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

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Abstract

Background:

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

Methods

Seventeen older people 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 infantilizing. 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 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, 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 by older people, while Paro was preferred by roboticists.

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 process.

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. Assistive robotics, which can be classified as rehabilitation and social robots (7), could help in this respect and alleviate this pressure on health and social care resources (3).

In this paper, we consider companion robots – a subset of social robots often designed congruent with animal aesthetics and behaviours (7, 8). A prominent example of a

companion robot is Paro, the robot seal (9). Research has suggested numerous benefits of interacting with Paro, including reduced agitation and depression in dementia (10, 11), more adaptive stress response (12), reduced care provider burden (12), and significantly improved affect and communication between dementia patients and day care staff (13). Further research has suggested Paro may reduce psychoactive and analgesic medication use (14), and even decrease blood pressure (15). 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. (19) found no significant improvement for depression (seeing a significant decrease only for loneliness). 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 as, for example, its vocalisations can be distressing (21). Moyle et al. (22) also found considerable variation in responses to Paro in a large randomised controlled trial (RCT).

While this disparity may be due to 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 has both shown good acceptability (23), and found that it encouraged less interaction than a soft toy (24), while

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, 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 differ between varied groups of end-users, for example those with physical impairments (29), children (30), or older people, thus research is required specific to the aim of each robotic system. Generally, Integrating user requirements and experiences into design can be difficult (29). Similarly, 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.

There currently appears to be little known about how older people perceive robots (31). One exception is a study that explored meaning behind robotic pets with 41 independent older adults (32). Results suggested robotic pets could provide social entertainment and interactions, 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 available companion robots. A limitation was the use of unfamiliar, often brightly coloured child-orientated pets, providing a limited range of features for older adults to 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 involved at all, it is usually through care providers, and at the end of the design process (32).

In this paper, we therefore seek to investigate any notable differences in opinion between 'robot-users' and 'robot-creators' about the design of companion robots for older people, and in doing so, provide some initial insight into older peoples design requirements for companion robots. This evidence of different perceptions between designers and end-users may also help persuade designers of 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.

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 housing 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). 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.

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

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

Station	Animal robot/toy	Range of features for comparison
1 – All soft-fur, differing levels of interactivity, familiar and unfamiliar options	Paro	<ul style="list-style-type: none"> • Unfamiliar • Not life-like • Interactive • Animal noises • No life-simulation • Soft-fur
	Joy for All dog	<ul style="list-style-type: none"> • Familiar • Life-like • Interactive • Animal noises • Life-simulation (heart beat) • Soft-fur
	Joy for All cat	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Unfamiliar • Not life-like • Interactive • Non-animal noises • No life-simulation • Hard-shell
	Pleo rb	<ul style="list-style-type: none"> • Unfamiliar • Not life-like • Interactive • Non-animal noises • No life-simulation • