  - The participation of older people themselves, contrasts with previous research using care provider opinions as proxy.
  - The range of robots and toys, some specifically designed for older people, extends previous studies with a limited array of robot features.
  - The short interaction time between participants and robots of ten minutes allowed limited time for familiarity with devices.

- Small sample size (although in-depth qualitative analysis does allow for increased confidence in results and smaller group size may have limited influence of social desirability bias or group dynamics).

## BACKGROUND

Life expectancy, and thus proportion of the population at retirement age or above, is increasing worldwide (1). As human function deteriorates with age (2), this creates a greater demand for services (3) while the numbers of health and social care workers decreases (1), putting pressure on health and social care resources (4). Steptoe et al. (5) suggested a growing need for research on maintaining wellbeing: while supporting physical functioning is often addressed, the psychological health of the ageing population has received less attention (6). Assistive robotics, whether rehabilitation or social robots (7), could help in this respect and alleviate some pressure on health and social care resources (3).

Here, we consider companion robots – a subset of social robots often designed congruent with animal aesthetics and behaviours (7, 8) that alleviate issues of traditional animal assisted therapy (9), including reducing risks for the animals themselves (9, 10). A prominent example is Paro, the robot seal (10). Research has suggested numerous benefits of interacting with Paro, including reduced agitation and depression in dementia (11, 12), more adaptive stress response (13), reduced care provider burden (13), and significantly improved affect and communication between dementia patients and day care staff (14). Paro may additionally reduce psychoactive and analgesic medication use (15), and even decrease blood pressure (16).

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3 These positive results have however been questioned (17). A comparison between an  
4 active Paro and an inactive one found benefits of the active robot were limited to  
5 engagement (18). One study (19) found no significant improvement for depression  
6 (seeing a significant decrease only for loneliness); another (20) compared live dog  
7 visits to Paro sessions over 6 weeks, and found no improvement for depression with  
8 either intervention. Research assessing suitability of Paro for a dementia unit  
9 suggested it required adaptations; for example, its vocalisations can be distressing (21).  
10 Finally, a large randomised controlled trial (RCT) found considerable variation in  
11 responses to Paro (22).  
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26 While this disparity may result from individual variability, it is also possible robot design  
27 factors may be impairing wider acceptance. Similar differences have been observed  
28 for other devices; for example, research on AIBO has both shown good acceptability  
29 (23), and found that it encouraged less interaction than a soft toy (24). Meanwhile, a  
30 review of acceptability towards robots used in aged care suggests a number of robots  
31 have failed (3).  
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42 The Almere model of acceptability of social robots among older people strongly  
43 suggests acceptability can impact intention to use, and therefore actual use of a device  
44 (25). Furthermore, using robots in contexts they were not designed for can perpetrate  
45 negative perceptions of them and reduce acceptability (4), which may explain some of  
46 the conflicting results on robot companions. User-centred design, in general, thus  
47 requires designers to have a deep understanding of those they design for, and to  
48 involve them in all stages of the process (26).  
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3 Considering perceived requirement can vary between stakeholder groups (27), as can  
4 technology acceptance (28), design requirements likely differ between varied groups  
5 of end-users, for example those with physical impairments (29), children (30), or older  
6 people. Research should thus be specific to the aim of each robotic system. Generally,  
7 integrating user requirements and experiences into design can be difficult (29). One  
8 challenge noted by Chammas et al. (26) is the acceptance, recognition and  
9 incorporation of user-centred design in practice. Therefore, considering potential  
10 additional effort required, evidence establishing the value of this approach might help  
11 encourage designers to adopt this type of methodology.  
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26 While little appears to be currently known about how older people perceive robots (31),  
27 one study explored meaning behind robotic pets with 41 independent older people  
28 (32), finding that robotic pets could provide social entertainment and interactions.  
29 While functional support was appealing, the fiction of robotic comfort was a potential  
30 tension (32). Participants reported preference for soft fur and suggested play features  
31 as an improvement, currently absent from available companion robots. A limitation  
32 was the use of unfamiliar, often brightly coloured, child-orientated pets, restricting the  
33 range of features participants could inform perceptions on.  
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46 More generally, while older people and people with dementia are implicated in  
47 companion robot design, they are often not involved (33), even given a clearly  
48 identified need for ensuring devices adequately meet the needs of the end-users (4).  
49 Instead, older people are often assigned stereotypical needs (33). When they are  
50 involved, it is usually through care providers, and at the end of the design process  
51 (32).  
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5 Here, we therefore investigate any notable differences in opinion between 'robot-  
6 users' and 'robot-creators' regarding the design of companion robots and provide initial  
7 insights into older peoples' design requirements. The different perceptions between  
8 designers and end-users we document also demonstrate the importance of user-  
9 centred design.  
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## 18 **METHODS**

### 21 **Design**

22 This study was one of many sub-studies forming a doctoral collaborative-action-  
23 research (CAR) project. We conducted observations of roboticists and older people  
24 separately interacting with a variety of robots, providing a comprehensive range of  
25 features for comparison. Both groups then participated in focus group discussions  
26 informed by their interaction experience.  
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### 38 **Patient and public involvement**

39 Due to the wider projects' CAR approach, key stakeholders have been continually  
40 involved in designing studies forming this doctoral project. Stakeholders have included  
41 older people, family members, and health and social care professionals, including  
42 dementia liaison services, psychologists and care home management and staff. The  
43 older people involved in this study subsequently provided feedback on methods for  
44 future research.  
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### 56 **Participants and settings**

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3 In total, 35 participants collaborated: 17 older people (5 male, 12 female, age range  
4 60-99 years), and 18 roboticists (10 male, 8 female, age range 24-37). Older people  
5 were recruited at a supported living complex that houses individuals of and above  
6 retirement age within apartments, with a manager present on site. Roboticists were  
7 recruited at an away-day event of researchers from a robotics research centre. These  
8 included research students, academics, and individuals developing and researching  
9 robotics and social robots, many within the health and social care field. The  
10 researchers were therefore familiar with this field, and the students may represent a  
11 next generation of developers.  
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## 26 **Procedure**

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28 In both settings, participants gave written informed consent, then formed groups of up  
29 to four people. Each group moved through three interaction stations where participants  
30 engaged in free interaction with a selection of robots or toys. Each station provided a  
31 different range of robot/toy features, aesthetics and abilities (Figure 1), and was filmed  
32 using two cameras. Non-interactive toys and devices with varying sophistication were  
33 included as comparison to the high sophistication levels of robots such as Paro.  
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Participants spent 10 minutes at each station, with researchers present to assist and  
answer questions.

After free interaction with all available robots and toys, participants engaged in semi-structured focus group discussions, guided by Key Questions (Table 1). Questions were informed by previous research (34), amended only to include more features of interest and ensure relevance with end-users as opposed to care providers. Finally, participants were debriefed.

**Table 1: Key questions used to guide focus group discussions**

Key Questions
1. Which of the animals did you like? What is it about those animals that makes you like them?
2. Thinking of designing a new robot for older people, what possibilities and properties should a suitable pet robot have? (e.g. Look, feel, abilities) <ol style="list-style-type: none"> <li>a. What features and qualities are necessary?</li> <li>b. What features and qualities are desirable?</li> <li>c. Which expressions are important?</li> <li>d. Why?</li> </ol>
3. What possibilities and properties should a suitable pet robot <i>not</i> have?
4. How do you feel about a companion robot speaking? And having a basic conversation?
5. The hedgehog is handmade, what are your thoughts on personalising robots; individuals designing or creating for personal preference of looks, feel and type of animal?
6. What do you think about how realistic or unrealistic the animal should be? How would you feel about a mythical animal?
7. How do you feel about life-simulation features?
8. Would you fancy having one of these animals yourself to keep, which one would you choose? (for roboticists – which one would you choose for an older person?)

Robots starting positions at each station (see Figure 2 for an example) were randomised, from left to right, to avoid introduction of bias. Researchers maintained a conscious effort to keep interaction unbiased, refraining from leading questions, and

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3 restricting their role to introducing animals and answering questions during free  
4 interactions. The procedure was maintained as much as possible between both  
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6 settings. Roboticists were asked to think of the target audience of older people when  
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8 responding to Key Questions.  
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## 11 12 13 14 **Materials**

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16 In addition to video recordings, field notes, paper participant information sheets,  
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18 consent forms and debriefs were collected.  
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23 Ethical approval was received from the Faculty of Science and Engineering ethics  
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25 committee at the University of Plymouth. All participants provided full, written  
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27 informed consent prior to the study.  
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## 31 32 33 **Data Analysis**

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35 Discussions at all stations were transcribed verbatim and analysed by two researchers  
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37 (HB, KE). There were two sets of data for each setting, i) unprompted opinions based  
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39 on comments and discussions during free interaction with the range of robots and toys,  
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41 and ii) focus group responses. Both sets of data were analysed separately with NVivo  
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43 using content analysis to garner emerging themes. Content analysis was selected for  
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45 inclusion of frequencies of theme occurrence (35), and involves systematic coding and  
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47 categorising of text to garner trends, frequencies and relationships of words in  
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49 discourse (36). Researchers undertook a process of data immersion, coding, grouping  
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51 codes, generating categories and reporting, as prescribed by Elo and Kyngas (37).  
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58 The results are reported in three sections:  
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- Section 1 provides the themes arising during content analysis of older peoples free interactions, giving initial insight into end-user requirements.
- Section 2 focuses on the themes from focus group discussions and features most commonly discussed by both groups in response to Key Questions (Table 1).
- Section 3 maps the relationship between older people's unprompted opinions and their focus group responses.

## RESULTS

### Section 1: Content Analysis of Older Peoples' Free Interaction with the Robots

This section provides an in-depth exploration of themes, both positive and negative, arising during unprompted, free interactions between older people (OP) and the comprehensive range of companion robots. These themes were: interactivity, familiarity, shell design and ownership.

#### Interactivity

The interactivity theme emerged on 185 occasions through codes: *interactivity*, *speech and talking*, *commanding the robot*, *fun*, *noises* and *interactivity lacking*, strongly suggesting that during live, unprompted interactions, older people demonstrated preference for interactive devices over non-interactive alternatives. The results also indicated eye contact, obeying commands and speech could be improvements on currently available devices.

Interactivity elicited positive comments from participants such as "*fascinating*," (OP15) and provided a sense of achievement when a device appeared responsive; "*I got the*

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3 *cat to roll over!*" (OP16). Participants demonstrated most enjoyment when robots  
4 appeared reactive to the individual themselves, rather than producing random  
5 movements or sounds; *"fun isn't it!"* (OP6). In contrast, non-interactive devices  
6 provoked negative responses. The Perfect Petzzz dog was described as *"a bit of a*  
7 *disappointment,"* (OP6) as the dog *"doesn't do much"* (OP16) which may become  
8 *"boring"* (OP12) as *"you can't do more than pat its head"* (OP17). Perhaps surprisingly,  
9 participants also underappreciated the interactivity of Paro. The Joy for All animals  
10 were seen as highly interactive, despite more limited technological features, while  
11 Paro was described as *"on strike"* (OP7) because participants felt it *"just moves its*  
12 *head"* (OP3, OP1). Participants interacting with Paro sometimes displayed slight envy  
13 towards peers interacting with the Joy for All animals, *"you've done more with that cat*  
14 *than I got to do"* (OP11).

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33 Despite enjoying interactivity of available robots, older people also expressed a  
34 desire for command response from robots during free interactions. The commands  
35 each animal received varied. Those directed at the Joy for All dog were based on  
36 expectations of live dogs, with participants requesting *"high five"* (OP3-4), *"give paw"*  
37 (OP3, OP5, OP8, OP10, OP15, OP17) or *"lie down"* (OP5), on 11 occasions. The  
38 Joy for All cat received similar requests including *"can you wag your tail?"* (OP3,  
39 OP1, OP8). Miro mainly received directional commands, *"turn around!"* (OP5-6,  
40 OP10-11, OP13, OP15, OP17-18) *"stop, turn, turn left, turn left"* (OP13) and Pleo  
41 received requests to play and eat; *"open wide, open wide, open up, that's it!"* (OP13).  
42 Participants also repeatedly asked robots to *"look at me"* (OP5, OP7, OP16, OP15)  
43 suggesting facial tracking and eye contact could be a future interactivity  
44 improvement: Paro and the Joy for All animals received praise as *"special"* for  
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3 “looking right at” the participant (OP2, OP4, OP13, OP17). Most frustration was  
4 noted commanding the non-interactive Perfect Petzzz dog, with 15 participants  
5 requesting or commanding the dog to “wake up” (OP1-6, OP9-13, OP16-18) or  
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10 “open your eyes” (OP5-6, OP8-9, OP12, OP16). Participants reported limited appeal  
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13 in an animal without responses, suggesting the non-interactive dog appeared “dead”  
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15 (OP17).  
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19 Participants also demonstrated desire for robot speech, comparing devices to the  
20 resident budgie, and asking “talk to me good boy” (OP7) because it would “be better  
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Participants also demonstrated desire for robot speech, comparing devices to the  
resident budgie, and asking “talk to me good boy” (OP7) because it would “be better  
than talking to myself” (OP7). Another participant commented “it’s the company [sic] I  
talk to the furniture! [sic] if you live alone you often don’t hear voices” (OP13), and “I  
like to talk to things [sic] I think I just like to hear a voice” (OP14). Another spoke to  
Pleo, saying “I wish you could talk, yes I wish you could talk” (OP16). Similarly, on 11  
occasions, participants confused Miro’s electronic noises (not recognisable as specific  
animal vocalisations) with language, repeating, “what are you saying?” (OP5) “you’re  
trying to talk aren’t you?” (OP17) and “I don’t know if it’s actual words or not” (OP14).  
Upon understanding Miro’s noises were not “actual words” one participant described  
the robot as “a dead loss” (OP17).

Nonetheless, participants still initiated conversation with non-speaking animals; “what  
can we call you? We can call you Dino. It’s not very original [sic], Dino, do you want to  
play again or eat?” (OP6). This sometimes resulted in disappointment when devices  
failed to respond verbally, “you won’t be much use to me if you don’t talk to me” (OP9),  
“he doesn’t talk back though,” “can it hear? It’s got no ears!” “If he can’t hear, he can’t  
talk to me” (OP16).

## Familiarity

This theme represents participants' desire for companion robots to be realistic and familiar in form, and emerged from codes; *realistic animal, familiarity, comparison to real animals, reminiscence, life-simulation, and toys*. Evidence arose on 71 occasions.

Participants commented on preferring cats or dogs, as what they had *"always had"* (OP13, OP17) and were *"used to"* (OP8). The realistic, familiar options available also elicited comparisons to real animals, on 25 occasions with the Perfect Petzzz dog, and Joy for All cat and dog. Participants compared devices to previous pets, *"this one's like Harry"* (OP5) or discussed benefits of robot alternatives as being *"far easier"* (OP3) because *"you don't have to take it out [sic] and clean up after it"* (OP8) and *"it won't malt"* (OP4). Familiar animals also prompted reminiscence on 12 occasions, probably due to greater relatability, such as *"I had [sic] Yorkshire terrier, tiny terrier, used to get lagged in the mud"* (OP8). Only one occasion was negative: one participant had experienced *"a dead cat in the water off the pier when I was about 9"* (OP5).

In contrast, unfamiliar forms were perceived by older people as *"a toy"* (OP1) and more infantilising. During interactions with Miro and Pleo, one participant discussed preference for *"something, that to me, looks like something we've had, like dogs and cats and things, we've had dogs and cats you see"* (OP10). Participants showed clear preference for familiar forms, and realistic design, over unfamiliar when both were available; *"that is realistic [dog], we're not very likely to come into contact with*



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3 *one of them [seal]" (OP5)*. Participants suggested seals were incongruent with their  
4 context, believing seals belong *"on the ice floats" (OP4)* or *"eaten with pepper sauce"*  
5 *(OP4)*. The familiar animals were most often the devices praised for looking  
6 *"realistic" (OP3)*, or behaving in a way that appeared *"very real" (OP5)*.  
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15 Additionally, the breathing feature of the Perfect Petzzz dog was well received; *"it's*  
16 *fascinating to watch him breathing" (OP15)*. It appears any feature increasing the  
17 'realness' of a companion was beneficial. Participants reported life-simulation  
18 features such as the breathing made the robots look *"living" (OP17)*. This feature  
19 was commented on 13 times, and often a source of conversation between  
20 participants.  
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### 31 **Shell design**

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33 This theme arose on 89 occasions through codes; *realistic animal, physical features,*  
34 *shell-type, favouritism, preference, texture and likeability*. The evidence strongly  
35 suggested older people preferred soft, furry companion robots, but also favoured big  
36 eyes. Participants did prefer features making animals appear more realistic, as  
37 discussed above.  
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47 Paro's eyes were specifically commented on positively by six older people. The *"big*  
48 *eyes" (OP1, OP4)* were described as *"cute" (OP2)* and appeared to draw participants  
49 towards the seal; *"ohhh look at your eyes!" (OP11)*. Participants also particularly  
50 appreciated Paro's prominent eyelashes; *"ladies will wish they had lashes like him!"*  
51 *(OP6)*. Other large eyes also received praise, including Furby's animated eyes that  
52 were particularly *"captivating" (OP16)*.  
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6 Older people praised animals with fur for cuddliness and suggested, in response to  
7 non-furry options, that they “*want something [sic] you could smooth and it feels like*  
8 *an animal, you know, like that [Joy for All] cats got fur*” (OP10). On 11 occasions  
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10 participants responded negatively to plastic shells of Pleo and Miro, as they did not  
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12 “*feel quite as friendly*” (OP11). In contrast, Paro’s fur was described as “*lovely*” (OP8)  
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14 and “*soft*” (OP11). While participants appeared to acknowledge Paro possessed  
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16 softer fur than alternative furry animals, the Joy for All cat fur was praised for being  
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18 less pristine. Participants suggested the cat “*looks a bit bedraggled*” (OP7) which  
19  
20 resulted in time spent brushing and grooming. One participant suggested the fur  
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22 looked “*so real*” (OP1) suggesting the longer, shaggier coat felt more congruent with  
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24 cat expectations.  
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### 33 Ownership

34 This theme arose on 30 occasions, through codes; *naming, ownership, and*  
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36 *personalisation* and represents older people demonstrating some attachment  
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38 towards robots during free interactions.  
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44 Naming was thought to relate to ownership, as naming a live animal occurs with  
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46 possession, and signifies a developing relationship (38). Older people sometimes  
47  
48 used names of previous pets, such as “*Milo*” (OP1) because “*they’ve got a cat called*  
49  
50 *Milo*” (OP3). Other participants chose generic names, such as “*Fido*” (OP11) or  
51  
52 “*Tigger*” (OP4) while some got creative with names like “*Shandy*” (OP7) because the  
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54 dog “*is a mixture*” (OP7). Once older people had allocated a name, it endured  
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3 throughout their interaction, “*are you wagging your tail for me Shandy?*” (OP7).  
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5 Naming occurred mostly with the Joy for All cat and dog.  
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10 Further evidence for ownership came from a code of the same name. Ten older  
11 people commented on acquiring a robot during free interactions, such as “*do you*  
12 *know, I’d love this [cat], I’d love this in my apartment*” (OP2). Another suggested “*the*  
13 *service should have one [Joy for All dog]*” (OP6) with peers commenting in  
14 agreement; “*we’ll all go out and buy one now!*” (OP17). Of all occurrences,  
15 ownership was only shown towards the Joy for All cat and dog, suggesting good  
16 acceptability of these two devices.  
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28 We felt personalisation related to ownership, as wanting to adapt a robot for personal  
29 use implies a desire to keep it. Evidence for personalisation was not prolific during  
30 free interactions, with hints of personalisation being desired occurring only twice.  
31 One participant enjoyed the Joy for All dog, but requested a larger size as “*I don’t do*  
32 *little doggies*” (OP16). The participant requested it “*look like a golden retriever*”  
33 because “*it’s the only dog we’ve ever known*” (OP16). It is possible evidence was  
34 limited during free interactions as participants were unaware of the possibility.  
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## 47 **Section 2: Focus Group Results**

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49 This section presents the focus groups results as a numerical comparison between  
50 end-users and developers, to provide a clear understanding of any differences  
51 between the two groups. The features presented represent the most prevalent themes  
52 during content analysis of responses to Key Questions (Table 1). For both groups, an  
53 overall score was calculated for each feature (n participants responding positively  
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minus n participants responding negatively). The difference between roboticists and older people's opinions for each feature was then calculated. Examples of focus group responses for comparison are also provided, for greater depth of understanding.

**Table 2: The number of older people and roboticists providing positive, negative or non-responses for each feature and the resultant level of difference or agreement**

		Soft							Life- simulation
		Interactivity	Fur	Talking	Personalised	Realistic	Familiar	Mythical	
<b>Older People</b> n=17	Positive	15	12	12	15	12	4	1	5
	Negative	0	1	5	1	1	0	5	0
	None	2	4	0	1	4	13	11	12
	<b>Score</b>	<b>15</b>	<b>11</b>	<b>7</b>	<b>14</b>	<b>11</b>	<b>4</b>	<b>-4</b>	<b>5</b>
<b>Roboticists</b> n=18	Positive	14	8	2	7	2	1	1	3
	Negative	2	1	13	8	11	10	1	2
	None	2	9	3	3	5	7	16	13
	<b>Score</b>	<b>12</b>	<b>7</b>	<b>-11</b>	<b>-1</b>	<b>-9</b>	<b>-9</b>	<b>0</b>	<b>1</b>
<b>Score difference</b>		<b>3</b>	<b>4</b>	<b>18</b>	<b>15</b>	<b>20</b>	<b>13</b>	<b>4</b>	<b>4</b>

Key: green = difference  $\leq$  4, orange = difference  $\geq$  13

Table 2 compares opinions of older people and roboticists towards design of companion robots specifically for older people. The largest divergences in opinions were noted for scores for realistic aesthetic, robots talking human language, personalisation of robots and familiar form. Older people and roboticists seem to agree

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3 on the need for interactivity and soft-fur in response to Key Questions 1 and 2 (Table  
4  
5 1). There also appears to be some agreement between the two groups on inclusion of  
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7 life-simulation features and mythical design, although older people were generally  
8  
9 more positive towards life-simulation and more negative towards mythical design.  
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11 Some participants did not respond to every feature, resulting in lower numbers of  
12  
13 responses for some features. Familiarity, life-simulation and mythical design received  
14  
15 lower responses, possibly suggesting these features were less important, and thus  
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17 participants felt less inclined to comment. However, this could also derive from the  
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19 semi-structured nature of the focus groups, where realistic, familiar or mythical design  
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21 were all discussed in relation to Key Question 10.  
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38 The preferred animal among older people in response to Key Question 8 was the  
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40 Joy for All cat, with 9/17 (53%) participants selecting this animal (Figure 3), followed  
41  
42 by the Joy for All dog. Paro, Miro and the homemade hedgehog were not selected by  
43  
44 any older person. The preferred animal among roboticists was Paro (11/18), followed  
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46 by Pleo the dinosaur, then the homemade hedgehog. The Joy for All dog and cat,  
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48 Miro, the Perfect Petzzz dog and Furby were not selected by any roboticists, and some  
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50 roboticists did not select any of the available animals.  
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58 **Table 3: Examples of evidence from each group during focus group discussions**  
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Theme	Older People	Example Evidence	Robotocists
Interactivity	<p data-bbox="424 309 938 376">“If you’re sat there on your own, you want some reaction” (OP6)</p> <p data-bbox="400 421 938 595">“That one [Joy for All cat] is almost perfect, but perhaps if you could say, do you want to play, and then it could then do something, a little bit more interactive” (OP13)</p>	<p data-bbox="975 309 1505 488">“I think something passive, that doesn’t make a lot of sounds, it could be stressful, too much [sic] You could have a sack that’s warm and purrs” (R3)</p> <p data-bbox="975 533 1505 741">“I think it should have high level interaction, because it would keep the interaction longer as well, if you just have a pet like this with one or two features, it’s done, it’s limited” (R9)</p>	
Soft fur	<p data-bbox="400 790 938 902">“Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder” (OP5)</p> <p data-bbox="400 947 938 1043">“Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle” (OP13)</p>	<p data-bbox="975 790 1505 936">“I don’t think so, because it isn’t cleanable, if you wanted something to cuddle you could just buy a stuffed toy” (R14)</p> <p data-bbox="1027 981 1505 1043">“Nice and furry, you could kinda cuddle it” (R18)</p>	
Talking	<p data-bbox="400 1160 938 1227">“[animals] don’t talk, there are sounds that creatures make” (OP6)</p> <p data-bbox="400 1272 938 1447">“For older people living on their own in particular, we all talk to ourselves anyway, you don’t feel so stupid if you talk to something that responds to you” (OP13)</p>	<p data-bbox="975 1160 1505 1447">“from a technological point of view, speech should be left out of the equation, especially with elderly people, and people with dementia, they wouldn’t have expressions or fully structured sentences which would get frustrating if the robot didn’t understand” (R1)</p> <p data-bbox="975 1491 1505 1637">“I can see the appeal, [sic] a rudimentary conversation might be quite nice, as long as you didn’t feel like a twit doing it” (R11)</p>	
Personalisation	<p data-bbox="400 1709 938 1776">“If it was knitted, it wouldn’t be able to move its eyes and mouth” (OP5)</p> <p data-bbox="400 1821 938 1995">“It’s quite a good idea, yeah I do, someone who’s got a particular animal” “We were talking about colours, I like that one, she’s always had black cats, It would be nice to</p>	<p data-bbox="975 1709 1505 1962">“That might ruin the illusion I’d say” “if you’ve eaten like a chicken, if you’ve seen the actual process, you would not feel so good about it [sic], when you see the finished product without knowing how, it’s sometimes better” (R2)</p>	

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	have a choice of different colours” (OP13)	“It would be amazing, it would give it a personal touch, it’s like having a new [smartphone] and getting a new cover, people love that” (R10)
Realistic	“For someone who’s always had animals, they feel that loss, so for them, something realistic that they could interact with” (OP1)  “as long as it’s got big eyes and attractive I don’t mind” (OP17)	“It would make more sense” (R1)  “No [sic] if it’s not realistic, you wouldn’t be hoping it would be a real dog so” (R16)
Familiarity	“because they [cat and dog] are more domesticated animals, whereas a seal you wouldn’t have a seal in your home” (OP1)  “I think if you’d had a cat or a dog, it would be better to have something you could relate to” (OP12)	“for the elderly it should be something familiar” (R2)  “I think because of uncanny valley it doesn’t have to be something that we are used too” (R7)
Mythical	“That’s a generation thing, kids would love it but not here” (OP1)  “Maybe in five years time..” (OP16)	“I also think something super unrealistic like the Furby would be creepy as well, it’s so bizarre you could be turned off by it, it’s weird, a baby seal, you’re not accustomed to the animal so whatever it does is just cute” (R8)  “The mythical Furby looks right because you’ve got no expectations, so you cannot do it wrong, you cannot break expectations” (R13)
Life-simulation	“Warmth under belly to keep your knees warm!” (OP1)  “If it was breathing, it would be almost a real cat, and again, it’s a soothing thing” (OP14)	“I can feel on the dinosaur, coming from an engineering point of view, with all that inside and trouble circulating the air, you can feel it gets warm, but I think that’s actually a good thing, that you can feel, it’s even more, like lizard like, even more appearing like something” (R6)  “The problem is I think it has to be done well, and it’s really difficult to do

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well, it could end up creepy and weird” (R14)

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Table 3 provides examples of the different views of older adults and roboticists during focus group discussions, further examples can be found in Supplementary File 1.

### Section 3 – Relationship between Free Interaction and Focus Group Data

This section explores how the themes arising during unprompted, free interaction support the validity of the prompted focus group results (Figure 4): all older people who discussed interactivity (15/17, 88.24%) desired this feature for a robot pet. As seen in Section 1, this feature was highly valued by older people during free interactions, with many participants desiring additional interaction, such as obeying commands and talking. In the the focus group theme of talking 12/17 (71%) older people felt positively towards robot speech.

The free interaction theme *familiarity* supports the focus group results where all older people who commented (4/17, 24%) preferred familiar forms, and 12/17 (71%) preferred realistic or life-like appearance, with only 1/17 (6%) older people responding negatively to life-like appearance (thus 92.31% of responses were positive). The higher percentage of non-responses to familiarity could suggest participants felt less strongly about this feature, and thus less inclined to comment. However, the qualitative results from free interactions would dispute this, with very strong support arising in favour of a familiar animal. Therefore, it may instead be possible that participants did not necessarily distinguish between realistic and familiar (as realistic, unrealistic and mythical were the words used within the Key Questions).



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3 The free interaction theme on shell-type and clear preference for soft fur are  
4 congruent with focus group results where 12/17 (71%) older people preferred soft fur,  
5 while only 1/17 (6%) disagreed (92% of responses positive). Life-simulation was not  
6 discussed at length during free interactions, although the Perfect Petzzz breathing  
7 feature was well received. This feature also had lower response rates during focus  
8 groups. The lower response rate for this feature could again suggest that, while life-  
9 simulation may be desirable, supported through decisive responses (100% of  
10 responses were positive), it may be less of a priority, with 12/17 (71%) older people  
11 not providing opinions. Despite limited direct discussion during free interactions, the  
12 potential inclusion of this feature is supported by the familiarity theme, whereby any  
13 aesthetic or technological features increasing the 'realness' of a pet appeared well  
14 received during unprompted free interaction.

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33 While personalisation was not highly prevalent during free interaction, some  
34 evidence was seen within the ownership theme, with a participant requesting a golden-  
35 retriever design. Within focus groups, 15/17 (88%) older people felt positively towards  
36 personalisation, and only 1/17 (6%) provided opposition (94% of responses were  
37 positive). It is possible personalisation garnered limited discussion during free  
38 interactions as participants were unaware it was possible. The range of suggestions  
39 of preferred animals upon proposal of personalisation however would certainly  
40 suggest some benefit to this approach.

