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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

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

These positive results have however been questioned (17). A comparison between an active Paro and an inactive one found benefits of the active robot were limited to engagement (18). One study (19) found no significant improvement for depression (seeing a significant decrease only for loneliness); another (20) compared live dog visits to Paro sessions over 6 weeks, and found no improvement for depression with either intervention. Research assessing suitability of Paro for a dementia unit suggested it required adaptions; for example, its vocalisations can be distressing (21). Finally, a large randomised controlled trial (RCT) found considerable variation in responses to Paro (22).

While this disparity may result from individual variability, it is also possible robot design factors may be impairing wider acceptance. Similar differences have been observed for other devices; for example, research on AIBO has both shown good acceptability (23), and found that it encouraged less interaction than a soft toy (24). Meanwhile, a review of acceptability towards robots used in aged care suggests a number of robots have failed (3).

The Almere model of acceptability of social robots among older people strongly suggests acceptability can impact intention to use, and therefore actual use of a device (25). Furthermore, using robots in contexts they were not designed for can perpetrate negative perceptions of them and reduce acceptability (4), which may explain some of the conflicting results on robot companions. User-centred design, in general, thus requires designers to have a deep understanding of those they design for, and to involve them in all stages of the process (26).

Considering perceived requirement can vary between stakeholder groups (27), as can technology acceptance (28), design requirements likely differ between varied groups of end-users, for example those with physical impairments (29), children (30), or older people. Research should thus be specific to the aim of each robotic system. Generally, integrating user requirements and experiences into design can be difficult (29). One challenge noted by Chammas et al. (26) is the acceptance, recognition and incorporation of user-centred design in practice. Therefore, considering potential additional effort required, evidence establishing the value of this approach might help encourage designers to adopt this type of methodology.

While little appears to be currently known about how older people perceive robots (31), one study explored meaning behind robotic pets with 41 independent older people (32), finding that robotic pets could provide social entertainment and interactions. While functional support was appealing, the fiction of robotic comfort was a potential tension (32). Participants reported preference for soft fur and suggested play features as an improvement, currently absent from available companion robots. A limitation was the use of unfamiliar, often brightly coloured, child-orientated pets, restricting the range of features participants could inform perceptions on.

More generally, while older people and people with dementia are implicated in companion robot design, they are often not involved (33), even given a clearly identified need for ensuring devices adequately meet the needs of the end-users (4). Instead, older people are often assigned stereotypical needs (33). When they are involved, it is usually through care providers, and at the end of the design process (32).

Here, we therefore investigate any notable differences in opinion between 'robot-users' and 'robot-creators' regarding the design of companion robots and provide initial insights into older peoples' design requirements. The different perceptions between designers and end-users we document also demonstrate the importance of user-centred design.

METHODS

Design

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

Patient and public involvement

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

Participants and settings

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

Procedure

In both settings, participants gave written informed consent, then formed groups of up to four people. Each group moved through three interaction stations where participants engaged in free interaction with a selection of robots or toys. Each station provided a different range of robot/toy features, aesthetics and abilities (Figure 1), and was filmed using two cameras. Non-interactive toys and devices with varying sophistication were included as comparison to the high sophistication levels of robots such as Paro. 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). Question 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)
a. What features and qualities are necessary?
b. What features and qualities are desirable?
c. Which expressions are important?
d. Why?
3. What possibilities and properties should a suitable pet robot *not* 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

restricting their role to introducing animals and answering questions during free interactions. The procedure was maintained as much as possible between both settings. Roboticists were asked to think of the target audience of older people when responding to Key Questions.

Materials

In addition to video recordings, field notes, paper participant information sheets, consent forms and debriefs were collected.

Ethical approval was received from the Faculty of Science and Engineering ethics committee at the University of Plymouth. All participants provided full, written informed consent prior to the study.

Data Analysis

Discussions at all stations were transcribed verbatim and analysed by two researchers (HB, KE). There were two sets of data for each setting, i) unprompted opinions based on comments and discussions during free interaction with the range of robots and toys, and ii) focus group responses. Both sets of data were analysed separately with NVivo using content analysis to garner emerging themes. Content analysis was selected for inclusion of frequencies of theme occurrence (35), and involves systematic coding and 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, 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*

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 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 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 displayed slight envy towards peers interacting with the Joy for All animals, *"you've done more with that cat than I got to do" (OP11).*

Despite enjoying interactivity of available robots, older people also expressed a desire for command response from robots during free interactions. The commands each animal received varied. Those directed at the Joy for All dog were based on expectations of live dogs, with participants requesting *"high five" (OP3-4), "give paw" (OP3, OP5, OP8, OP10, OP15, OP17)* or *"lie down" (OP5),* on 11 occasions. The Joy for All cat received similar requests including *"can you wag your tail?" (OP3, OP1, OP8).* Miro mainly received directional commands, *"turn around!" (OP5-6, OP10-11, OP13, OP15, OP17-18) "stop, turn, turn left, turn left" (OP13)* and Pleo received requests to play and eat; *"open wide, open wide, open up, that's it!" (OP13).* Participants also repeatedly asked robots to *"look at me" (OP5, OP7, OP16, OP15)* suggesting facial tracking and eye contact could be a future interactivity improvement: Paro and the Joy for All animals received praise as "*special"* for

"looking right at" the participant *(OP2, OP4, OP13, OP17).* Most frustration was noted commanding the non-interactive Perfect Petzzz dog, with 15 participants requesting or commanding the dog to *"wake up" (OP1-6, OP9-13, OP16-18)* or *"open your eyes" (OP5-6, OP8-9, OP12, OP16).* Participants reported limited appeal in an animal without responses, suggesting the non-interactive dog appeared *"dead" (OP17).*

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*

one of them [seal]" (OP5). Participants suggested seals were incongruent with their context, believing seals belong *"on the ice floats" (OP4)* or *"eaten with pepper sauce" (OP4).* The familiar animals were most often the devices praised for looking *"realistic" (OP3),* or behaving in a way that appeared *"very real"* (OP5).

Additionally, the breathing feature of the Perfect Petzzz dog was well received; *"it's fascinating to watch him breathing" (OP15)*. It appears any feature increasing the 'realness' of a companion was beneficial. Participants reported life-simulation features such as the breathing made the robots look *"living" (OP17).* This feature was commented on 13 times, and often a source of conversation between participants.

Shell design

This theme arose on 89 occasions through codes; *realistic animal, physical features, shell-type, favouritism, preference, texture* and *likeability.* The evidence strongly suggested older people preferred soft, furry companion robots, but also favoured big eyes. Participants did prefer features making animals appear more realistic, as discussed above.

Paro's eyes were specifically commented on positively by six older people. The "*big eyes" (OP1, OP4)* were described as *"cute" (OP2)* and appeared to draw participants towards the seal; *"ohhh look at your eyes!" (OP11).* Participants also particularly appreciated Paro's prominent eyelashes; *"ladies will wish they had lashes like him!" (OP6).* Other large eyes also received praise, including Furby's animated eyes that were particularly *"captivating" (OP16).*

Older people praised animals with fur for cuddliness and suggested, in response to non-furry options, that they *"want something [sic] you could smooth and it feels like an animal, you know, like that [Joy for All] cats got fur" (OP10).* On 11 occasions participants responded negatively to plastic shells of Pleo and Miro, as they did not *"feel quite as friendly" (OP11).* In contrast, Paro's fur was described as *"lovely" (OP8)* and *"soft" (OP11).* While participants appeared to acknowledge Paro possessed softer fur than alternative furry animals, the Joy for All cat fur was praised for being less pristine. Participants suggested the cat *"looks a bit bedraggled" (OP7)* which resulted in time spent brushing and grooming. One participant suggested the fur looked *"so real" (OP1)* suggesting the longer, shaggier coat felt more congruent with cat expectations.

Ownership

This theme arose on 30 occasions, through codes; *naming, ownership,* and *personalisation* and represents older people demonstrating some attachment towards robots during free interactions.

Naming was thought to relate to ownership, as naming a live animal occurs with possession, and signifies a developing relationship (38). Older people sometimes used names of previous pets, such as *"Milo" (OP1)* because *"they've got a cat called Milo" (OP3).* Other participants chose generic names, such as *"Fido" (OP11)* or *"Tigger" (OP4)* while some got creative with names like *"Shandy" (OP7)* because the dog *"is a mixture" (OP7).* Once older people had allocated a name, it endured

throughout their interaction, *"are you wagging your tail for me Shandy?" (OP7).* Naming occurred mostly with the Joy for All cat and dog.

Further evidence for ownership came from a code of the same name. Ten older people commented on acquiring a robot during free interactions, such as *"do you know, I'd love this [cat], I'd love this in my apartment" (OP2).* Another suggested *"the service should have one [Joy for All dog]" (OP6)* with peers commenting in agreement; *"we'll all go out and buy one now!" (OP17).* Of all occurrences, ownership was only shown towards the Joy for All cat and dog, suggesting good acceptability of these two devices.

We felt personalisation related to ownership, as wanting to adapt a robot for personal use implies a desire to keep it. Evidence for personalisation was not prolific during free interactions, with hints of personalisation being desired occurring only twice. One participant enjoyed the Joy for All dog, but requested a larger size as *"I don't do little doggies" (OP16).* The participant requested it *"look like a golden retriever"* because *"it's the only dog we've ever known" (OP16).* It is possible evidence was limited during free interactions as participants were unaware of the possibility.

Section 2: Focus Group Results

This section presents the focus groups results as a numerical comparison between end-users and developers, to provide a clear understanding of any differences between the two groups. The features presented represent the most prevalent themes during content analysis of responses to Key Questions (Table 1). For both groups, an overall score was calculated for each feature (n participants 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: The number of older people and roboticists providing positive, negative or non-responses for each feature and the resultant level of difference or agreement

		Interactivity	Soft Fur	Talking	Personalised	Realistic	Familiar	Mythical	Life-simulation
Older People 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
	Score	**15**	**11**	**7**	**14**	**11**	**4**	**-4**	**5**
Roboticists 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
	Score	**12**	**7**	**-11**	**-1**	**-9**	**-9**	**0**	**1**
Score difference		**3**	**4**	**18**	**15**	**20**	**13**	**4**	**4**

Key: green = difference ≤ 4, orange = difference ≥ 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

on the need for interactivity and soft-fur in response to Key Questions 1 and 2 (Table 1). There also appears to be some agreement between the two groups on inclusion of life-simulation features and mythical design, although older people were generally more positive towards life-simulation and more negative towards mythical design. Some participants did not respond to every feature, resulting in lower numbers of responses for some features. Familiarity, life-simulation and mythical design received lower responses, possibly suggesting these features were less important, and thus participants felt less inclined to comment. However, this could also derive from the semi-structured nature of the focus groups, where realistic, familiar or mythical design were all discussed in relation to Key Question 10.

The preferred animal among older people in response to Key Question 8 was the Joy for All cat, with 9/17 (53%) participants selecting this animal (Figure 3), followed by the Joy for All dog. Paro, Miro and the homemade hedgehog were not selected by any older person. The preferred animal among roboticists was Paro (11/18), followed by Pleo the dinosaur, then the homemade hedgehog. The Joy for All dog and cat, Miro, the Perfect Petzzz dog and Furby were not selected by any roboticists, and some roboticists did not select any of the available animals.

Table 3: Examples of evidence from each group during focus group discussions

Theme	Example Evidence	
	Older People	Robotocists
Interactivity	"If you're sat there on your own, you want some reaction" (OP6) "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)	"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) "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)
Soft fur	"Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder" (OP5) "Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle" (OP13)	"I don't think so, because it isn't cleanable, if you wanted something to cuddle you could just buy a stuffed toy" (R14) "Nice and furry, you could kinda cuddle it" (R18)
Talking	"[animals] don't talk, there are sounds that creatures make" (OP6) "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)	"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) "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)
Personalisation	"If it was knitted, it wouldn't be able to move its eyes and mouth" (OP5) "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	"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)

	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 warms!" (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

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

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).

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

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

DISCUSSION

User-centred design is often cited as beneficial (4, 26) but rarely used in companion robot development. The differing preferences of end-users and potential developers

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

Further to highlighting the value of user-centred design, this study provided initial insights on end-user design requirements. Older people and roboticists both saw interactivity as important. Older people wanted interactivity for companionship, fun, and reduced loneliness through responsiveness. Some roboticists on the other hand raised concerns on over-stimulating older people. Our older adults displayed little interest towards non-interactive animals, whose lack of responsiveness appeared frustrating. This disinterest in unresponsive/inactive companions is congruent with the finding that an ‘active’ Paro was more engaging than an ‘inactive’ Paro (18). While

interactivity appears essential, our results demonstrated the advanced responsivity of Paro may be unnecessary. Despite having fewer technological abilities, the Joy for All cat was perceived as most interactive, most likely because of its greater range of movements available, including animated head and legs, rolling-over, blinking and cleaning movements. Therefore, the range and variety of responses may be more important than the sophistication of sensors a robot possesses.

Our older people were interested in companion robots understanding and responding to simple commands. Use of commands is only briefly mentioned in previous literature (32), and our findings appear contrary to a study (40) that found no evidence for the importance of enjoyment or playfulness factors among community dwelling older adults. Our group actively sought playfulness from robots, believing this would sustain enjoyment for longer. Responsiveness to simple commands such as *"paw"* could be a consideration for future robot design. Interestingly, there were fewer command expectations for the Joy for All cat than other robots, perhaps due to a reduced association between live cats and training versus live dogs. These expectations could be used to support use of an unfamiliar form such as Paro, whose design was aimed at reducing expectations (41). However, older people still displayed command expectations for Pleo, Miro and Paro, (unfamiliar forms), disputing this theory. One could speculate that the cat's larger quantity of movements results in a reduced need to command actions.

Older people also positively evaluated the potential for human speech from a companion robot. These results contradict the suggestion that, congruent with the uncanny valley theory, human acceptability of sounds depends on the realism of the

context (42). In one study (43) participants related less to an AIBO dog beeping than a computer emitting an identical sound, perhaps due to contradiction in context between a dog and a beeping noise, thus suggesting that animal sounds would be most acceptable for animal robots. Our results, however, indicated positive attitudes towards speech capabilities for provision of company. Frennert and Ostlund(33) reported that developers were influenced by stereotypical perceptions of older people as lonely and fragile, but failed to incorporate requirements of participating older people into design. Our group of older people thought loneliness could be eased through devices capable of simple conversation. This could be a user-driven improvement to currently available companion animals if our results are replicated in wider samples. It is possible, however, that this feature will be evaluated differently in possible future research with a sample of cognitively impaired older people. Our participants were cognitively intact and therefore aware of the artificial nature of the robots or toys; older people with dementia may find the incongruence of human speech from an animal less acceptable.

Eye contact was a further improvement desired by older people, some of whom were disappointed when robots failed to look towards them. Gaze following may increase social relevance of the robot. This may be particularly true when eye movement is intentional rather than random (44). While the pre-programmed movements of the Joy for All cat were positively evaluated, intentional gaze following may be an improvement for optimal social companionship. The importance of improving sociability for robot acceptance was noted before (45), and this addition of apparent social behaviour could improve acceptability.

Most older people preferred soft, cuddly fur for the outer shell. Our group of roboticists generally agreed, although both groups raised concerns regarding hygiene in comparison to a hard shell. This corroborates previous findings on care providers' preferences for robots aimed at their older service users (34, 46), although others have reported older people's preference for mechanical design on robots (28). These results may reflect the broader range of socially assistive robots used (machine-like, mechanical, human-like and animal-like robots); however, results generally imply a robot should indeed be recognisable as robotic (28). One study (21) also reported a family member demonstrating stigma towards his father interacting with soft-toys, suggested potential gender barriers with soft, cuddly robots. Our study found no notable difference between males and females, and suggests that companion robots for this market should use soft fur in the design. Providing the optimum tactile characteristics are particularly important considering evidence suggests touch is one of the most important modalities of interaction for dementia patients, creating a natural method to engage with animaloid robots (47).

Considering the importance of tactile characteristics (46), a further feature for consideration in future development is life-simulation, another capability positively evaluated by older people, but lacking from current examples including Paro. Our research supports the previously reported (46) assumption of care-providers that a simulated heartbeat would be a valuable addition to Paro, but additionally demonstrates that older people themselves also valued life-simulation features, including simulated heartbeat, simulated breathing and the feeling of purring. Older people even suggested warmth as an additional feature. This result appears congruent with older adults' desire for a realistic, life-like companion.

A realistic, familiar animal form was a definite aesthetic requirement for our group of older people. This was also reflected in their choice of Joy for All cat as their preferred device, as a familiar, realistic option, with Paro not selected by any older adult. Previous research focusing on opinions of care providers revealed criticism of Pleo for lack of familiarity (34), while the intentionally unfamiliar Paro (41) is the most often utilised companion robot in research (10). The end-users in our research thought that Paro, like Pleo, was too unfamiliar. The most familiar animals, the Joy for All cat and dog, were preferred for being more relatable and congruent with the contexts in which older people lived. The unfamiliar forms appeared incongruent and infantilising, perhaps explaining the tension Lazar et al. (32) found towards their selection of unfamiliar animals.

This is relevant insofar as some companion robots, such as Paro, are intentionally designed using unfamiliar forms to avoid the robots failing to meet expectations (41). Most of our roboticists followed this line of thinking and responded negatively to familiar animals, unsurprisingly selecting Paro as their preferred companion robot. It is further likely the roboticists appreciated the advanced technical capabilities of Paro, but our study suggests such sophistication may be unnecessary for older people. Research conducted 19 years ago also suggested older people disliked the feel and behavior of a robot cat compared to real cats (47); however, currently available robotic cats are likely more realistic than the Tama OMRON Corp cat used in that study.

The preference for realistic and familiar robots may result from relatability, with older people perhaps having personal experience of cats and dogs given the prevalence of

ownership of these species (48). Familiar animals may provide recognisable potential for a loving relationship. Even individuals without personal pet ownership experience will have likely witnessed others with pets, and therefore the familiar form of a dog or cat is symbolic of that potential bond and relationship. The tendency for our group of older people to name the Joy for All cat and dog more often than alternatives suggests familiarity may additionally help facilitate a sense of ownership. Thus, our results imply that, rather than being problematic (41), memories and schemas of familiar animals may actually be beneficial. A further implication of familiar companion robots relates to reminiscence theory, which suggests benefits of reminiscence for older people including decreased depression (49). Reminiscence therapy uses memories, feelings and thoughts from the past to facilitate pleasure (50). Evidence of reminiscence was found in our study, and seems congruent with this theory, as memories of past pets and animals were shared with positive affect. It is therefore possible familiar companion robots would have additional wellbeing benefits, particularly for individuals with dementia.

The possibility of personalisation was also positively perceived by older people and thus could be a consideration for future robot design. Personalisation has been mentioned in previous research (28, 34), but has not been explored directly with end-users. Our older people positively evaluated a more person-centred approach to robot aesthetics, praising the potential to interchange robot 'skins' to match personal preference. It is possible personalised robots would be more acceptable than a single design for all users. This could alleviate some disparity in response to Paro, as seen in previous RCT research (22).

In contrast, our roboticists underestimated the value of personalisable aesthetics, and failed to predict older people's desire for human speech and life-simulation features. The transcript evidence suggests roboticists had an awareness of Mori's uncanny valley hypothesis (51). This is not surprising given their field of interest, and it is possible this, and related literature, had influenced roboticists' views on robot design to favour unrealistic and unfamiliar forms, and to undervalue life-simulation features that would undoubtedly increase the realistic impression of a robot.

Although our study was limited by recruiting older people from just one setting and roboticists from one University (although from varied educational and occupational backgrounds) we found marked differences in their views that need to be accounted for in the development of companion robots. If creative methods of coproduction are used (52), both groups would need to think more about why they liked certain features and it is likely they would develop a new product that would be owned by this co-design group. Although there are no guarantees, a product so designed might have a higher chance of being liked by the wider population of older people.

Our study recruited older people from a retirement complex and the generalisability of their views to care home residents is limited. Our finding of the acceptability of such devices among a more independent sample is in contrast to previous research which implied more independent older people felt 'too able' to use robots (28). Thus, there may be a market among this more independent sample that has previously been underestimated.

Another limitation of our study was the short interaction time of ten minutes at each

station, providing initial preferences. Research has suggested acceptance should be measured over longer periods of use, allowing for familiarisation and more informed attitudes towards the device, which may be more predictive of actual use (53). 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 was however longer than previous research where participants only interacted with each robot for one minute (34).

Our study's smaller group sizes compared to previous research (34) 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. On the other hand, use of qualitative, free interaction transcriptions increases confidence in our focus group results, even where response numbers were low, as preferences were often evident through unprompted interaction.

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

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

https://osf.io/kps2w/?view_only=12ec0a445086403db685c3b41e1e3127

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Figure Legends

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

Figure 2: Interaction Station 2

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

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

Station	Animal robot/toy	Range of features for comparison
1 – All soft-fur, differing levels of interactivity, familiar and unfamiliar options	Paro 	• Unfamiliar • Not life-like • Interactive • Animal noises • No life-simulation • Soft-fur
	Joy for All dog 	• Familiar • Life-like • Interactive • Animal noises • Life-simulation (heart beat) • Soft-fur
	Joy for All cat 	• Familiar • Life-like • Interactive • Animal noises • Life-simulation (purring) • Soft-fur
2 – Interactivity vs soft-fur, interactive devices have plastic shells, soft-furry dog is non-interactive. Familiar and unfamiliar options.	Miro 	• Unfamiliar • Not life-like • Interactive • Non-animal noises • No life-simulation • Hard-shell
	Pleo rb 	• Unfamiliar • Not life-like • Interactive • Non-animal noises • No life-simulation • Soft-plastic shell
	Perfect Petzzz Dog 	• Familiar • Life-like • Non-interactive • No noises • Life-simulation (breathing) • Soft-fur
3 – Mythical, unfamiliar option, human speech, completely inert option. Personalisable option.	Furby 	• Unfamiliar • Not life-like (mythical) • Interactive • Non-animal noises (speech) • No life-simulation • Soft-fur
	Hedgehog 	• Unfamiliar • Not life-like • Non-interactive • No noises • No life-simulation • Soft-fur

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

90x234mm (300 x 300 DPI)

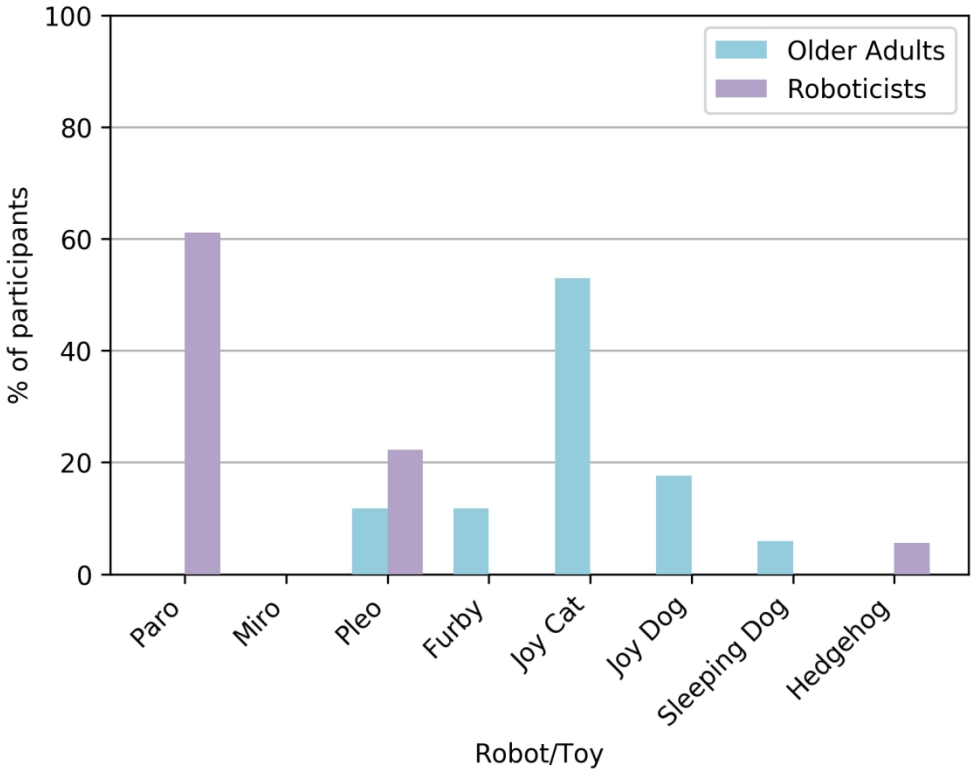

Figure 3: Choice of robot/toy for use with older people, shown by participant group

137x109mm (300 x 300 DPI)

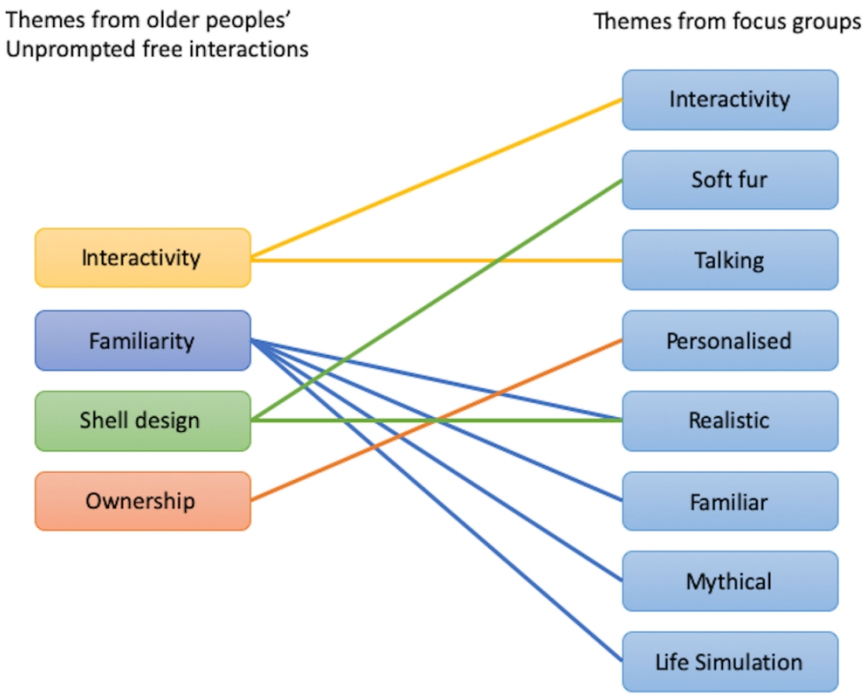

Figure 4: Mapping the relationship between older people's unprompted opin-ions and focus group themes

119x90mm (300 x 300 DPI)

Supplementary Materials

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

Theme	Example Evidence	
	Older People	Robotocists
Interactivity	"it [Pleo] interacted more so you could spend loads of time just playing" (OP4) "If you're sat there on your own, you want some reaction" (OP6) "He [Joy for All dog] had more interaction, he was doing more of less what I wanted him to do" (OP15) "I'd like it to respond to me" (OP7) "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)	"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) "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) "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) "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)
Soft fur	"Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder" (OP5) "Soft furry face, the dinosaur interaction was good but it's still like dragging your hand over rubber" (OP6) "you can't stroke plastic" (OP10) "Furry, the seal [Paro] was lovely" (OP12)	"It should be soft" (R4) "Definitely have the fluffiness of the seal, around the same level of interactivity" (R5) "The dinosaur is cute but the texture is horrific" (R8) "The fur is attractive" (R10) "I don't think so, because it isn't cleanable, if you wanted something to

	"Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle" (OP13) "if you're having an animal, it has to have animal fur" (OP14)	cuddle you could just buy a stuffed toy" (R14) "Nice and furry, you could kinda cuddle it" (R18)
Talking	"Yes, because there's a lot of time in your flat on your own, just having something to interact with" (OP1) "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 went in the front door, if it just said sorta, hello! That would be nice" (OP8) "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) "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)	"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) "If you're going for animals, then I don't think speech is important [sic] yeah animal sounds" (R2) "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) "It actually gets annoying because it's repetitive, there is this boundary, where if you've interacted for five minutes…. It gets annoying." (R6) "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)
Personalisation		

	"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)

		"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)
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)
Mythical		

	“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)
Life simulation	“Warmth under belly to keep your knees warms!” (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)

Title: ~~The~~ Companion robots for older people: the importance of user-~~centered~~centred design~~: Comparing the~~ demonstrated through observations and focus groups comparing preferences of older people and roboticists ~~towards companion robot design.~~ in South West England.

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Abstract

~~Background~~Objectives:

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

Design

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

~~Methods~~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. ~~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~~ infantili~~z~~s~~z~~ing. 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~~

classified aswhether rehabilitation orand social robots (7), could help in this respect and alleviate thissome pressure on health and social care resources (3).

In this paperHere, 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 (916), including reducing risks for the animals themselves (9, 106). A prominent example of a companion robot is Paro, the robot seal (910). Research has suggested numerous benefits of interacting with Paro, including reduced agitation and depression in dementia (10, 11, 12), more adaptive stress response (132), reduced care provider burden (132), and significantly improved affect and communication between dementia patients and day care staff (143). Further research has suggested Paro may additionally reduce psychoactive and analgesic medication use (154), and even decrease blood pressure (165). Generally speaking, companion robots alleviate issues of traditional animal assisted therapy (16), including reducing risks for the animals themselves (9, 16).

These positive results have however been questioned (17). A comparison between an active Paro and an inactive one found benefits of the active robot were limited to engagement (18). Robinson et al.One study (19) found no significant improvement for depression (seeing a significant decrease only for loneliness); another. Thodberg et al. (20), compared live dog visits to Paro sessions over 6 weeks, and found no improvement for depression with either intervention. Research assessing the suitability of Paro for a dementia unit suggested it may need to be adapted for such settings asrequired adaptions,; for example, its vocalisations can be distressing (21). Moyle et al. (22) also found considerable variation in responses to Paro inFinally, a

large randomised controlled trial (RCT) found considerable variation in responses to Paro (22).

While this disparity may ~~be due to~~result from individual variability, it is also possible robot design factors may be impairing wider acceptance. Similar differences have been observed for other devices; ~~regarding AIBO,~~ for example, research on AIBO has both shown good acceptability (23), and found that it encouraged less interaction than a soft toy (24).~~,~~ Meanwhile, ~~while a~~a review of acceptability towards robots used in aged care suggests a number of robots have failed (3).

The Almere model of acceptability of social robots among older people strongly suggests acceptability can impact intention to use, and therefore actual use of a device (25). Furthermore, using robots in contexts they were not designed for can perpetrate negative perceptions of them and reduce acceptability~~,~~ (4), which may explain some of the conflicting results on robot companions ~~(4).~~. User-centred design, in general, thus requires designers to have a deep understanding of those they design for, and to involve them in all stages of the process (26).

Considering ~~that~~ perceived requirement can vary between stakeholder groups (27), as can technology acceptance (28), ~~it is likely~~ design requirements ~~would~~likely differ between varied groups of end-users, for example those with physical impairments (29), children (30), or older people.~~,~~ ~~thus r~~Research ~~is required~~should thus be specific to the aim of each robotic system. Generally, ~~Integrating~~integrating user requirements and experiences into design can be difficult (29). ~~Similarly, o~~One challenge noted by Chammas et al. (26) is the acceptance, recognition and incorporation of user-centred

design in practice. Therefore, considering potential additional effort required, evidence establishing the value of this approach might help ~~to~~ encourage designers to adopt this type of methodology.

While ~~There currently appears to be little~~little appears to be currently known about how older people perceive robots (31)~~.~~, ~~O~~one ~~exception is a~~ study ~~that~~ explored meaning behind robotic pets with 41 independent older ~~adults~~people (32), finding that~~. Results suggested~~ robotic pets could provide social entertainment and interactions~~.~~, While functional support was appealing, ~~but~~ the fiction of robotic comfort was a potential tension (32). Participants reported preference for soft fur and suggested play features as an improvement, ~~which appear absent on~~ currently absent from available companion robots. A limitation was the use of unfamiliar, often brightly coloured, child-orientated pets, restricting the ~~providing a limited~~ range of features ~~for~~ participants~~older~~ ~~adults~~people ~~to~~could inform perceptions on.

More generally, while older people and people with dementia are implicated in companion robot design, they are often not involved (33), even given a clearly identified need for ensuring devices adequately meet the needs of the end-users (4). Instead, older people are often assigned stereotypical needs (33)~~., with studies rarely involving older people in robotics design: when~~ When they are involved ~~at all~~, it is usually through care providers, and at the end of the design process (32).

~~In this paper~~Here, we therefore ~~seek to~~ investigate any notable differences in opinion between 'robot-users' and 'robot-creators' regarding~~about~~ the design of companion robots ~~for older people,~~ and ~~and in doing so,~~ provide ~~some~~ initial insights into older

peoples' design requirements ~~for companion robots~~. ~~This evidence of~~The different perceptions between designers and end-users we document ~~may also help persuade designers of~~also demonstrate the importance of user-centred design.

METHODS

Design

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

Patient and public involvement

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

Participants and settings

In total, 35 participants collaborated: 17 older people (5 male, 12 female, age range 60-99 years), and 18 roboticists (10 male ~~and~~, 8 female, age range 24-37). Older people were recruited at a supported living complex that houses individuals of and above retirement age within apartments, with a manager present on site. Roboticists

were recruited at an away-day event of researchers from a robotics research centre. These included research students, academics, and individuals developing and researching robotics and social robots, many within the health and social care field. The researchers were therefore familiar with this field, and the students may represent a next generation of developers.

Procedure

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

Following After free interaction with all available robots and toys, participants finally engaged in semi-structured focus group discussions, guided by key questions (tableKey Questions (Table 1).,, which Question were informed by previous research (34). Questions were amended, however, amended only to include more features of

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 ~~prefer~~like? What is it about ~~that animal~~those animals that makes you like ~~it~~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)
a. What features and qualities are necessary?
b. What features and qualities are desirable?
c. Which expressions are important?
d. Why?
3. What possibilities and properties should a suitable pet robot *not* have?
4. How do you feel about a companion robot speaking? And ~~have~~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~~,~~. ~~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

settings. Roboticists were asked to think of the target audience of older people when responding to ~~key questions~~Key Questions.

Materials

~~We used~~ In addition to video recordings ~~equipment to capture interactions between participants and robots. Note pads were used for researchers to make~~, field notes, ~~were recorded, further to~~ paper participant information sheets, consent forms and debriefs were collected.

Ethical approval was received from the Faculty of Science and Engineering ethics committee at the University of Plymouth. All participants provided full, written informed consent prior to the study.

Data Analysis

Discussions at all stations were transcribed verbatim and analysed by two researchers (HB, KE). There were two sets of data for each setting, i) unprompted opinions based on comments and discussions during free interaction with the range of robots and toys, and ii) focus group responses. Both sets of data were analysed separately with NVivo using content analysis to garner emerging themes. Content analysis was selected for inclusion of frequencies of theme occurrence (35), and involves systematic coding and 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

comprehensive range of ~~robots. The themes arising during analysis of older people interactions~~companion robots. These themes ~~were;~~ were: interactivity, familiarity, shell design and ownership.

Interactivity

The ~~theme of~~ interactivity theme emerged on 185 occasions through ~~the~~ codes: *interactivity, speech and talking, commanding the robot, fun, noises* and *interactivity lacking*~~. This theme~~, strongly suggest~~inged~~ 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 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

displayed slight envy towards peers interacting with the Joy for All animals, *"you've done more with that cat than I got to do" (OP11).*

Despite enjoying ~~the~~ interactivity of available robots, older people also expressed a desire for command response from robots during free interactions. The commands each animal received varied. ~~The commands~~Those directed at the Joy for All dog were based on expectations of live dogs, with participants requesting *"high five" (OP3-4), "give paw" (OP3, OP5, OP8, OP10, OP15, OP17)* or *"lie down" (OP5),* on 11 occasions. The Joy for All cat received similar requests including *"can you wag your tail?" (OP3, OP1, OP8).* Miro mainly received directional commands, *"turn around!" (OP5-6, OP10-11, OP13, OP15, OP17-18) "stop, turn, turn left, turn left" (OP13)* and Pleo received requests to play and eat; *"open wide, open wide, open up, that's it!" (OP13).* Participants also repeatedly asked robots to *"look at me" (OP5, OP7, OP16, OP15)* suggesting facial tracking and eye contact could be a future ~~improvement to the~~ interactivity ~~of such devices.~~improvement: Paro and the Joy for All animals received praise as "*special"* for *"looking right at"* the participant *(OP2, OP4, OP13, OP17).* ~~Further support for this suggestion came from older people praising robots as *"special",*~~ particularly Paro and the Joy for All animals, ~~when they appeared to befor~~ *~~"looking right at"~~* ~~the participant *(OP2, OP4, OP13, OP17)*~~. Most frustration was ~~seen~~ noted ~~in~~ commanding the non-interactive Perfect Petzzz ~~sleeping~~ dog, with 15 participants requesting or commanding the dog to *"wake up" (OP1-6, OP9-13, OP16-18)* or *"open your eyes" (OP5-6, OP8-9, OP12, OP16).* Participants reported limited appeal in an animal without responses, suggesting the non-interactive dog appeared *"dead" (OP17).*

Participants also demonstrated desire for robot speech ~~during free interactions~~, 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).* ~~Further support came from participant responses to Miro's electronic noises, not recognisable as specific animal vocalisations.~~ Similarly, o~~O~~n 11 occasions, participants confused ~~the~~ 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).*

~~Despite this apparent desire for verbal responses~~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 ~~during older persons unprompted, free interactions~~.

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 ~~animals they had known~~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~~,~~; ~~as the~~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 one of them [seal]" (OP5).* Participants suggested seals were incongruent with their context, believing seals belong *"on the ice floats" (OP4)* or *"eaten with pepper sauce" (OP4).* The familiar animals were most often the devices praised for looking *"realistic" (OP3),* or behaving in a way that appeared *"very real"* (OP5).

~~Further to preferring realistic design~~Additionally, the breathing feature of the Perfect Petzzz dog was well received; *"it's fascinating to watch him breathing" (OP15)*. It appears any feature increasing the 'realness' of a companion was beneficial~~,~~. ~~p~~Participants ~~reporting~~reported life ~~-~~simulation features such as the breathing made the robots look *"living" (OP17).* This feature was commented on 13 times, and often a source of conversation between participants~~, however appeal of the Perfect Petzzz dog was still limited by lack of interactivity~~.

Shell design

This theme arose on 89 occasions ~~during older peoples free interactions,~~ through codes; *realistic animal, physical features, shell-type, favouritism, preference, texture* and *likeability.* The evidence strongly suggest~~ed~~ed older people preferred soft, furry companion robots, but also favoured big eyes. Participants did prefer features making animals appear more realistic, ~~although this is~~as discussed above.

Paro's eyes were specifically commented on positively by six older people. The "*big eyes" (OP1, OP4)* were described as *"cute" (OP2)* and appeared to draw participants towards the seal; *"ohhh look at your eyes!" (OP11).* Participants also particularly appreciated Paro's prominent eyelashes; *"ladies will wish they had lashes like him!" (OP6).* Other large eyes also received praise, ~~such as~~including Furby's animated eyes that were particularly *"captivating" (OP16).*

Older people praised animals with fur for cuddliness and suggested, in response to non-furry options, that they *"want something [sic] you could smooth and it feels like an animal, you know, like that [Joy for All] cats got fur" (OP10).* On 11 occasions participants responded negatively to plastic shells of Pleo and Miro, as they did not *"feel quite as friendly" (OP11).* In contrast, Paro's fur was described as *"lovely" (OP8)* and *"soft" (OP11).* ~~Participants~~ While participants appeared to acknowledge Paro possessed softer fur than alternative furry animals~~, however,~~, the Joy for All cat fur was praised for being less pristine. Participants suggested the cat *"looks a bit bedraggled" (OP7)* which resulted in time spent brushing and grooming ~~the cat~~. One participant suggested the fur looked *"so real" (OP1)* suggesting the longer, shaggier coat felt more congruent with cat expectations.

Ownership

This theme arose on 30 occasions, through codes; *naming, ownership,* and *personalisation* and represents older people demonstrating some attachment towards robots during free interactions.

Naming was thought to relate to ownership, as ~~provision of a name to~~naming a live animal occurs with possession, and ~~has been shown in research to relate to~~signifies a developing relationship (38). Older people sometimes used names of previous pets, such as *"Milo" (OP1)* because *"they've got a cat called Milo" (OP3).* Other participants chose generic names, such as *"Fido" (OP11)* or *"Tigger" (OP4)* while some got creative with names like *"Shandy" (OP7)* because the dog *"is a mixture" (OP7).* Once older people had allocated a name, it endured throughout their

interaction, *"are you wagging your tail for me Shandy?" (OP7).* ~~This tendency to name~~Naming occurred mostly with the Joy for All cat and dog.

Further evidence for ownership came from a code of the same name. Ten older people commented on acquiring a robot during free interactions, such as *"do you know, I'd love this [cat], I'd love this in my apartment" (OP2).* Another suggested ~~about the Joy for All dog that~~ *"the service should have one" [Joy for All dog]" (OP6)* with peers commenting in agreement~~. Another suggested~~; *"we'll all go out and buy one now!" (OP17).* Of all occurrences, ownership was only shown towards the Joy for All cat and dog, suggesting good acceptability of these two devices.

We felt personalisation related to ownership, as wanting to adapt a robot for personal use implies a desire to keep it. Evidence for personalisation was not prolific during free interactions, with hints of personalisation being desired occurring only twice. One participant enjoyed the Joy for All dog, but requested a larger size as *"I don't do little doggies" (OP16).* The participant requested it *"look like a golden retriever"* because *"it's the only dog we've ever known" (OP16).* It is possible evidence was limited during free interactions as participants were unaware of the possibility.

Section 2: Focus Group Results

This section presents the ~~results of the~~ focus groups results as a numerical comparison between end-users and developers, to provide a clear understanding of any differences between the two groups. The features presented represent the most prevalent themes during content analysis of responses to Key Questions (Table 1). For both groups, an overall score was calculated for each feature (n participants

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 t~~The number of older people and roboticists providing positive, negative or non-responses for each feature and the resultant level of difference or agreement

		Interactivity	Soft Fur	Talking	Personalised	Realistic	Familiar	Mythical	Life-simulation
Older People 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
	Score	**15**	**11**	**7**	**14**	**11**	**4**	**-4**	**5**
Roboticists 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
	Score	**12**	**7**	**-11**	**-1**	**-9**	**-9**	**0**	**1**
Score difference		**3**	**4**	**18**	**15**	**20**	**13**	**4**	**4**

Key: green = difference ≤ 4, orange = difference ≥ 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,

robots talking human language, personalisation of robots and familiar form. Older people and roboticists seem to agree on the need for interactivity and soft-fur in response to ~~key questions~~Key Questions 1 and 2 (~~table~~Table 1). There also appears to be some agreement between the two groups on inclusion of life-simulation features and mythical design, although ~~generally~~ older people were generally more positive towards life-~~-~~simulation and more negative towards mythical design. Some participants did not respond to every feature, resulting in lower numbers of responses for some features. ~~Table 2 shows f~~Familiarity, life-simulation and mythical design received lower responses, possibly ~~this could s~~suggesting these features were less important, and thus participants felt less inclined to comment. However, this could also ~~represent~~ derive from the semi-structured nature of the focus groups, ~~and that~~where realistic, familiar or mythical design were all discussed in relation to ~~key question~~Key Question 10.

The ~~most~~ preferred animal among older people in response to Key Question 8 was the Joy for All cat, with 9/17 (53%) participants selecting this animal (~~figure~~Figure 3), followed by~~.~~ ~~The second most popular animal was~~ the Joy for All dog. Paro, Miro and the homemade hedgehog were not selected by any older person. The ~~most~~ preferred animal ~~for~~among roboticists was Paro (11/18), followed by Pleo the dinosaur, then the homemade hedgehog. The Joy for All dog and cat, Miro, the Perfect Petzzz ~~sleeping~~

dog and Furby were not selected by any roboticists, and some roboticists did not select any of the available animals.

Table 3: Examples of evidence from each group during focus group discussions

Theme	Example Evidence: Older People	Example Evidence: Robotocists
Interactivity	"If you're sat there on your own, you want some reaction" (OP6) "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)	"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) "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)
Soft fur	"Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder" (OP5) "Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle" (OP13)	"I don't think so, because it isn't cleanable, if you wanted something to cuddle you could just buy a stuffed toy" (R14) "Nice and furry, you could kinda cuddle it" (R18)
Talking	"[animals] don't talk, there are sounds that creatures make" (OP6) "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)	"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) "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)

Personalisation	"If it was knitted, it wouldn't be able to move its eyes and mouth" (OP5) "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)	"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) "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 warms!"	"I can feel on the dinosaur, coming from an engineering point of view,

	(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~~

devicesthis feature was highly valued by older people during free interactions, with many participants desiring additional interaction, such as obeying commands and talking. This theme during free interaction thus also supportsIn the the focus group theme of talking, where 12/17 (71%) older people felt positively towards robot speech.