## 41 42 43 44 45 46 47 48 49 50 51 52 53 **DISCUSSION**

54 User-centred design is often cited as beneficial (4, 26) but rarely used in companion  
55 robot development. The differing preferences of end-users and potential developers  
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3 in our direct comparison demonstrated the importance of user-centred design when  
4 developing companion robots for older people. Our results justify additional effort for  
5 the reportedly difficult process of integrating user requirements into design (29), and  
6 may aid acceptability of user-centred design in practice (26). Some of our roboticists  
7 felt user involvement in development could damage illusions of the robot, perhaps  
8 helping explain the minimal use of this process. However, rather than damaging  
9 illusions, adopting user-centred design may actually ensure devices receive adequate  
10 acceptability to promote use (25). Future development of robots using user-centred  
11 approaches may result in more consistent positive outcomes than those previously  
12 reported for Paro (17, 18, 20, 21). Implications of improved design, acceptability and  
13 use would be significant given the potential benefits of companion robots for older  
14 people, those with dementia, and their family and care team (11-16). Our results  
15 suggest strong acceptability and preference of the Joy for All cat and dog, and limited  
16 acceptability of Paro when these more familiar/realistic comparisons are available.  
17 This result is important given a lack of comparison studies of companion robots (39)  
18 and apparent selection bias towards Paro in research (10).

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42 Further to highlighting the value of user-centred design, this study provided initial  
43 insights on end-user design requirements. Older people and roboticists both saw  
44 interactivity as important. Older people wanted interactivity for companionship, fun,  
45 and reduced loneliness through responsiveness. Some roboticists on the other hand  
46 raised concerns on over-stimulating older people. Our older adults displayed little  
47 interest towards non-interactive animals, whose lack of responsiveness appeared  
48 frustrating. This disinterest in unresponsive/inactive companions is congruent with the  
49 finding that an 'active' Paro was more engaging than an 'inactive' Paro (18). While  
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3 interactivity appears essential, our results demonstrated the advanced responsivity of  
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5 Paro may be unnecessary. Despite having fewer technological abilities, the Joy for All  
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7 cat was perceived as most interactive, most likely because of its greater range of  
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9 movements available, including animated head and legs, rolling-over, blinking and  
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11 cleaning movements. Therefore, the range and variety of responses may be more  
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13 important than the sophistication of sensors a robot possesses.  
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19 Our older people were interested in companion robots understanding and responding  
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21 to simple commands. Use of commands is only briefly mentioned in previous literature  
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23 (32), and our findings appear contrary to a study (40) that found no evidence for the  
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25 importance of enjoyment or playfulness factors among community dwelling older  
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27 adults. Our group actively sought playfulness from robots, believing this would sustain  
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29 enjoyment for longer. Responsiveness to simple commands such as “paw” could be a  
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31 consideration for future robot design. Interestingly, there were fewer command  
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33 expectations for the Joy for All cat than other robots, perhaps due to a reduced  
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35 association between live cats and training versus live dogs. These expectations could  
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37 be used to support use of an unfamiliar form such as Paro, whose design was aimed  
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39 at reducing expectations (41). However, older people still displayed command  
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41 expectations for Pleo, Miro and Paro, (unfamiliar forms), disputing this theory. One  
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43 could speculate that the cat’s larger quantity of movements results in a reduced need  
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45 to command actions.  
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54 Older people also positively evaluated the potential for human speech from a  
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56 companion robot. These results contradict the suggestion that, congruent with the  
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58 uncanny valley theory, human acceptability of sounds depends on the realism of the  
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3 context (42). In one study (43) participants related less to an AIBO dog beeping than  
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5 a computer emitting an identical sound, perhaps due to contradiction in context  
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7 between a dog and a beeping noise, thus suggesting that animal sounds would be  
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9 most acceptable for animal robots. Our results, however, indicated positive attitudes  
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11 towards speech capabilities for provision of company. Frennert and Ostlund(33)  
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13 reported that developers were influenced by stereotypical perceptions of older people  
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15 as lonely and fragile, but failed to incorporate requirements of participating older  
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17 people into design. Our group of older people thought loneliness could be eased  
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19 through devices capable of simple conversation. This could be a user-driven  
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21 improvement to currently available companion animals if our results are replicated in  
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23 wider samples. It is possible, however, that this feature will be evaluated differently in  
24  
25 possible future research with a sample of cognitively impaired older people. Our  
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27 participants were cognitively intact and therefore aware of the artificial nature of the  
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29 robots or toys; older people with dementia may find the incongruence of human  
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31 speech from an animal less acceptable.  
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40 Eye contact was a further improvement desired by older people, some of whom were  
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42 disappointed when robots failed to look towards them. Gaze following may increase  
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44 social relevance of the robot. This may be particularly true when eye movement is  
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46 intentional rather than random (44). While the pre-programmed movements of the Joy  
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48 for All cat were positively evaluated, intentional gaze following may be an improvement  
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50 for optimal social companionship. The importance of improving sociability for robot  
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52 acceptance was noted before (45), and this addition of apparent social behaviour  
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54 could improve acceptability.  
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3 Most older people preferred soft, cuddly fur for the outer shell. Our group of roboticists  
4 generally agreed, although both groups raised concerns regarding hygiene in  
5 comparison to a hard shell. This corroborates previous findings on care providers'  
6 preferences for robots aimed at their older service users (34, 46), although others have  
7 reported older people's preference for mechanical design on robots (28). These results  
8 may reflect the broader range of socially assistive robots used (machine-like,  
9 mechanical, human-like and animal-like robots); however, results generally imply a  
10 robot should indeed be recognisable as robotic (28). One study (21) also reported a  
11 family member demonstrating stigma towards his father interacting with soft-toys,  
12 suggested potential gender barriers with soft, cuddly robots. Our study found no  
13 notable difference between males and females, and suggests that companion robots  
14 for this market should use soft fur in the design. Providing the optimum tactile  
15 characteristics are particularly important considering evidence suggests touch is one  
16 of the most important modalities of interaction for dementia patients, creating a natural  
17 method to engage with animaloid robots (47).  
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40 Considering the importance of tactile characteristics (46), a further feature for  
41 consideration in future development is life-simulation, another capability positively  
42 evaluated by older people, but lacking from current examples including Paro. Our  
43 research supports the previously reported (46) assumption of care-providers that a  
44 simulated heartbeat would be a valuable addition to Paro, but additionally  
45 demonstrates that older people themselves also valued life-simulation features,  
46 including simulated heartbeat, simulated breathing and the feeling of purring. Older  
47 people even suggested warmth as an additional feature. This result appears congruent  
48 with older adults' desire for a realistic, life-like companion.  
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5 A realistic, familiar animal form was a definite aesthetic requirement for our group of  
6 older people. This was also reflected in their choice of Joy for All cat as their preferred  
7 device, as a familiar, realistic option, with Paro not selected by any older adult.  
8 Previous research focusing on opinions of care providers revealed criticism of Pleo for  
9 lack of familiarity (34), while the intentionally unfamiliar Paro (41) is the most often  
10 utilised companion robot in research (10). The end-users in our research thought that  
11 Paro, like Pleo, was too unfamiliar. The most familiar animals, the Joy for All cat and  
12 dog, were preferred for being more relatable and congruent with the contexts in which  
13 older people lived. The unfamiliar forms appeared incongruent and infantilising,  
14 perhaps explaining the tension Lazar et al. (32) found towards their selection of  
15 unfamiliar animals.  
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33 This is relevant insofar as some companion robots, such as Paro, are intentionally  
34 designed using unfamiliar forms to avoid the robots failing to meet expectations (41).  
35 Most of our roboticists followed this line of thinking and responded negatively to  
36 familiar animals, unsurprisingly selecting Paro as their preferred companion robot. It  
37 is further likely the roboticists appreciated the advanced technical capabilities of Paro,  
38 but our study suggests such sophistication may be unnecessary for older people.  
39 Research conducted 19 years ago also suggested older people disliked the feel and  
40 behavior of a robot cat compared to real cats (47); however, currently available robotic  
41 cats are likely more realistic than the Tama OMRON Corp cat used in that study.  
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56 The preference for realistic and familiar robots may result from relatability, with older  
57 people perhaps having personal experience of cats and dogs given the prevalence of  
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3 ownership of these species (48). Familiar animals may provide recognisable potential  
4 for a loving relationship. Even individuals without personal pet ownership experience  
5 will have likely witnessed others with pets, and therefore the familiar form of a dog or  
6 cat is symbolic of that potential bond and relationship. The tendency for our group of  
7 older people to name the Joy for All cat and dog more often than alternatives suggests  
8 familiarity may additionally help facilitate a sense of ownership. Thus, our results imply  
9 that, rather than being problematic (41), memories and schemas of familiar animals  
10 may actually be beneficial. A further implication of familiar companion robots relates  
11 to reminiscence theory, which suggests benefits of reminiscence for older people  
12 including decreased depression (49). Reminiscence therapy uses memories, feelings  
13 and thoughts from the past to facilitate pleasure (50). Evidence of reminiscence was  
14 found in our study, and seems congruent with this theory, as memories of past pets  
15 and animals were shared with positive affect. It is therefore possible familiar  
16 companion robots would have additional wellbeing benefits, particularly for individuals  
17 with dementia.  
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40 The possibility of personalisation was also positively perceived by older people and  
41 thus could be a consideration for future robot design. Personalisation has been  
42 mentioned in previous research (28, 34), but has not been explored directly with end-  
43 users. Our older people positively evaluated a more person-centred approach to robot  
44 aesthetics, praising the potential to interchange robot 'skins' to match personal  
45 preference. It is possible personalised robots would be more acceptable than a single  
46 design for all users. This could alleviate some disparity in response to Paro, as seen  
47 in previous RCT research (22).  
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3 In contrast, our roboticists underestimated the value of personalisable aesthetics, and  
4 failed to predict older people's desire for human speech and life-simulation features.  
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6 The transcript evidence suggests roboticists had an awareness of Mori's uncanny  
7 valley hypothesis (51). This is not surprising given their field of interest, and it is  
8 possible this, and related literature, had influenced roboticists' views on robot design  
9 to favour unrealistic and unfamiliar forms, and to undervalue life-simulation features  
10 that would undoubtedly increase the realistic impression of a robot.  
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21 Although our study was limited by recruiting older people from just one setting and  
22 roboticists from one University (although from varied educational and occupational  
23 backgrounds) we found marked differences in their views that need to be accounted  
24 for in the development of companion robots. If creative methods of coproduction are  
25 used (52), both groups would need to think more about why they liked certain features  
26 and it is likely they would develop a new product that would be owned by this co-design  
27 group. Although there are no guarantees, a product so designed might have a higher  
28 chance of being liked by the wider population of older people.  
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42 Our study recruited older people from a retirement complex and the generalisability of  
43 their views to care home residents is limited. Our finding of the acceptability of such  
44 devices among a more independent sample is in contrast to previous research which  
45 implied more independent older people felt 'too able' to use robots (28). Thus, there  
46 may be a market among this more independent sample that has previously been  
47 underestimated.  
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58 Another limitation of our study was the short interaction time of ten minutes at each  
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3 station, providing initial preferences. Research has suggested acceptance should be  
4 measured over longer periods of use, allowing for familiarisation and more informed  
5 attitudes towards the device, which may be more predictive of actual use (53). Future  
6 longitudinal research is therefore required exploring how these initial preferences  
7 develop over time, to assess any differences in loss of engagement, or wellbeing  
8 outcomes. Our interaction period was however longer than previous research where  
9 participants only interacted with each robot for one minute (34).

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21 Our study's smaller group sizes compared to previous research (34) may have limited  
22 influence of social desirability bias or group dynamics. The small sample size, and  
23 small numbers of responses to some features during focus groups, is a further  
24 limitation. On the other hand, use of qualitative, free interaction transcriptions  
25 increases confidence in our focus group results, even where response numbers were  
26 low, as preferences were often evident through unprompted interaction.

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37 An important strength of the current study is the active participation of older people  
38 themselves. Some previous research exploring design features of companion robots  
39 for older people focused mainly on care provider opinions (28, 46). Our research has  
40 provided support for some previously identified features, but furthered this evidence  
41 base through identification of design features previously unthought-of by care  
42 providers. A further strength includes the use of a range of robots and toys, some  
43 specifically designed for older people, unlike previous related literature (32), providing  
44 a varied array of features of interest and allowing older people to provide truly informed  
45 opinions.

## Conclusion

We have provided empirical support for the necessity and value of incorporating user-centred design in the development of companion robots targeted at older people. While user-centred design has been recommended previously, there has been little direct evidence to support this requirement. Our results demonstrate stark differences in preferences and requirement between older people and roboticists, suggesting engaging the end-user in the design and development of companion robots is essential. This study also began the process of researching companion robot design with end-users themselves. The older people in our sample have suggested soft fur, interactivity and big 'cute' eyes, as being priority features on a robot. Older people also strongly suggested the robot should take the form of a realistic, familiar animal, raising questions surrounding the design of the most well researched companion robot, Paro. Further desirable functions were also identified that are not currently included as standard on companion robots, such as eye-contact, life-simulation features, personalisation, obeying commands and the potential for interactive language.

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## Competing Interest

The authors declare that they have no competing interests.

## Author Contributions

All authors read and approved the manuscript.

HB designed the study, performed data collection, transcribed, analysed and interpreted results and lead on producing the manuscript.

KE transcribed data, analysed and interpreted results and aided in production of the original manuscript.

RW supervised the project, provided expertise and advice towards the study conception and design, discussed results and substantively revised the manuscript.

ST supervised the project, provided expertise and advice towards the study conception and design, discussed results and substantively revised the manuscript.

RJ oversaw participant recruitment and data collection, supervised the project, provided expertise and advice towards the study conception and design, discussed results and substantively revised the manuscript.

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4 project, which is part funded by the European Regional Development Fund (ERDF),  
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6 for the loan of some of the robots used in this research.  
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## 12 Data Sharing

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14 The datasets generated and analysed during this study are available at the Open  
15 Science Framework using the following link:

16  
17 [https://osf.io/kps2w/?view\\_only=12ec0a445086403db685c3b41e1e3127](https://osf.io/kps2w/?view_only=12ec0a445086403db685c3b41e1e3127)  
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## 37 Figure Legends

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40 **Figure 1: Robots and toys at each interaction station, and the associated**  
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45 **Figure 2: Interaction Station 2**  
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47 **Figure 3: Choice of robot/toy for use with older people, shown by participant**  
48 **group**  
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52 **Figure 4: Mapping the relationship between older people’s unprompted**  
53 **opinions and focus group themes**  
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Station	Animal robot/toy	Range of features for comparison
1 – All soft-fur, differing levels of interactivity, familiar and unfamiliar options	 <p>Paro</p>	<ul style="list-style-type: none"> <li>• Unfamiliar</li> <li>• Not life-like</li> <li>• Interactive</li> <li>• Animal noises</li> <li>• No life-simulation</li> <li>• Soft-fur</li> </ul>
	 <p>Joy for All dog</p>	<ul style="list-style-type: none"> <li>• Familiar</li> <li>• Life-like</li> <li>• Interactive</li> <li>• Animal noises</li> <li>• Life-simulation (heart beat)</li> <li>• Soft-fur</li> </ul>
	 <p>Joy for All cat</p>	<ul style="list-style-type: none"> <li>• Familiar</li> <li>• Life-like</li> <li>• Interactive</li> <li>• Animal noises</li> <li>• Life-simulation (purring)</li> <li>• Soft-fur</li> </ul>
2 – Interactivity vs soft-fur, interactive devices have plastic shells, soft-furry dog is non-interactive. Familiar and unfamiliar options.	 <p>Miro</p>	<ul style="list-style-type: none"> <li>• Unfamiliar</li> <li>• Not life-like</li> <li>• Interactive</li> <li>• Non-animal noises</li> <li>• No life-simulation</li> <li>• Hard-shell</li> </ul>
	 <p>Pleo rb</p>	<ul style="list-style-type: none"> <li>• Unfamiliar</li> <li>• Not life-like</li> <li>• Interactive</li> <li>• Non-animal noises</li> <li>• No life-simulation</li> <li>• Soft-plastic shell</li> </ul>
	 <p>Perfect Petzz Dog</p>	<ul style="list-style-type: none"> <li>• Familiar</li> <li>• Life-like</li> <li>• Non-interactive</li> <li>• No noises</li> <li>• Life-simulation (breathing)</li> <li>• Soft-fur</li> </ul>
3 – Mythical, unfamiliar option, human speech, completely inert option. Personalisable option.	 <p>Furby</p>	<ul style="list-style-type: none"> <li>• Unfamiliar</li> <li>• Not life-like (mythical)</li> <li>• Interactive</li> <li>• Non-animal noises (speech)</li> <li>• No life-simulation</li> <li>• Soft-fur</li> </ul>
	 <p>Hedgehog</p>	<ul style="list-style-type: none"> <li>• Unfamiliar</li> <li>• Not life-like</li> <li>• Non-interactive</li> <li>• No noises</li> <li>• No life-simulation</li> <li>• Soft-fur</li> </ul>

Figure 1: Robots and toys at each interaction station, and the associated features for comparison

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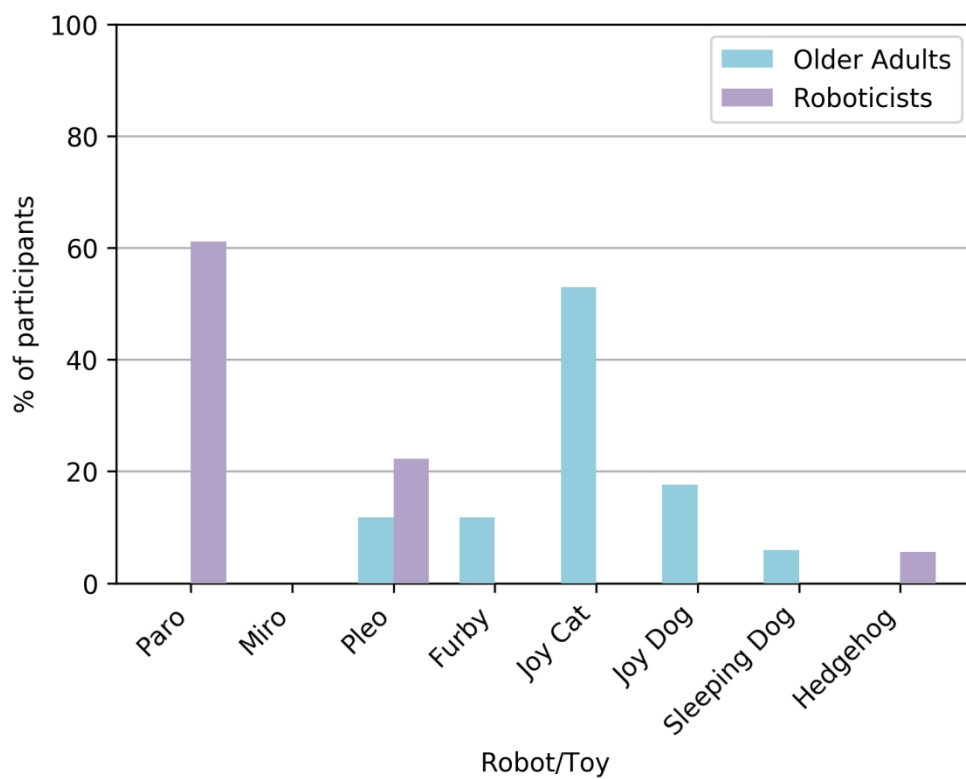


Figure 3: Choice of robot/toy for use with older people, shown by participant group

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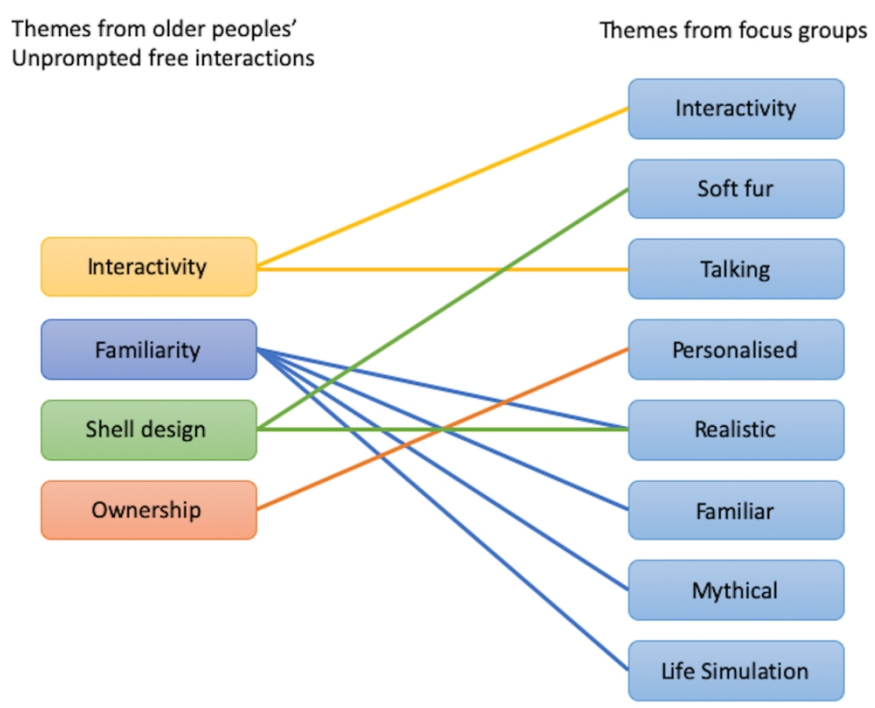


Figure 4: Mapping the relationship between older people's unprompted opinions and focus group themes

119x90mm (300 x 300 DPI)

## Supplementary Materials

Table 1: Further examples of older people's and roboticists responses during focus group discussions.

Theme	Older People	Example Evidence	Robotocists
Interactivity	<p>“it [Pleo] interacted more so you could spend loads of time just playing” (OP4)</p> <p>“If you're sat there on your own, you want some reaction” (OP6)</p> <p>“He [Joy for All dog] had more interaction, he was doing more of less what I wanted him to do” (OP15)</p> <p>“I'd like it to respond to me” (OP7)</p> <p>“That one [Joy for All cat] is almost perfect, but perhaps if you could say, do you want to play, and then it could then do something, a little bit more interactive” (OP13)</p>	<p>“The more sensors it has, and the more functionality it has the better, so they wouldn't get bored so easily, more it interacts” (R1)</p> <p>“I think something passive, that doesn't make a lot of sounds, it could be stressful, too much [sic] You could have a sack that's warm and purrs” (R3)</p> <p>“I think it should have high level interaction, because it would keep the interaction longer as well, if you just have a pet like this with one or two features, it's done, it's limited” (R9)</p> <p>“I don't know, thinking of older people, I like the idea of a cat, it could just be on your lap and purrs, it doesn't have to look at you, cats don't generally” (R18)</p>	
Soft fur	<p>“Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder” (OP5)</p> <p>“Soft furry face, the dinosaur interaction was good but it's still like dragging your hand over rubber” (OP6)</p> <p>“you can't stroke plastic” (OP10)</p> <p>“Furry, the seal [Paro] was lovely” (OP12)</p>	<p>“It should be soft” (R4)</p> <p>“Definitely have the fluffiness of the seal, around the same level of interactivity” (R5)</p> <p>“The dinosaur is cute but the texture is horrific” (R8)</p> <p>“The fur is attractive” (R10)</p> <p>“I don't think so, because it isn't cleanable, if you wanted something to</p>	

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“Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle” (OP13)

cuddle you could just buy a stuffed toy” (R14)

“if you’re having an animal, it has to have animal fur” (OP14)

“Nice and furry, you could kinda cuddle it” (R18)

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Talking

“Yes, because there’s a lot of time in your flat on your own, just having something to interact with” (OP1)

“from a technological point of view, speech should be left out of the equation, especially with elderly people, and people with dementia, they wouldn’t have expressions or fully structured sentences which would get frustrating if the robot didn’t understand” (R1)

“It might be nice to have a conversation” “If you said to it what’s your name, it would be nice if it could” (OP3)

“[animals] don’t talk, there are sounds that creatures make” (OP6)

“If you’re going for animals, then I don’t think speech is important [sic] yeah animal sounds” (R2)

“If you went in the front door, if it just said sorta, hello! That would be nice” (OP8)

“I think it is important that the robot is honest, with what it understands, it shouldn’t pretend to understand more than it actually understands, which is the case with Pepper, you get frustrated” (R3)

“Picking up something like that and talking, it could be good” (OP11)

“For older people living on their own in particular, we all talk to ourselves anyway, you don’t feel so stupid if you talk to something that responds to you” (OP13)

“It actually gets annoying because it’s repetitive, there is this boundary, where if you’ve interacted for five minutes.... It gets annoying.” (R6)

“I’m not sure, I’ve read about these Japanese and American ones that you can have a whole conversation with, highly sophisticated, but there’s no understanding at all” (OP16)

“People with advanced dementia, it’s really hard to interact with” (R7)

“No, if you make it talk there are a thousand ways to make it talk creepy as well, sounds would be better” (R9)

“I can see the appeal, [sic] a rudimentary conversation might be quite nice, as long as you didn’t feel like a twit doing it” (R11)

“It would take away from the intelligence of the thing” (R15)

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Personalisation

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“not everyone likes a dog, or there’s a particular colour they want” (OP1)

“I think that’s brilliant” (OP3)

“Yes it would be nice to have a squirrel” (OP4)

“If it was knitted, it wouldn’t be able to move its eyes and mouth” (OP5)

“Yeah, different ones, a Persian cat” (OP11)

“It’s quite a good idea, yeah I do, someone who’s got a particular animal”

“We were talking about colours, I like that one, she’s always had black cats, It would be nice to have a choice of different colours” (OP13)

“If you had someone in mind, so and so really liked black cats” (OP17)

“That might ruin the illusion I’d say” “if you’ve eaten like a chicken, if you’ve seen the actual process, you would not feel so good about it [sic], when you see the finished product without knowing how, it’s sometimes better” (R2)

“would create love and contact and proximity” (R5)

“People get more attached to it because they created it” (R6)

“I’m not sure if it’s a little patronising” (R7)

“It would be amazing, it would give it a personal touch, it’s like having a new [smartphone] and getting a new cover, people love that” (R10)

“my mum has a cat, she gets quite lonely, but if you had her make a fake cat, it just wouldn’t work” (R14)

“it could take away from the magic of the thing” (R15)

Realistic

“For someone who’s always had animals, they feel that loss, so for them, something realistic that they could interact with” (OP1)

“yeah realistic” (OP9)

“For older people, stick to cats and dogs” (OP12)

“I would prefer life like” (OP11)

“It’s better to have something that’s familiar, and real” (OP16)

“as long as it’s got big eyes and attractive I don’t mind” (OP17)

“It would make more sense” (R1)

“I think it matters less how it looks” (R3)

“I think it could not be so realistic, because (inaudible) expectations” (R9)

“As long as they’re animals, I don’t see an issue with it being realistic or non-realistic” (R11)

“I’m not sure it does, if anything the cat is too real without looking quite right” (R13)



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“I feel like it has to look cute but that doesn’t necessarily mean it has to look realistic” (R15)

“No it can be whatever, if it’s not realistic, you wouldn’t be hoping it would be a real dog so” (R16)

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Familiarity

“because they [cat and dog] are more domesticated animals, whereas a seal you wouldn’t have a seal in your home” (OP1)

“for older people stick to cats and dogs, like, might not know what a squirrel is perhaps” (OP10)

“I think if you’d had a cat or a dog, it would be better to have something you could relate to” (OP12)

“It’s better to have something that’s familiar” (OP16)

“for the elderly it should be something familiar” (R2)

“interactivity is more important, you are not interacting with these animals by looking [sic]” “I don’t think it has to be recognisable, it’s more important how it feels, the movements, sounds, purring, but you could put it in a Pokemon” (R3)

“I think because of uncanny valley it doesn’t have to be something that we are used too” (R7)

“a baby seal, you’re not accustomed to the animal so whatever it does is just cute [sic] you’re not accustomed to it” (R8)

“We’re accustomed to dogs and cats and maybe a fake dog or cat seems to be kind of creepy, but Paro, I’m not accustomed to seals” (R9)

“The [Joy for All] dog doesn’t do what it is expected to do, it doesn’t run around or get up like a dog does, I think because people don’t have expectations of what a seal does, they would imagine that’s what it would do, so with the other’s it would cause frustration they didn’t do what was expected” (R15)

“I think we don’t really know what a seal is or does, so you kind of imagine that’s what it would do, where as the others you have some expectations of which could frustrate you” (R17)

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Mythical

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“That’s a generation thing, kids would love it but not here” (OP1)

“That [Furby] is just a head, not one like that” “I want it to be more like an animals” (OP10)

“the mythical one is suitable for a child” (OP13)

“I wouldn’t want a mythical one at this time” (OP15)

“Maybe in five years time..” (OP16)

“I also think something super unrealistic like the Furby would be creepy as well, it’s so bizarre you could be turned off by it, it’s weird, a baby seal, you’re not accustomed to the animal so whatever it does is just cute” (R8)

“The mythical Furby looks right because you’ve got no expectations, so you cannot do it wrong, you cannot break expectations” (R13)

“Warmth under belly to keep your knees warm!” (OP1)

“Yes I like the Purring” (OP2)

“Make you feel comforted” (OP13).