The free interaction theme of *familiarity* arising during unprompted interactions 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, meaning (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,. tTherefore, it could alternatively be suggestedmay 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).

The free interaction theme on shell-type theme, and clear preference for soft fur during older peoples' free interactions, isare congruent with focus group results where 12/17 (71%) older people preferred soft fur, while only 1/17 (6%) disagreed (92% of responses positive). Life--simulation was not discussed at length during free interactions, although the Perfect Petzzz breathing feature on the dog was well received. This feature also had lower response rates during focus groups. The lower response rate for this feature could again suggest that, while life-simulation may be desirable, supported through decisive responses (100% of responses were positive), this featureit may be less of a priority, with 12/17 (71%) older people not providing

opinions. Despite limited direct discussion during free interactions, the potential inclusion of this feature is supported by the familiarity theme, whereby any aesthetic or technological features increasing the 'realness' of a pet appeared well received during unprompted free interaction.

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

DISCUSSION

User-centred design is generally often cited as beneficial (4, 26); however the extent of its use) but rarely used in companion robot development is currently minimal. This study has demonstrated, through. The differing ent design preferences of end-users and potential developers in our direct comparison, demonstrated the importance of implementing user-centred design in the development oftowhen developing companion robots targeted atfor older people, due to large differences in design preference between end-users and potential developers. The . Our results therefore justify additional effort for the reportedly difficult process of integrating user requirements into design (29), and may aid acceptability ofwith the challenge of user-centred design being accepted in practice (26). Some of our roboticists felt user

involvement in development could damage illusions of the robot, perhaps helping explain the minimal use of this process. However, rather than damaging illusions, adopting user-centred design may actually ensure devices receive adequate acceptability to promote use (25). Future development of robots ~~utilising a~~using user-centred ~~approach~~approaches may result in more consistent positive outcomes than those previously reported for Paro (17, 18, 20, 21~~), whose contradictory results may in-part result from design features our results suggest are undesirable to end-users.~~). Implications of improved design, acceptability and use would be significant ~~due to~~given the ~~reported~~ potential benefits of companion robots for older people, those with dementia, and their family and care team (1~~10~~-1~~65~~). ~~Results of our study would~~Our results suggest strong acceptability and preference of the Joy for All cat and dog, and limited acceptability of Paro when these more familiar/realistic comparisons are available. This result is ~~particularly~~ important ~~when considering the~~given a lack of ~~available companion robot~~ comparison studies of companion robots (39) and apparent selection bias towards Paro in research (10~~9~~).

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

~~Regarding robot abilities, older~~Older people ~~strongly preferred an interactive device,~~and roboticists both saw interactivity as important. Older people wanted interactivity for ~~the purpose of providing~~ companionship, fun, and ~~reducing~~reduced loneliness through responsiveness. ~~Interactivity was also a strong preference for our group of~~Some roboticists~~, however some~~ on the other hand raised concerns on over-stimulating older people. Our older adults displayed little interest towards non-

interactive animals, whose lack of responsiveness appeared frustrating. This disinterest in unresponsive/inactive companions is congruent with the finding that an 'active' Paro was more engaging than an 'inactive' Paro (18). While interactivity appears essential, our results demonstrated the advanced responsivity of Paro may be unnecessary. Despite having fewer technological abilities, the Joy for All cat was perceived as most interactive, most likely because of ~~. This appeared to result from a~~its greater range of movements available, including animated head and legs, rolling-over, blinking and cleaning movements. Therefore, the range and variety of responses may be more important than the sophistication of sensors a robot possesses.

~~We also found~~Our older ~~adults had continuous interest~~people were interested in ~~the~~ companion robots understanding and responding to simple commands. Use of commands is only briefly mentioned in previous literature (32), and our findings appear contrary to ~~the results of Klamer and Allouch~~a study (40) ~~who~~that found no evidence for the importance of enjoyment or playfulness factors among community dwelling older adults. Our group ~~of older people~~ actively sought playfulness from robots, believing this would sustain enjoyment for longer. Responsiveness to simple commands such as *"paw"* could be a consideration for future robot design. Interestingly, there were fewer command expectations for the Joy for All cat than other ~~alternatives~~robots, perhaps due to a reduced association between live cats and training versus live dogs. These expectations could be used to support use of an unfamiliar form such as Paro, whose design was aimed at reducing expectations (41). However, older people still displayed command expectations for Pleo, Miro and Paro, (unfamiliar forms), ~~therefore~~ disputing this theory. One could speculate that the cat's larger quantity of movements results in a reduced need to command actions.

Older people also positively evaluated the potential for human speech from a companion robot. These results contradict the suggestion that, congruent with the uncanny valley theory, human acceptability of sounds depends on the realism of the context (42). ~~Komatsu and Yamada~~In one study (43) ~~demonstrated that~~ participants related less to an AIBO dog beeping than a computer emitting an identical sound, perhaps due to contradiction in context between a dog and a beeping noise, thus suggesting~~.~~ ~~While this would suggest~~ that animal sounds would be most acceptable for animal robots~~,~~. ~~o~~Our results, however, indicated positive attitudes towards speech capabilities for provision of company. Frennert and Ostlund~~Frennert and Ostlund~~~~Another study~~ (33) ~~found~~ reported that developers were influenced by stereotypical perceptions of older people as lonely and fragile, but failed to incorporate requirements of participating older people into design. Our group of older people thought loneliness could be eased through devices capable of simple conversation. This could be a user-driven improvement to currently available companion animals ~~should~~if our results ~~be~~are replicated in wider samples. It is possible, however, that this feature will be evaluated differently ~~with~~ in possible future research with a sample of cognitively impaired older people. Our participants were cognitively intact and therefore aware of the artificial nature of the robots or toys~~,~~; older people with dementia ~~however~~ may find the incongruence of human speech from an animal less acceptable~~,~~ ~~this therefore requires further research~~.

Eye contact was a further improvement desired by older people, ~~with our results demonstrating~~ some ~~disappointment and frustration~~of whom were disappointed when robots failed to look towards ~~the user~~them. Gaze following may increase social

relevance of the robot. This may be particularly true when eye movement is intentional rather than random (44). While the pre-programmed movements of the Joy for All cat were positively evaluated, intentional gaze following ~~would perhaps~~may be an improvement for optimal social companionship. ~~de Graaf et al. (45) noted t~~The importance of improving sociability for robot acceptance was noted before (45), and ~~therefore~~ this addition of apparent social behaviour could improve acceptability ~~further~~.

~~Regarding the outer shell, most~~Most older people preferred soft, cuddly fur for the outer shell. Our group of roboticists generally agreed, although both groups raised concerns regarding hygiene in comparison to a hard shell. This corroborates previous findings ~~that~~ on care providers' preferences ~~preferred soft, cuddly fur on~~for robots aimed at their older service users (34, 46~~). On the contrary, other results~~), although others have reported older people's preference for mechanical design on ~~a robot~~robots (28). These results may reflect the broader range of socially assistive robots used (machine-like, mechanical, human-like and animal-like robots)~~,~~; however, ~~generally~~ results generally impl~~ied~~y a robot should indeed be recognisable as robotic (28). ~~Robinson et al.~~One study (21) also reported a family member demonstrating stigma towards his father interacting with soft-toys, suggested ~~a~~ potential gender ~~barrier~~barriers with soft, cuddly robots. Our study found no notable difference between males and females~~. This support provided directly by older people themselves would strongly suggest soft fur should be implemented in the design of~~Our study, and suggests that companion robots ~~aimed at~~for this market should use soft fur in the design. Providing the optimum tactile characteristics are particularly important considering evidence suggests touch is one of the most important modalities of

interaction for dementia patients, creating a natural method to engage with animaloid robots (47).