“If it was breathing, it would be almost a real cat, and again, it’s a soothing thing” (OP14)

“It would [sic] make them [older people] want to pet it more” (R2)

“I can feel on the dinosaur, coming from an engineering point of view, with all that inside and trouble circulating the air, you can feel it gets warm, but I think that’s actually a good thing, that you can feel, it’s even more, like lizard like, even more appearing like something” (R6)

“The problem is I think it has to be done well, and it’s really difficult to do well, it could end up creepy and weird” (R14)

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3 **Title:** The Companion robots for older people: the importance of user-  
4 centered centred design: Comparing the demonstrated through observations and  
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6 focus groups comparing preferences of older people and roboticists towards  
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8 companion robot design. — in South West England.  
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14 **Authors:** Bradwell, H. L<sup>1\*</sup>, Edwards, K. J<sup>1.</sup>, Winnington, R<sup>1,2.</sup>, Thill, S<sup>3.</sup> and Jones, R.  
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16 B<sup>1.</sup>  
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24 <sup>1</sup> Faculty of Health and Human Sciences, University of Plymouth, Plymouth, Devon,  
25  
26 UK  
27  
28

29 <sup>2</sup> Auckland University of Technology, 90 Akorange Drive, Northcote, Auckland, NZ.  
30  
31

32 <sup>3</sup> Donders Institute for Brain, Cognition, and Behaviour, Radboud University,  
33  
34 Nijmegen 6525 HR, The Netherlands  
35  
36  
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38

39 \* Corresponding author: hannah.bradwell@plymouth.ac.uk, Academic Office (S06)  
40  
41 Knowledge Spa, Royal Cornwall Hospital Treliske, Truro, Cornwall, UK, TR1 3HD,  
42  
43 tel: 07975927341  
44  
45

46 katie.edwards@plymouth.ac.uk, rhona.winnington@aut.ac.nz, s.thill@donders.ru.nl,  
47  
48 ray.jones@plymouth.ac.uk  
49  
50  
51

52  
53 Orcid Numbers:

54  
55 H. Bradwell: 0000-0002-9103-1069  
56

57 K. Edwards: 0000-0001-6212-6010  
58

59 R. Jones: 0000-0002-2963-3421  
60

1  
2  
3 S. Thill: 0000-0003-1177-4119  
4

5 R. Winnington: 0000-0002-6504-2856  
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8 Main Text: [66356259](#)  
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12 **Abstract**  
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14 **Background Objectives:**  
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16 Companion robots, such as Paro, may reduce agitation and depression for  
17 older people with dementia. However, contradictory research outcomes in  
18 social robot research suggest robot design is not always optimal. While many  
19 researchers therefore suggest user-centred centred design is important, there is  
20 still little evidence on as to the difference this might make. Here, we we aimed  
21 to assess its importance by comparing perceptions of companion robot design  
22 perceptions between older people (end-users) and roboticists (developers).  
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33 **Design**  
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35 Older people and roboticists interacted with 8 different companion robots or  
36 alternatives at two separate events in groups of 2-4 people. These interactions  
37 were recorded, participants' comments and observations were transcribed and  
38 content analysed. Subsequently, each group participated in focus groups  
39 discussions on perceptions of companion robot design. Discussions were  
40 recorded, transcribed and content analysed.  
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54 **Methods Participants and Settings**  
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56 Seventeen older people (5 male, 12 female, ages 60-99) at a supported living  
57 retirement complex, and 18 roboticists (10 male, 8 female, ages 24-37) at a  
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~~research centre away-day. and 18 roboticists interacted, at two separate events and in groups of 2-4 people, with eight different companion robots. These interactions were recorded, participants' comments and observations were transcribed and content analysed. Subsequently, each group participated in focus group discussions on perceptions of companion robot design. Discussions were recorded, transcribed and content analysed.~~

## Results

We found significant differences in design preferences between older people and roboticists. Older people desired soft, furry, interactive animals that were familiar and realistic, while unfamiliar forms were perceived as ~~more~~ infantilising. By contrast, most roboticists eschewed familiar and realistic design, thinking unfamiliar forms better suited older people. Older people also expressed a desire for features not seen as important by developers. ~~For example, a~~ A large difference was seen in attitude towards ~~the~~ ability to talk: 12/17 (71%) older people but only 2/18 (11%) roboticists requested ~~human~~ speech. Older people ~~also~~ responded positively towards life-simulation features, eye contact, ~~robot~~ personalisation ~~of robots~~ and obeying commands, features undervalued by roboticists. These differences were reflected in preferred device ~~selection~~, with ~~the~~ "Joy for All" cat ~~preferred~~ chosen most often by older people, while ~~Paro was preferred by~~ roboticists most often chose Paro.

## Conclusions

The observed mis-alignment of opinion between end-users and developers on desirable design features of companion robots demonstrates the need for user-centred design ~~in the development processes~~ during development.

**Keywords:** Social robots, companion robots, acceptability, Paro, dementia, older people, gerontology, healthcare, social care, user-centered design

### Strengths and limitations of this study

- Novel direct comparison between older people (end-users) and roboticists (developers).
- The participation of older people themselves, contrasts with previous research using care provider opinions as proxy.
- The range of robots and toys, some specifically designed for older people, extends previous studies with a limited array of robot features.
- The short interaction time between participants and robots of ten minutes allowed limited time for familiarity with devices.
- Small sample size ~~compared to previous research~~ (although in-depth qualitative analysis does allow for increased confidence in results and smaller group size) may have limited influence of social desirability bias or group dynamics).

### BACKGROUND

Life expectancy, and thus ~~the~~ proportion of the population at retirement age or above, is increasing worldwide (1). As human function deteriorates with age (2), this creates a greater demand for services (3) while the numbers of health and social care workers decreases (1), putting pressure on health and social care resources (4). Steptoe et al. (5) suggested ~~there is~~ a growing need for research on maintaining wellbeing: while supporting physical functioning is often addressed ~~(6)~~, the psychological health of the ageing population has received less attention ~~– (6)~~. Assistive robotics, ~~which can be~~

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3 ~~classified as whether~~ rehabilitation ~~and~~ social robots (7), could help in this respect  
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5 and alleviate ~~this some~~ pressure on health and social care resources (3).  
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10 ~~In this paper~~Here, we consider companion robots – a subset of social robots often  
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12 designed congruent with animal aesthetics and behaviours (7, 8) ~~that alleviate issues~~  
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14 ~~of traditional animal assisted therapy (916), including reducing risks for the animals~~  
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16 ~~themselves (9, 106)~~. A prominent example ~~of a companion robot~~ is Paro, the robot  
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18 seal (910). Research has suggested numerous benefits of interacting with Paro,  
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20 including reduced agitation and depression in dementia (10, 11, 12), more adaptive  
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22 stress response (132), reduced care provider burden (132), and significantly improved  
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24 affect and communication between dementia patients and day care staff (143). ~~Further~~  
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26 ~~research has suggested~~ Paro may ~~additionally~~ reduce psychoactive and analgesic  
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28 medication use (154), and even decrease blood pressure (165). ~~Generally speaking,~~  
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30 ~~companion robots alleviate issues of traditional animal assisted therapy (16), including~~  
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32 ~~reducing risks for the animals themselves (9, 16)~~.  
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40 These positive results have however been questioned (17). A comparison between an  
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42 active Paro and an inactive one found benefits of the active robot were limited to  
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44 engagement (18). ~~Robinson et al.~~One study (19) found no significant improvement for  
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46 depression (seeing a significant decrease only for loneliness); ~~another.~~ ~~Thedberg et~~  
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48 ~~al.~~(20), compared live dog visits to Paro sessions over 6 weeks, and found no  
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50 improvement for depression with either intervention. Research assessing ~~the~~  
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52 suitability of Paro for a dementia unit suggested it ~~may need to be adapted for such~~  
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54 ~~settings as required adaptations~~; for example, its vocalisations can be distressing (21).  
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58 ~~Moyle et al. (22) also found considerable variation in responses to Paro in~~Finally, a  
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3 large randomised controlled trial (RCT) found considerable variation in responses to  
4 Paro (22).  
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10 While this disparity may ~~be due to~~ result from individual variability, it is also possible  
11 robot design factors may be impairing wider acceptance. Similar differences have  
12 been observed for other devices; ~~regarding AIBO,~~ for example, research on AIBO has  
13 both shown good acceptability (23), and found that it encouraged less interaction than  
14 a soft toy (24). Meanwhile, while a review of acceptability towards robots used in  
15 aged care suggests a number of robots have failed (3).  
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26 The Almere model of acceptability of social robots among older people strongly  
27 suggests acceptability can impact intention to use, and therefore actual use of a device  
28 (25). Furthermore, using robots in contexts they were not designed for can perpetrate  
29 negative perceptions of them and reduce acceptability, ~~(4),~~ which may explain some  
30 of the conflicting results on robot companions ~~(4).~~ User-centred design, in general,  
31 thus requires designers to have a deep understanding of those they design for, and to  
32 involve them in all stages of the process (26).  
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45 Considering ~~that~~ perceived requirement can vary between stakeholder groups (27), as  
46 can technology acceptance (28), ~~it is likely~~ design requirements ~~would likely~~ differ  
47 between varied groups of end-users, for example those with physical impairments  
48 (29), children (30), or older people, ~~thus r~~ Research is required should thus be specific  
49 to the aim of each robotic system. Generally, ~~Integrating~~ integrating user requirements  
50 and experiences into design can be difficult (29). ~~Similarly, o~~ One challenge noted by  
51 Chammas et al. (26) is the acceptance, recognition and incorporation of user-centred  
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3 design in practice. Therefore, considering potential additional effort required, evidence  
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5 establishing the value of this approach might help ~~to~~ encourage designers to adopt  
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7 this type of methodology.  
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12 ~~While There currently appears to be little~~ little appears to be currently known about how  
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14 older people perceive robots (31). ~~One exception is a study that~~ explored meaning  
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16 behind robotic pets with 41 independent older ~~adults~~ people (32), ~~finding that. Results~~  
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18 ~~suggested~~ robotic pets could provide social entertainment and interactions. ~~While~~  
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20 functional support was appealing, ~~but~~ the fiction of robotic comfort was a potential  
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22 tension (32). Participants reported preference for soft fur and suggested play features  
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24 as an improvement, ~~which appear absent on~~ currently ~~absent from~~ available  
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26 companion robots. A limitation was the use of unfamiliar, often brightly coloured, child-  
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28 orientated pets, ~~restricting the providing a limited~~ range of features ~~for~~  
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30 ~~participants~~ older ~~adults~~ people ~~to~~ could inform perceptions on.  
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38 More generally, while older people and people with dementia are implicated in  
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40 companion robot design, they are often not involved (33), even given a clearly  
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42 identified need for ensuring devices adequately meet the needs of the end-users (4).  
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44 Instead, older people are often assigned stereotypical needs (33), ~~with studies rarely~~  
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46 ~~involving older people in robotics design: when~~ ~~When they are~~ involved ~~at all~~, it is  
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48 usually through care providers, and at the end of the design process (32).  
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54 ~~In this paper~~ Here, we therefore ~~seek to~~ investigate any notable differences in opinion  
55  
56 between 'robot-users' and 'robot-creators' ~~regarding~~ about the design of companion  
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58 robots ~~for older people, and and in doing so,~~ provide ~~some~~ initial insights into older  
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3 peoples' design requirements ~~for companion robots. This evidence of~~The different  
4 perceptions between designers and end-users ~~we document may also help persuade~~  
5 ~~designers of~~also demonstrate the importance of user-centred design.  
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## 10 11 **METHODS**

### 12 13 14 15 **Design**

16  
17 This study was one of many sub-studies forming a doctoral collaborative-action-  
18 research (CAR) project. We conducted observations of roboticists and older people  
19 separately interacting with a variety of robots, providing a comprehensive range of  
20 features for comparison. Both groups then participated in focus group discussions  
21 informed by their interaction experience.  
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### 31 **Patient and public involvement**

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33 Due to the wider projects' CAR approach, key stakeholders have been continually  
34 involved in designing studies forming this doctoral project. Stakeholders have included  
35 older people, family members, and health and social care professionals, including  
36 dementia liaison services, psychologists and care home management and staff. The  
37 older people involved in this study subsequently provided feedback on methods for  
38 future research.  
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### 50 **Participants and settings**

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52 In total, 35 participants collaborated: 17 older people (5 male, 12 female, age range  
53 60-99 years), and 18 roboticists (10 male ~~and~~, 8 female, age range 24-37). Older  
54 people were recruited at a supported living complex that houses individuals of and  
55 above retirement age within apartments, with a manager present on site. Roboticists  
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3 were recruited at an away-day event of researchers from a robotics research centre.  
4  
5 These included research students, academics, and individuals developing and  
6  
7 researching robotics and social robots, many within the health and social care field.  
8  
9 The researchers were therefore familiar with this field, and the students may represent  
10  
11 a next generation of developers.  
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## 17 Procedure

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19 In both settings, participants gave written informed consent, then formed groups of up  
20  
21 to four people. Each group ~~then~~ moved through three interaction stations where  
22  
23 participants engaged in free interaction with a selection of robots or toys. Each  
24  
25 ~~interaction station was filmed using two separate cameras, and~~ provided a different  
26  
27 range of robot/toy features, aesthetics and abilities (Figure 1), ~~and was filmed using~~  
28  
29 ~~two cameras~~. Non-interactive toys and devices with varying sophistication were  
30  
31 included as comparison to the high sophistication levels of robots such as Paro.  
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33 Participants spent 10 minutes at each station, with researchers present to assist and  
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35 answer questions.  
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51 ~~Following After~~ free interaction with all available robots and toys, participants ~~finally~~  
52  
53 engaged in semi-structured focus group discussions, guided by ~~key questions~~  
54  
55 ~~(tableKey Questions (Table 1), which Question~~ were informed by previous research  
56  
57 ~~(34). Questions were amended, however, amended only~~ to include more features of  
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interest ~~to~~and ensure relevance with end-users as opposed to care providers.

Following completion ~~Finally~~, participants were debriefed.

**Table 1: Key questions used to guide focus group discussions**

Key Questions
1. Which of the animals did you <del>prefer</del> like? What is it about <del>that animal</del> <u>those animals</u> that makes you like <del>it</del> them?
2. Thinking of designing a new robot for older people, what possibilities and properties should a suitable pet robot have? (e.g. Look, feel, abilities) <ol style="list-style-type: none"> <li>a. What features and qualities are necessary?</li> <li>b. What features and qualities are desirable?</li> <li>c. Which expressions are important?</li> <li>d. Why?</li> </ol>
3. What possibilities and properties should a suitable pet robot <i>not</i> have?
4. How do you feel about a companion robot speaking? And <del>have</del> having a basic conversation?
5. The hedgehog is handmade, what are your thoughts on personalising robots; individuals designing or creating for personal preference of looks, feel and type of animal?
6. What do you think about how realistic or unrealistic the animal should be? How would you feel about a mythical animal?
7. How do you feel about life-simulation features?
8. Would you fancy having one of these animals yourself to keep?, <u>which one would you choose? (for roboticists – which one would you choose for an older person?)</u>

Robots starting positions at each station (see Figure 2 for an example) were randomised, from left to right, to avoid introduction of bias. ~~Figure 2 shows an example interactions~~interaction station. Researchers maintained a conscious effort to keep interaction unbiased, refraining from leading questions, and restricting their role to introducing animals and ~~responding to participant~~answering questions during ~~the~~ free interactions. The procedure was maintained as much as possible between both

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2  
3 settings. Roboticians were asked to think of the target audience of older people when  
4  
5 responding to ~~key questions~~Key Questions.  
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### 19 **Materials**

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21 ~~We used~~In addition to video recordings ~~equipment to capture interactions between~~  
22 ~~participants and robots. Note pads were used for researchers to make,~~ field notes,  
23 ~~we recorded, further to~~ paper participant information sheets, consent forms and  
24  
25  
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28 debriefs were collected.  
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33 Ethical approval was received from the Faculty of Science and Engineering ethics  
34  
35 committee at the University of Plymouth. All participants provided full, written  
36  
37 informed consent prior to the study.  
38  
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41

### 42 **Data Analysis**

43  
44 Discussions at all stations were transcribed verbatim and analysed by two researchers  
45  
46 (HB, KE). There were two sets of data for each setting, i) unprompted opinions based  
47  
48 on comments and discussions during free interaction with the range of robots and toys,  
49  
50 and ii) focus group responses. Both sets of data were analysed separately with NVivo  
51  
52 using content analysis to garner emerging themes. Content analysis was selected for  
53  
54 inclusion of frequencies of theme occurrence (35), and involves systematic coding and  
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56  
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59  
60 categorising of text to garner trends, frequencies and relationships of words in

discourse (36). Researchers undertook a process of data immersion, coding, grouping codes, generating categories and reporting, as prescribed by Elo and Kyngas (37).

The results are reported in three sections:

- Section 1 provides the themes arising during content analysis of older peoples free interactions. ~~Section 1, thus provides providinggiving~~ initial insight into end-user ~~requirements. The emergent themes provide unprompted opinions and depth of understanding towards older peoples design~~ requirements.
- Section 2 focuses on the ~~prominent~~ themes from focus group discussions; ~~the selection of and~~ features most commonly discussed by both groups in response to Key Questions (Table 1). ~~These features were assessed for frequency of positive or negative response, to allow numerical comparison of opinions between end-users and developers. Examples of each group's responses are provided.~~
- Section 3 maps the relationship between older ~~adult's~~ people's unprompted opinions and their focus group responses, ~~to provide greater confidence in the prompted focus group results.~~

## RESULTS

### Section 1: Content Analysis of Older Peoples' Free Interaction with the Robots

This section provides an in-depth exploration of themes, both positive and negative, arising during unprompted, free interactions between older people (OP) and ~~all of the companion robots. This procedure provides an insight into the features and abilities perceived positively and negatively during real-world interaction with a the~~

1  
2  
3 comprehensive range of ~~robots. The themes arising during analysis of older people~~  
4 ~~interactions~~ companion robots. These themes were; were: interactivity, familiarity, shell  
5  
6 design and ownership.  
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## 10 11 12 **Interactivity**

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17 The ~~theme of~~ interactivity theme emerged on 185 occasions through ~~the~~ codes:  
18 *interactivity, speech and talking, commanding the robot, fun, noises and interactivity*  
19 *lacking.* ~~This theme,~~ strongly suggesting ing that during live, unprompted interactions,  
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older people demonstrated preference for interactive devices over non-interactive alternatives. The results also indicated eye contact, obeying commands and speech could be improvements on currently available devices.

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Interactivity elicited positive comments from participants such as “*fascinating,*” (OP15) and provided a sense of achievement when a device appeared responsive; “*I got the cat to roll over!*” (OP16). Participants demonstrated most enjoyment when robots appeared reactive to the individual themselves, rather than producing random movements or sounds; “*fun isn’t it!?!?”* (OP6). In contrast, non-interactive devices provoked negative responses. The ~~non-interactive~~ Perfect Petzzz dog was described as “*a bit of a disappointment,*” (OP6) as the dog “*doesn’t do much*” (OP16) which may become “*boring*” (OP12) as “*you can’t do more than pat its head*” (OP17). Perhaps surprisingly, participants also underappreciated the interactivity of Paro. The Joy for All animals were seen as highly interactive, despite ~~their~~ more limited technological features, while Paro was described as “*on strike*” (OP7) –because participants felt it “*just moves its head*” (OP3, OP1). Participants interacting with Paro sometimes

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3 displayed slight envy towards peers interacting with the Joy for All animals, “you’ve  
4  
5 *done more with that cat than I got to do*” (OP11).  
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10 Despite enjoying ~~the~~ interactivity of available robots, older people also expressed a  
11  
12 desire for command response from robots during free interactions. The commands  
13  
14 each animal received varied. ~~The commands~~Those directed at the Joy for All dog  
15  
16 were based on expectations of live dogs, with participants requesting “*high five*”  
17  
18 (OP3-4), “*give paw*” (OP3, OP5, OP8, OP10, OP15, OP17) or “*lie down*” (OP5), on  
19  
20 11 occasions. The Joy for All cat received similar requests including “*can you wag*  
21  
22 *your tail?*” (OP3, OP1, OP8). Miro mainly received directional commands, “*turn*  
23  
24 *around!*” (OP5-6, OP10-11, OP13, OP15, OP17-18) “*stop, turn, turn left, turn left*”  
25  
26 (OP13) and Pleo received requests to play and eat; “*open wide, open wide, open up,*  
27  
28 *that’s it!*” (OP13). Participants also repeatedly asked robots to “*look at me*” (OP5,  
29  
30 OP7, OP16, OP15) suggesting facial tracking and eye contact could be a future  
31  
32 ~~improvement to the~~ interactivity ~~of such devices.~~improvement: Paro and the Joy for  
33  
34 All animals received praise as “special” for “looking right at” the participant (OP2,  
35  
36 OP4, OP13, OP17). Further support for this suggestion came from older people  
37  
38 praising robots as “*special*”, particularly Paro and the Joy for All animals, when they  
39  
40 appeared to be ~~for~~ “*looking right at*” the participant (OP2, OP4, OP13, OP17). Most  
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42 frustration was ~~seen~~noted ~~in~~ commanding the non-interactive Perfect Petzzz  
43  
44 ~~sleeping~~ dog, with 15 participants requesting or commanding the dog to “*wake up*”  
45  
46 (OP1-6, OP9-13, OP16-18) or “*open your eyes*” (OP5-6, OP8-9, OP12, OP16).  
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Participants reported limited appeal in an animal without responses, suggesting the  
non-interactive dog appeared “*dead*” (OP17).



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6 Participants also demonstrated desire for robot speech ~~during free interactions~~,  
7 comparing devices to the resident budgie, and asking “*talk to me good boy*” (OP7)  
8 because it would “*be better than talking to myself*” (OP7). Another participant  
9 commented “*it’s the company [sic] I talk to the furniture! [sic] if you live alone you often*  
10 *don’t hear voices*” (OP13), and “*I like to talk to things [sic] I think I just like to hear a*  
11 *voice*” (OP14). Another spoke to Pleo, saying “*I wish you could talk, yes I wish you*  
12 *could talk*” (OP16). ~~Further support came from participant responses to Miro’s~~  
13 ~~electronic noises, not recognisable as specific animal vocalisations. Similarly, o~~  
14 On 11  
15 occasions, participants confused ~~the Miro’s electronic noises (not recognisable as~~  
16 ~~specific animal vocalisations)~~ with language, repeating, “*what are you saying?*” (OP5)  
17 “*you’re trying to talk aren’t you?*” (OP17) and “*I don’t know if it’s actual words or not*”  
18 (OP14). Upon understanding Miro’s noises were not “*actual words*” one participant  
19 described the robot as “*a dead loss*” (OP17).  
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38 ~~Despite this apparent desire for verbal responses~~ Nonetheless, participants still  
39 initiated conversation with non-speaking animals; “*what can we call you? We can call*  
40 *you Dino. It’s not very original [sic], Dino, do you want to play again or eat?*” (OP6).  
41 This sometimes resulted in disappointment when devices failed to respond verbally,  
42 “*you won’t be much use to me if you don’t talk to me*” (OP9), “*he doesn’t talk back*  
43 *though,*” “*can it hear? It’s got no ears!*” “*If he can’t hear, he can’t talk to me*” (OP16).  
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### 54 **Familiarity**

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56 This theme represents participants’ desire for companion robots to be realistic and  
57 familiar in form, and emerged from codes; *realistic animal, familiarity, comparison to*  
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3 *real animals, reminiscence, life-simulation, and toys. Evidence arose on 71*  
4  
5 occasions ~~during older persons unprompted, free interactions.~~

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10 Participants commented on preferring cats or dogs, as what they had *“always had”*  
11 *(OP13, OP17)* and were *“used to” (OP8)*. The realistic, familiar options available also  
12 elicited comparisons to real animals, on 25 occasions with the Perfect Petzzz dog,  
13 and Joy for All cat and dog. Participants compared devices to ~~animals they had~~  
14 ~~known previous pets~~, *“this one’s like Harry” (OP5)* or discussed benefits of robot  
15 alternatives as being *“far easier” (OP3)* because *“you don’t have to take it out [sic]*  
16 *and clean up after it” (OP8)* and *“it won’t malt” (OP4)*. Familiar animals also  
17 prompted reminiscence on 12 occasions, probably due to greater relatability, such as  
18 *“I had [sic] Yorkshire terrier, tiny terrier, used to get lagged in the mud” (OP8)*. Only  
19 one occasion was negative; ~~as the one~~ participant had experienced *“a dead cat in*  
20 *the water off the pier when I was about 9” (OP5).*

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38 In contrast, unfamiliar forms were perceived by older people as *“a toy” (OP1)* and  
39 more infantilising. During interactions with Miro and Pleo, one participant discussed  
40 preference for *“something, that to me, looks like something we’ve had, like dogs and*  
41 *cats and things, we’ve had dogs and cats you see” (OP10)*. Participants showed  
42 clear preference for familiar forms, and realistic design, over unfamiliar when both  
43 were available; *“that is realistic [dog], we’re not very likely to come into contact with*  
44 *one of them [seal]” (OP5)*. Participants suggested seals were incongruent with their  
45 context, believing seals belong *“on the ice floats” (OP4)* or *“eaten with pepper sauce”*  
46 *(OP4)*. The familiar animals were most often the devices praised for looking  
47 *“realistic” (OP3)*, or behaving in a way that appeared *“very real” (OP5)*.  
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6 Further to preferring realistic design~~Additionally~~, the breathing feature of the Perfect  
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8 Petzzz dog was well received; *“it’s fascinating to watch him breathing”* (OP15). It  
9  
10 appears any feature increasing the ‘realness’ of a companion was beneficial.  
11  
12 ~~Participants reporting~~reported life simulation features such as the breathing made  
13  
14 the robots look *“living”* (OP17). This feature was commented on 13 times, and often  
15  
16 a source of conversation between participants, ~~however appeal of the Perfect Petzzz~~  
17  
18 ~~dog was still limited by lack of interactivity.~~

## 23 24 Shell design

25  
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27  
28 This theme arose on 89 occasions ~~during older peoples free interactions~~, through  
29  
30 codes; *realistic animal, physical features, shell-type, favouritism, preference, texture*  
31  
32 and *likeability*. The evidence strongly suggested ~~older~~ older people preferred soft, furry  
33  
34 companion robots, but also favoured big eyes. Participants did prefer features  
35  
36 making animals appear more realistic, ~~although this is~~ discussed above.

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42 Paro’s eyes were specifically commented on positively by six older people. The *“big*  
43  
44 *eyes”* (OP1, OP4) were described as *“cute”* (OP2) and appeared to draw participants  
45  
46 towards the seal; *“ohhh look at your eyes!”* (OP11). Participants also particularly  
47  
48 appreciated Paro’s prominent eyelashes; *“ladies will wish they had lashes like him!”*  
49  
50 (OP6). Other large eyes also received praise, ~~such as including~~ Furby’s animated  
51  
52 eyes that were particularly *“captivating”* (OP16).  
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3 Older people praised animals with fur for cuddliness and suggested, in response to  
4 non-furry options, that they “*want something [sic] you could smooth and it feels like*  
5 *an animal, you know, like that [Joy for All] cats got fur*” (OP10). On 11 occasions  
6  
7 participants responded negatively to plastic shells of Pleo and Miro, as they did not  
8  
9 “*feel quite as friendly*” (OP11). In contrast, Paro’s fur was described as “*lovely*” (OP8)  
10  
11 and “*soft*” (OP11). ~~Participants~~ While participants appeared to acknowledge Paro  
12  
13 possessed softer fur than alternative furry animals, ~~however,~~ the Joy for All cat fur  
14  
15 was praised for being less pristine. Participants suggested the cat “*looks a bit*  
16  
17 *bedraggled*” (OP7) which resulted in time spent brushing and grooming ~~the cat~~. One  
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19 participant suggested the fur looked “*so real*” (OP1) suggesting the longer, shaggier  
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21 coat felt more congruent with cat expectations.  
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## 30 Ownership

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33 This theme arose on 30 occasions, through codes; *naming, ownership, and*  
34  
35 *personalisation* and represents older people demonstrating some attachment  
36  
37 towards robots during free interactions.  
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44 Naming was thought to relate to ownership, as ~~provision of a name to naming~~ a live  
45  
46 animal occurs with possession, and ~~has been shown in research to relate to signifies~~  
47  
48 a developing relationship (38). Older people sometimes used names of previous  
49  
50 pets, such as “*Milo*” (OP1) because “*they’ve got a cat called Milo*” (OP3). Other  
51  
52 participants chose generic names, such as “*Fido*” (OP11) or “*Tigger*” (OP4) while  
53  
54 some got creative with names like “*Shandy*” (OP7) because the dog “*is a mixture*”  
55  
56 (OP7). Once older people had allocated a name, it endured throughout their  
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3 interaction, “are you wagging your tail for me Shandy?” (OP7). ~~This tendency to~~  
4 ~~name~~Naming occurred mostly with the Joy for All cat and dog.  
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10 Further evidence for ownership came from a code of the same name. Ten older  
11 people commented on acquiring a robot during free interactions, such as “do you  
12 know, I’d love this [cat], I’d love this in my apartment” (OP2). Another suggested  
13 ~~about the Joy for All dog that~~ “the service should have one” [Joy for All dog] (OP6)  
14 with peers commenting in agreement. ~~Another suggested;~~ “we’ll all go out and buy  
15 one now!” (OP17). Of all occurrences, ownership was only shown towards the Joy  
16 for All cat and dog, suggesting good acceptability of these two devices.  
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28 We felt personalisation related to ownership, as wanting to adapt a robot for personal  
29 use implies a desire to keep it. Evidence for personalisation was not prolific during  
30 free interactions, with hints of personalisation being desired occurring only twice.  
31 One participant enjoyed the Joy for All dog, but requested a larger size as “I don’t do  
32 little doggies” (OP16). The participant requested it “look like a golden retriever”  
33 because “it’s the only dog we’ve ever known” (OP16). It is possible evidence was  
34 limited during free interactions as participants were unaware of the possibility.  
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## 47 Section 2: Focus Group Results

48 This section presents the ~~results of the~~ focus groups results as a numerical  
49 comparison between end-users and developers, to provide a clear understanding of  
50 any differences between the two groups. The features presented represent the most  
51 prevalent themes during content analysis of responses to Key Questions (Table 1).  
52 For both groups, an overall score was calculated for each feature (n participants  
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responding positively minus n participants responding negatively). The difference between roboticists and older people's opinions for each feature was then calculated. Examples of focus group responses for comparison are also provided, for greater depth of understanding.