Considering the importance of tactile characteristics (46), a further feature for consideration in future development is life-simulation, another capability positively evaluated by older people, but lacking from current examples including Paro~~, amongst others.~~. Our research supports the previously reported (46) assumption of care-providers that a simulated heartbeat would be a valuable addition to Paro, but additionally demonstrates that older people themselves also valued life-simulation features, including simulated heartbeat, simulated breathing and the feeling of purring. Older people even suggested warmth as an additional ~~life-simulation~~ feature. This result appears congruent with older adults' desire for a realistic, life-like companion.

A realistic, familiar animal form was a definite aesthetic requirement for our group of older people. This was also reflected in their choice of Joy for All cat as their preferred device, as a familiar, realistic option, with ~~no older people selecting~~ Paro not selected by any older adult. Previous research focusing on opinions of care providers revealed criticism ~~towards~~of Pleo for lack of familiarity (34), while ~~. In contrast,~~ the intentionally unfamiliar Paro (41) is the most often utilised companion robot in research (10~~9~~). ~~Other), and research on older adult perceptions towards robot pets did not produce familiarity as a result (32), however although this may result from the lack of familiar options available for comparison.~~ The end-users in our research ~~suggested~~thought that~~, additionally to~~ Paro, like Pleo, ~~Paro~~ was ~~also considered~~ too unfamiliar. ~~The strongest preference was seen towards the~~The most familiar animals, the Joy for All cat and dog, were preferred for being more relatable and congruent with the contexts

in which older people lived. The unfamiliar forms appeared incongruent and infantilising, perhaps explaining the tension Lazar et al. (32) ~~noted~~ found towards their selection of unfamiliar animals.

This is relevant insofar as some companion robots, such as Paro, are intentionally designed using ~~an~~ unfamiliar ~~form (a seal in the case of Paro)~~forms to avoid ~~negative schemas, or~~ the ~~robot~~robots failing to meet expectations (41). Most of our roboticists followed this line of thinking and responded negatively to familiar animals, unsurprisingly selecting Paro as their preferred companion robot. It is further likely the roboticists appreciated the advanced technical capabilities of Paro, but our study suggests such sophistication may be unnecessary for older people. Research conducted 19 years ago ~~using the Tama OMRON Corp cat~~ also suggested older people ~~complained about~~disliked the feel and behavior of a robot cat ~~in comparison~~compared to real cats (47)~~.~~ ~~H~~however, ~~this initial research was conducted 19 years ago, and it is therefore likely that~~ currently available robotic cats are ~~more~~likely more realistic than ~~the Tama OMRON Corp cat~~the Tama OMRON Corp cat used in that study~~those available at the time. The majority~~previously. ~~Most of our roboticists group responded negatively to a familiar animal design due to expectations people would hold of animals they were accustomed to, consistent with the thinking behind Paro (41), and unsurprisingly selected Paro as their preferred companion robot. It is likely the roboticists appreciate~~appreciated the advanced technical ~~capabilities of Paro, but this~~our study ~~would suggest~~suggests ~~such sophistication may be unnecessary for this group of end-users. Similarly, roboticists did not feel realistic appearance was appropriate. While the thinking behind designing Paro as an~~

~~unfamiliar animal seems logical (41), this theory seems to resonate poorly with end-users, having potential negative impact on preference~~older people~~.~~

The preference for realistic and familiar robots may result from relatability, with older people perhaps having personal experience of cats and dogs~~, due to~~ given the prevalence of ownership of these species (48). Familiar animals may provide recognisable potential for a loving relationship. Even individuals without personal pet ownership experience will have likely witnessed others with pets, and therefore the familiar form of a dog or cat is symbolic of that potential bond and relationship. The tendency for our group of older people to name the Joy for All cat and dog more often than alternatives suggests familiarity may additionally help facilitate a sense of ownership. Thus, our results imply that, rather than being problematic (41), memories and schemas of familiar animals may actually be beneficial. A further implication of familiar companion robots relates to reminiscence theory, which suggests benefits of reminiscence for older people including decreased depression (49). Reminiscence therapy uses memories, feelings and thoughts from the past to facilitate pleasure (50). Evidence of reminiscence was found in our study, and seems congruent with this theory, as memories of past pets and animals were shared with positive affect. It is therefore possible familiar companion robots would have additional wellbeing benefits, particularly for individuals with dementia.

~~-~~The possibility of personalisation was also positively perceived by older people and thus could be a consideration for future robot design. Personalisation has been mentioned in previous research (28~~)~~, ~~and identified by Heerink et al. (~~34~~), who commented on different users responding differently to different robots~~, but has not

been explored directly with end-users. Our ~~group of~~ older people positively evaluated a more person-centred approach to robot aesthetics, praising the potential to interchange robot 'skins' to match personal preference. It is possible personalised robots would be more acceptable than a single design for all users. This could alleviate some disparity in response to Paro, as seen in previous RCT research (22).

In contrast, our ~~group of~~ roboticists underestimated the value of personalisable aesthetics, and failed to predict older people's desire for human speech and life-simulation features. The transcript evidence suggests roboticists had an awareness of Mori's uncanny valley ~~theory~~ hypothesis (51). This is not surprising given their field of interest, and it is possible ~~the uncanny valley theory~~this, and related literature, had influenced ~~roboticists~~roboticists' ~~perceptions~~ views on robot design ~~n, swaying roboticists~~ to favour unrealistic and unfamiliar forms, and to undervalue life-simulation features that would undoubtedly increase ~~further~~ the realistic impression of a robot.

~~One~~

Although our study was limited by recruiting older people from ~~just~~just one setting and roboticists from ~~only~~ one University (although from varied educational and occupational backgrounds) we found marked differences in their views that need to be accounted for in the development of companion robots. If creative methods of coproduction are used (52), both groups would need to think more about why they liked certain features and it is likely they would develop a new product that would be owned by this co-design group. ~~There is no guarantee, but perhaps more chance~~Although there are no guarantees, ~~that~~ a product so designed ~~would then be~~might have a higher chance of being liked by the wider population of older people.

Our study recruited older people from a retirement complex and the generalisability of their views to care home residents is limited. Our finding of the acceptability of such devices among a more independent sample is in contrast to previous research which implied more independent older people felt 'too able' to use robots (28). Thus, there may be a market among this more independent sample that has previously been underestimated.

Another limitation of our study was the short interaction time of ten minutes at each station, providing initial preferences. Research has suggested acceptance should be measured over longer periods of use, allowing for familiarisation and more informed attitudes towards the device, which may be more predictive of actual use (~~52~~53). 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).

~~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

response numbers were low, as preferences were often evident through unprompted interaction.

~~A further consideration with the current study is that the sample of older people was recruited from a retirement complex. While this recruitment strategy allowed insight into this sample, the generalisability of these views to care home residents is limited. The larger-scale study of the same nature has been conducted within a range of care homes to address this issue. The current research does however suggest there is acceptability of such devices among a more independent sample. This is in contrast to previous research which implied more independent older people felt 'too able' to use robots (28). Thus, there may be a market among this more independent sample that has previously been underestimated.~~

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

Conclusion

~~This study has~~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 ~~the gravity of its~~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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Data Sharing

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

https://osf.io/kps2w/?view_only=12ec0a445086403db685c3b41e1e3127

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Figure Legends

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

Figure 2: Interaction Station 2

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

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