**Table 2: Comparing the number of older people and roboticists providing positive, negative or non-responses for each feature and the resultant level of difference or agreement**

		Soft							Life-
		Interactivity	Fur	Talking	Personalised	Realistic	Familiar	Mythical	simulation
<b>Older People</b> n=17	Positive	15	12	12	15	12	4	1	5
	Negative	0	1	5	1	1	0	5	0
	None	2	4	0	1	4	13	11	12
	<b>Score</b>	<b>15</b>	<b>11</b>	<b>7</b>	<b>14</b>	<b>11</b>	<b>4</b>	<b>-4</b>	<b>5</b>
<b>Roboticists</b> n=18	Positive	14	8	2	7	2	1	1	3
	Negative	2	1	13	8	11	10	1	2
	None	2	9	3	3	5	7	16	13
	<b>Score</b>	<b>12</b>	<b>7</b>	<b>-11</b>	<b>-1</b>	<b>-9</b>	<b>-9</b>	<b>0</b>	<b>1</b>
<b>Score difference</b>		<b>3</b>	<b>4</b>	<b>18</b>	<b>15</b>	<b>20</b>	<b>13</b>	<b>4</b>	<b>4</b>

Key: green = difference  $\leq$  4, orange = difference  $\geq$  13

Table 2 compares opinions of older people and roboticists towards design of companion robots specifically for older people. The score differences show the largest dissimilarities/divergences in opinions were noted for scores for realistic aesthetic,

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2  
3 robots talking human language, personalisation of robots and familiar form. Older  
4  
5 people and roboticists seem to agree on the need for interactivity and soft-fur in  
6  
7 response to ~~key questions~~Key Questions 1 and 2 (~~table~~Table 1). There also appears  
8  
9 to be some agreement between the two groups on inclusion of life-simulation features  
10  
11 and mythical design, although ~~generally~~ older people were generally more positive  
12  
13 towards life-~~simulation~~ and more negative towards mythical design. Some participants  
14  
15 did not respond to every feature, resulting in lower numbers of responses for some  
16  
17 features. ~~Table 2 shows~~ familiarity, life-simulation and mythical design received lower  
18  
19 responses, ~~possibly this could suggest~~ing these features were less important, and  
20  
21 thus participants felt less inclined to comment. However, this could also ~~represent~~  
22  
23 derive from the semi-structured nature of the focus groups, ~~and that~~where realistic,  
24  
25 familiar or mythical design were all discussed in relation to ~~key question~~Key Question  
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45 The ~~most~~ preferred animal among older people in response to Key Question 8 was  
46  
47 the Joy for All cat, with 9/17 (53%) participants selecting this animal (~~figure~~Figure 3),  
48  
49 followed by. ~~The second most popular animal was~~ the Joy for All dog. Paro, Miro and  
50  
51 the homemade hedgehog were not selected by any older person. The ~~most~~ preferred  
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53 animal ~~for~~among roboticists was Paro (11/18), followed by Pleo the dinosaur, then the  
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55 homemade hedgehog. The Joy for All dog and cat, Miro, the Perfect Petzzz ~~sleeping~~  
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3 dog and Furby were not selected by any roboticists, and some roboticists did not select  
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5 any of the available animals.  
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12 **Table 3: Examples of evidence from each group during focus group discussions**  
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Theme	Example Evidence	
	Older People	Robotocists
Interactivity	<p data-bbox="427 674 938 741">“If you’re sat there on your own, you want some reaction” (OP6)</p> <p data-bbox="400 786 938 965">“That one [Joy for All cat] is almost perfect, but perhaps if you could say, do you want to play, and then it could then do something, a little bit more interactive” (OP13)</p>	<p data-bbox="975 674 1506 853">“I think something passive, that doesn’t make a lot of sounds, it could be stressful, too much [sic] You could have a sack that’s warm and purrs” (R3)</p> <p data-bbox="975 898 1506 1111">“I think it should have high level interaction, because it would keep the interaction longer as well, if you just have a pet like this with one or two features, it’s done, it’s limited” (R9)</p>
Soft fur	<p data-bbox="411 1155 927 1267">“Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder” (OP5)</p> <p data-bbox="411 1301 927 1413">“Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle” (OP13)</p>	<p data-bbox="975 1155 1506 1301">“I don’t think so, because it isn’t cleanable, if you wanted something to cuddle you could just buy a stuffed toy” (R14)</p> <p data-bbox="1031 1335 1482 1413">“Nice and furry, you could kinda cuddle it” (R18)</p>
Talking	<p data-bbox="411 1525 938 1592">“[animals] don’t talk, there are sounds that creatures make” (OP6)</p> <p data-bbox="395 1637 938 1816">“For older people living on their own in particular, we all talk to ourselves anyway, you don’t feel so stupid if you talk to something that responds to you” (OP13)</p>	<p data-bbox="975 1525 1506 1816">“from a technological point of view, speech should be left out of the equation, especially with elderly people, and people with dementia, they wouldn’t have expressions or fully structured sentences which would get frustrating if the robot didn’t understand” (R1)</p> <p data-bbox="975 1861 1506 1995">“I can see the appeal, [sic] a rudimentary conversation might be quite nice, as long as you didn’t feel like a twit doing it” (R11)</p>



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19	Personalisation	<p>“If it was knitted, it wouldn’t be able to move its eyes and mouth” (OP5)</p> <p>“It’s quite a good idea, yeah I do, someone who’s got a particular animal” “We were talking about colours, I like that one, she’s always had black cats, It would be nice to have a choice of different colours” (OP13)</p>	<p>“That might ruin the illusion I’d say” “if you’ve eaten like a chicken, if you’ve seen the actual process, you would not feel so good about it [sic], when you see the finished product without knowing how, it’s sometimes better” (R2)</p> <p>“It would be amazing, it would give it a personal touch, it’s like having a new [smartphone] and getting a new cover, people love that” (R10)</p>
20 21 22 23 24 25 26 27 28 29	Realistic	<p>“For someone who’s always had animals, they feel that loss, so for them, something realistic that they could interact with” (OP1)</p> <p>“as long as it’s got big eyes and attractive I don’t mind” (OP17)</p>	<p>“It would make more sense” (R1)</p> <p>“No [sic] if it’s not realistic, you wouldn’t be hoping it would be a real dog so” (R16)</p>
30 31 32 33 34 35 36 37 38 39 40 41	Familiarity	<p>“because they [cat and dog] are more domesticated animals, whereas a seal you wouldn’t have a seal in your home” (OP1)</p> <p>“I think if you’d had a cat or a dog, it would be better to have something you could relate to” (OP12)</p>	<p>“for the elderly it should be something familiar” (R2)</p> <p>“I think because of uncanny valley it doesn’t have to be something that we are used too” (R7)</p>
42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57	Mythical	<p>“That’s a generation thing, kids would love it but not here” (OP1)</p> <p>“Maybe in five years time..” (OP16)</p>	<p>“I also think something super unrealistic like the Furby would be creepy as well, it’s so bizarre you could be turned off by it, it’s weird, a baby seal, you’re not accustomed to the animal so whatever it does is just cute” (R8)</p> <p>“The mythical Furby looks right because you’ve got no expectations, so you cannot do it wrong, you cannot break expectations” (R13)</p>
58 59 60	Life-simulation	<p>“Warmth under belly to keep your knees warm!”</p>	<p>“I can feel on the dinosaur, coming from an engineering point of view,</p>

(OP1)

“If it was breathing, it would be almost a real cat, and again, it’s a soothing thing” (OP14)

with all that inside and trouble circulating the air, you can feel it gets warm, but I think that’s actually a good thing, that you can feel, it’s even more, like lizard like, even more appearing like something” (R6)

“The problem is I think it has to be done well, and it’s really difficult to do well, it could end up creepy and weird” (R14)

Table 3 provides examples of the different views of older adults and roboticists during ~~the~~ focus group discussions, further examples can be found in Supplementary ~~Materials file~~ [File 1](#).

### Section 3 – Relationship between Free Interaction and Focus Group Data

This section explores how the themes arising during unprompted, free interaction support the validity of the prompted focus group results (~~figure~~ [Figure 4](#)).

~~The theme of interactivity arising during free interactions supports the focus group results above; demonstrating~~ all older people who discussed interactivity (15/17, 88.24%) desired this feature for a robot pet. As seen in Section 1, ~~interactivity of the~~

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3 ~~device~~this feature was highly valued by older people during free interactions, with  
4 many participants desiring additional interaction, such as obeying commands and  
5 talking. ~~This theme during free interaction thus also supports~~In the the focus group  
6 theme of talking, ~~where~~ 12/17 (71%) older people felt positively towards robot speech.  
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13 The free interaction theme ~~of familiarity arising during unprompted interactions~~  
14 supports the focus group results where all older people who commented (4/17, 24%)  
15 preferred familiar forms, and 12/17 (71%) preferred realistic or life-like appearance,  
16 with only 1/17 (6%) older people responding negatively to life-like appearance,  
17 ~~meaning~~ ~~(thus~~ 92.31% of responses were positive). The higher percentage of non-  
18 responses to familiarity could suggest participants felt less strongly about this feature,  
19 and thus less inclined to comment. However, the qualitative results from free  
20 interactions would dispute this, with very strong support arising in favour of a familiar  
21 animal. ~~†Therefore, it could alternatively be suggested~~may instead be possible that  
22 participants did not necessarily distinguish between realistic and familiar (~~as realistic,~~  
23 unrealistic and mythical were the words used within the Key Questions).  
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40 The free interaction theme ~~on shell-type theme~~, and clear preference for soft fur  
41 ~~during older peoples' free interactions, is~~are congruent with focus group results where  
42 12/17 (71%) older people preferred soft fur, while only 1/17 (6%) disagreed (92% of  
43 responses positive). Life—simulation was not discussed at length during free  
44 interactions, although the Perfect Petzzz breathing feature ~~on the dog~~ was well  
45 received. This feature also had lower response rates during focus groups. The lower  
46 response rate for this feature could again suggest that, while life-simulation may be  
47 desirable, supported through decisive responses (100% of responses were positive),  
48 ~~this feature~~it may be less of a priority, with 12/17 (71%) older people not providing  
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3 opinions. Despite limited direct discussion during free interactions, the potential  
4 inclusion of this feature is supported by the familiarity theme, whereby any aesthetic  
5 or technological features increasing the 'realness' of a pet appeared well received  
6 during unprompted free interaction.  
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14 While pPersonalisation was not highly prevalent during free interaction, however,  
15 some evidence was seen within the ownership theme, with a participant requesting a  
16 golden-retriever design ~~if he were to own one. When raised in the.~~ Within focus groups,  
17 15/17 (88%) older people felt positively towards personalisation, and only 1/17 (6%)  
18 provided opposition (94% of responses were positive). It is possible personalisation  
19 garnered limited discussion during free interactions as participants were unaware it  
20 was possible. The range of suggestions of preferred animals upon proposal of  
21 personalisation however would certainly suggest some benefit to this approach.  
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## 35 DISCUSSION

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37 User-centred design is generally often cited as beneficial (4, 26); ~~however the extent~~  
38 ~~of its use) but rarely used~~ in companion robot development ~~is currently minimal. This~~  
39 ~~study has demonstrated, through.~~ The differing ent design preferences of end-users  
40 and potential developers in our direct comparison; demonstrated the importance of  
41 implementing user-centred design in the development of when developing  
42 companion robots ~~targeted at~~ for older people, ~~due to large differences in design~~  
43 ~~preference between end-users and potential developers. The.~~ Our results ~~therefore~~  
44 justify additional effort for the reportedly difficult process of integrating user  
45 requirements into design (29), and may aid acceptability of ~~with the challenge of~~ user-  
46 centred design ~~being accepted~~ in practice (26). Some of our roboticists felt user  
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3 involvement in development could damage illusions of the robot, perhaps helping  
4 explain the minimal use of this process. However, rather than damaging illusions,  
5 adopting user-centred design may actually ensure devices receive adequate  
6 acceptability to promote use (25). Future development of robots ~~utilising~~ using user-  
7 centred ~~approach~~ approaches may result in more consistent positive outcomes than  
8 those previously reported for Paro (17, 18, 20, 21), ~~whose contradictory results may~~  
9 ~~in-part result from design features our results suggest are undesirable to end-users.~~  
10 Implications of improved design, acceptability and use would be significant ~~due to~~ given  
11 the ~~reported~~ potential benefits of companion robots for older people, those with  
12 dementia, and their family and care team (110-165). ~~Results of our study would~~ Our  
13 results suggest strong acceptability and preference of the Joy for All cat and dog, and  
14 limited acceptability of Paro when these more familiar/realistic comparisons are  
15 available. This result is ~~particularly~~ important ~~when considering the~~ given a lack of  
16 ~~available companion robot~~ comparison studies of companion robots (39) and apparent  
17 selection bias towards Paro in research (109).

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40 Further to highlighting the value of user-centred design, this study provided initial  
41 insights on end-user design requirements.

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46 ~~Regarding robot abilities, older~~ Older people ~~strongly preferred an interactive~~  
47 ~~device, and roboticists both saw interactivity as important. Older people wanted~~  
48 interactivity for ~~the purpose of providing~~ companionship, fun, and ~~reducing~~ reduced  
49 loneliness through responsiveness. ~~Interactivity was also a strong preference for our~~  
50 ~~group of~~ Some roboticists, ~~however some on the other hand~~ raised concerns on over-  
51 stimulating older people. Our older adults displayed little interest towards non-  
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3 interactive animals, whose lack of responsiveness appeared frustrating. This  
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5 disinterest in unresponsive/inactive companions is congruent with the finding that an  
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7 'active' Paro was more engaging than an 'inactive' Paro (18). While interactivity  
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9 appears essential, our results demonstrated the advanced responsivity of Paro may  
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11 be unnecessary. Despite having fewer technological abilities, the Joy for All cat was  
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13 perceived as most interactive, ~~most likely because of . This appeared to result from~~  
14  
15 ~~aits~~ greater range of movements available, including animated head and legs, rolling-  
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17 over, blinking and cleaning movements. Therefore, the range and variety of responses  
18  
19 may be more important than the sophistication of sensors a robot possesses.  
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26 ~~We also found~~Our older ~~adults had continuous interest~~people were interested in the  
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28 companion robots understanding and responding to simple commands. Use of  
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30 commands is only briefly mentioned in previous literature (32), and our findings appear  
31  
32 contrary to ~~the results of Klamer and Alloucha study~~ (40) ~~who~~that found no evidence  
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34 for the importance of enjoyment or playfulness factors among community dwelling  
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36 older adults. Our group ~~of older people~~ actively sought playfulness from robots,  
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38 believing this would sustain enjoyment for longer. Responsiveness to simple  
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40 commands such as "paw" could be a consideration for future robot design.  
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42 Interestingly, there were fewer command expectations for the Joy for All cat than other  
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44 ~~alternatives~~robots, perhaps due to a reduced association between live cats and  
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46 training versus live dogs. These expectations could be used to support use of an  
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48 unfamiliar form such as Paro, whose design was aimed at reducing expectations (41).  
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50 However, older people still displayed command expectations for Pleo, Miro and Paro,  
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52 (unfamiliar forms), ~~therefore~~disputing this theory. One could speculate that the cat's  
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54 larger quantity of movements results in a reduced need to command actions.  
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6 Older people also positively evaluated the potential for human speech from a  
7 companion robot. These results contradict the suggestion that, congruent with the  
8 uncanny valley theory, human acceptability of sounds depends on the realism of the  
9 context (42). ~~Komatsu and Yamada~~In one study (43) ~~demonstrated that~~ participants  
10 related less to an AIBO dog beeping than a computer emitting an identical sound,  
11 perhaps due to contradiction in context between a dog and a beeping noise, thus  
12 suggesting. ~~While this would suggest that~~ animal sounds would be most acceptable  
13 for animal robots. ~~Our results,~~ however, indicated positive attitudes towards speech  
14 capabilities for provision of company. ~~Frennert and Ostlund~~Frennert and  
15 ~~Ostlund~~Another study (33) ~~found reported~~ that developers were influenced by  
16 stereotypical perceptions of older people as lonely and fragile, but failed to incorporate  
17 requirements of participating older people into design. Our group of older people  
18 thought loneliness could be eased through devices capable of simple conversation.  
19 This could be a user-driven improvement to currently available companion animals  
20 ~~should if our~~ results ~~bear~~ replicated in wider samples. It is possible, however, that this  
21 feature will be evaluated differently with in possible future research with a sample of  
22 cognitively impaired older people. Our participants were cognitively intact and  
23 therefore aware of the artificial nature of the robots or toys; ~~older people with dementia~~  
24 ~~however~~ may find the incongruence of human speech from an animal less acceptable;  
25 ~~this therefore requires further research~~.

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54 Eye contact was a further improvement desired by older people, ~~with our results~~  
55 ~~demonstrating~~ some ~~disappointment and frustration of whom were disappointed~~ when  
56 robots failed to look towards ~~the user~~them. Gaze following may increase social  
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3 relevance of the robot. This may be particularly true when eye movement is intentional  
4 rather than random (44). While the pre-programmed movements of the Joy for All cat  
5 were positively evaluated, intentional gaze following ~~would perhaps~~ may be an  
6 improvement for optimal social companionship. ~~de Graaf et al. (45) noted t~~The  
7 importance of improving sociability for robot acceptance was noted before (45), and  
8 ~~therefore~~ this addition of apparent social behaviour could improve acceptability further.

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19 ~~Regarding the outer shell, most~~ Most older people preferred soft, cuddly fur for the  
20 outer shell. Our group of roboticists generally agreed, although both groups raised  
21 concerns regarding hygiene in comparison to a hard shell. This corroborates previous  
22 findings ~~that on~~ care providers' preferences preferred soft, cuddly fur on for robots  
23 aimed at their older service users (34, 46). ~~On the contrary, other results), although~~  
24 others have reported older people's preference for mechanical design on ~~a robot~~ robots  
25 (28). These results may reflect the broader range of socially assistive robots used  
26 (machine-like, mechanical, human-like and animal-like robots); however, generally  
27 results generally implied a robot should indeed be recognisable as robotic (28).  
28 ~~Robinson et al. One study~~ (21) also reported a family member demonstrating stigma  
29 towards his father interacting with soft-toys, suggested ~~a~~ potential gender  
30 barrier barriers with soft, cuddly robots. Our study found no notable difference between  
31 males and females. ~~This support provided directly by older people themselves would~~  
32 strongly suggest soft fur should be implemented in the design of Our study, and  
33 suggests that companion robots ~~aimed at~~ for this market should use soft fur in the  
34 design. Providing the optimum tactile characteristics are particularly important  
35 considering evidence suggests touch is one of the most important modalities of  
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3 interaction for dementia patients, creating a natural method to engage with animaloid  
4 robots (47).  
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10 Considering the importance of tactile characteristics (46), a further feature for  
11 consideration in future development is life-simulation, another capability positively  
12 evaluated by older people, but lacking from current examples including Paro, ~~amongst~~  
13 ~~others.~~ Our research supports the previously reported (46) assumption of care-  
14 providers that a simulated heartbeat would be a valuable addition to Paro, but  
15 additionally demonstrates that older people themselves also valued life-simulation  
16 features, including simulated heartbeat, simulated breathing and the feeling of purring.  
17 Older people even suggested warmth as an additional ~~life-simulation~~ feature. This  
18 result appears congruent with older adults' desire for a realistic, life-like companion.  
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33 A realistic, familiar animal form was a definite aesthetic requirement for our group of  
34 older people. This was also reflected in their choice of Joy for All cat as their preferred  
35 device, as a familiar, realistic option, with ~~no older people selecting Paro~~ not selected  
36 by any older adult. Previous research focusing on opinions of care providers revealed  
37 criticism ~~towards~~ Pleo for lack of familiarity (34), while ~~In contrast~~, the intentionally  
38 unfamiliar Paro (41) is the most often utilised companion robot in research- (109).  
39 ~~Other), and research on older adult perceptions towards robot pets did not produce~~  
40 ~~familiarity as a result (32), however although this may result from the lack of familiar~~  
41 ~~options available for comparison.~~ The end-users in our research suggested  
42 thought  
43 that, additionally to Paro, like Pleo, ~~Paro~~ was ~~also considered~~ too unfamiliar. ~~The~~  
44 ~~strongest preference was seen towards the~~ The most familiar animals, the Joy for All  
45 cat and dog, were preferred for being more relatable and congruent with the contexts  
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3 in which older people lived. The unfamiliar forms appeared incongruent and  
4  
5 infantilising, perhaps explaining the tension Lazar et al. (32) ~~noted~~found towards their  
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7 selection of unfamiliar animals.  
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12 This is relevant insofar as some companion robots, such as Paro, are intentionally  
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14 designed using ~~an unfamiliar form (a seal in the case of Paro)~~forms to avoid ~~negative~~  
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16 ~~schemas, or the robot~~robots failing to meet expectations (41). Most of our roboticists  
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18 followed this line of thinking and responded negatively to familiar animals,  
19  
20 unsurprisingly selecting Paro as their preferred companion robot. It is further likely the  
21  
22 roboticists appreciated the advanced technical capabilities of Paro, but our study  
23  
24 suggests such sophistication may be unnecessary for older people. Research  
25  
26 conducted 19 years ago using the Tama OMRON Corp cat ~~also~~ suggested older  
27  
28 people ~~complained about~~disliked the feel and behavior of a robot cat ~~in~~  
29  
30 ~~comparison~~compared to real cats (47); ~~However, this initial research was conducted~~  
31  
32 ~~19 years ago, and it is therefore likely that~~ currently available robotic cats are  
33  
34 ~~more~~likely more realistic than ~~the Tama OMRON Corp cat~~the Tama OMRON Corp cat  
35  
36 used in that study ~~those available at the time. The majority~~previously. Most of our  
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38 ~~roboticists group responded negatively to a familiar animal design due to expectations~~  
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40 ~~people would hold of animals they were accustomed to, consistent with the thinking~~  
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42 ~~behind Paro (41), and unsurprisingly selected Paro as their preferred companion~~  
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44 ~~robot. It is likely the roboticists appreciate~~appreciated the advanced technical  
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46 ~~capabilities of Paro, but this~~our study would suggestsuggests such sophistication may  
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48 ~~be unnecessary for this group of end-users. Similarly, roboticists did not feel realistic~~  
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50 ~~appearance was appropriate. While the thinking behind designing Paro as an~~  
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3 ~~unfamiliar animal seems logical (41), this theory seems to resonate poorly with end-~~  
4 ~~users, having potential negative impact on preference older people.~~  
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10 The preference for realistic and familiar robots may result from relatability, with older  
11 people perhaps having personal experience of cats and dogs, ~~due to given the~~  
12 prevalence of ownership of these species (48). Familiar animals may provide  
13 recognisable potential for a loving relationship. Even individuals without personal pet  
14 ownership experience will have likely witnessed others with pets, and therefore the  
15 familiar form of a dog or cat is symbolic of that potential bond and relationship. The  
16 tendency for our group of older people to name the Joy for All cat and dog more often  
17 than alternatives suggests familiarity may additionally help facilitate a sense of  
18 ownership. Thus, our results imply that, rather than being problematic (41), memories  
19 and schemas of familiar animals may actually be beneficial. A further implication of  
20 familiar companion robots relates to reminiscence theory, which suggests benefits of  
21 reminiscence for older people including decreased depression (49). Reminiscence  
22 therapy uses memories, feelings and thoughts from the past to facilitate pleasure (50).  
23 Evidence of reminiscence was found in our study, and seems congruent with this  
24 theory, as memories of past pets and animals were shared with positive affect. It is  
25 therefore possible familiar companion robots would have additional wellbeing benefits,  
26 particularly for individuals with dementia.  
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51 -The possibility of personalisation was also positively perceived by older people and  
52 thus could be a consideration for future robot design. Personalisation has been  
53 mentioned in previous research (28), ~~and identified by Heerink et al. (34), who~~  
54 ~~commented on different users responding differently to different robots~~, but has not  
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3 been explored directly with end-users. Our ~~group of~~ older people positively evaluated  
4 a more person-centred approach to robot aesthetics, praising the potential to  
5 interchange robot 'skins' to match personal preference. It is possible personalised  
6 robots would be more acceptable than a single design for all users. This could alleviate  
7 some disparity in response to Paro, as seen in previous RCT research (22).  
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17 In contrast, our ~~group of~~ roboticists underestimated the value of personalisable  
18 aesthetics, and failed to predict older people's desire for human speech and life-  
19 simulation features. The transcript evidence suggests roboticists had an awareness of  
20 Mori's uncanny valley ~~theory hypothesis~~ (51). This is not surprising given their field of  
21 interest, and it is possible ~~the uncanny valley theory this~~, and related literature, had  
22 influenced ~~roboticistsroboticists'~~ ~~perceptions views~~ on robot design ~~n~~, ~~swaying~~  
23 ~~roboticists~~ to favour unrealistic and unfamiliar forms, and to undervalue life-simulation  
24 features that would undoubtedly increase ~~further~~ the realistic impression of a robot.  
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40 ~~Although our study was limited by recruiting older people from just just one setting and~~  
41 ~~roboticists from only one University (although from varied educational and~~  
42 ~~occupational backgrounds) we found marked differences in their views that need to be~~  
43 ~~accounted for in the development of companion robots. If creative methods of~~  
44 ~~coproduction are used (52), both groups would need to think more about why they~~  
45 ~~liked certain features and it is likely they would develop a new product that would be~~  
46 ~~owned by this co-design group. There is no guarantee, but perhaps more~~  
47 ~~chance~~ Although there are no guarantees, that a product so designed would then  
48 ~~be~~ might have a higher chance of being liked by the wider population of older people.  
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6 Our study recruited older people from a retirement complex and the generalisability of  
7 their views to care home residents is limited. Our finding of the acceptability of such  
8 devices among a more independent sample is in contrast to previous research which  
9 implied more independent older people felt 'too able' to use robots (28). Thus, there  
10 may be a market among this more independent sample that has previously been  
11 underestimated.

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21 Another limitation of our study was the short interaction time of ten minutes at each  
22 station, providing initial preferences. Research has suggested acceptance should be  
23 measured over longer periods of use, allowing for familiarisation and more informed  
24 attitudes towards the device, which may be more predictive of actual use (5253).  
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Future longitudinal research is therefore required exploring how these initial  
preferences develop over time, to assess any differences in loss of engagement, or  
wellbeing outcomes. Our interaction period is was however longer than, ~~for example,~~  
previous research, where participants only interacted with each robot for one minute  
(34).

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~~We did also use~~ Our study's smaller group sizes ~~than compared to~~ previous research  
(34), ~~which~~ may have limited influence of social desirability bias or group dynamics.  
The small sample size, and small numbers of responses to some features during focus  
groups, is a further limitation. ~~However, we have conducted a larger-scale comparison~~  
~~that will further these results. The~~ On the other hand, use of qualitative, free interaction  
transcriptions ~~also~~ increases confidence in our focus group results, even where

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3 response numbers were low, as preferences were often evident through unprompted  
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5 interaction.  
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10 ~~A further consideration with the current study is that the sample of older people was~~  
11 ~~recruited from a retirement complex. While this recruitment strategy allowed insight~~  
12 ~~into this sample, the generalisability of these views to care home residents is limited.~~  
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14 ~~The larger-scale study of the same nature has been conducted within a range of care~~  
15 ~~homes to address this issue. The current research does however suggest there is~~  
16 ~~acceptability of such devices among a more independent sample. This is in contrast~~  
17 ~~to previous research which implied more independent older people felt 'too able' to~~  
18 ~~use robots (28). Thus, there may be a market among this more independent sample~~  
19 ~~that has previously been underestimated.~~  
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33 An important strength of the current study is the active participation of older people  
34 themselves. Some previous research exploring design features of companion robots  
35 for older people focused mainly on care provider opinions (28, 46). Our research has  
36 provided support for some previously identified features, but furthered this evidence  
37 base through identification of design features previously unthought-of ~~of~~ by care  
38 providers. A further strength includes the use of a range of robots and toys, some  
39 specifically designed for older people, unlike previous related literature (32), providing  
40 a varied array of features of interest and allowing older people to provide truly informed  
41 opinions.  
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## 54 55 56 **Conclusion** 57 58 59 60

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3 ~~This study has~~We have provided empirical support for the necessity and value of  
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5 incorporating user-centred design in the development of companion robots targeted  
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7 at older people. While user-centred design has been recommended previously, there  
8  
9 has been little direct evidence to support ~~the gravity of its~~this requirement. Our results  
10  
11 demonstrate stark differences in preferences and requirement between older people  
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13 and roboticists, suggesting engaging the end-user in the design and development of  
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15 companion robots is essential. This study also began the process of researching  
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17 companion robot design with end-users themselves. The older people in our sample  
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19 have suggested soft fur, interactivity and big 'cute' eyes, as being priority features on  
20  
21 a robot. Older people also strongly suggested the robot should take the form of a  
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23 realistic, familiar animal, raising questions surrounding the design of the most well  
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25 researched companion robot, Paro. Further desirable functions were also identified  
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27 that are not currently included as standard on companion robots, such as eye-contact,  
28  
29 life-simulation features, personalisation, obeying commands and the potential for  
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31 interactive language.  
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43  
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45  
46 study were loaned from the School of Nursing and Midwifery and the Ehealth  
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49  
50 part funded by the European Regional Development Fund (ERDF). All of the above  
51  
52 were 'general funds' to fund study in this area of endeavour. There were no specific  
53  
54 funds for this project and there is no commercial or other interest from the funders in  
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56 the findings of this study.  
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## Competing Interest

The authors declare that they have no competing interests.

## Author Contributions

All authors read and approved the manuscript.

HB designed the study, performed data collection, transcribed, analysed and interpreted results and lead on producing the manuscript.

KE transcribed data, analysed and interpreted results and aided in production of the original manuscript.

RW supervised the project, provided expertise and advice towards the study conception and design, discussed results and substantively revised the manuscript.

ST supervised the project, provided expertise and advice towards the study conception and design, discussed results and substantively revised the manuscript.

RJ oversaw participant recruitment and data collection, supervised the project, provided expertise and advice towards the study conception and design, discussed results and substantively revised the manuscript.

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3 The Ehealth Productivity and Innovation in Cornwall and the Isle of Scilly (EPIC)  
4 project, which is part funded by the European Regional Development Fund (ERDF),  
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6 for the loan of some of the robots used in this research.  
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## 10 11 12 **Data Sharing**

13  
14 The datasets generated and analysed during this study are available at the Open  
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16 Science Framework using the following link:

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18 [https://osf.io/kps2w/?view\\_only=12ec0a445086403db685c3b41e1e3127](https://osf.io/kps2w/?view_only=12ec0a445086403db685c3b41e1e3127)  
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## 37 Figure Legends

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40 **Figure 1: Robots and toys at each interaction station, and the associated**  
41 **features for comparison**  
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45 **Figure 2: Interaction Station 2**  
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47 **Figure 3: Choice of robot/toy for use with older people, shown by participant**  
48 **group**  
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52 **Figure 4: Mapping the relationship between older people's unprompted**  
53 **opinions and focus group themes**  
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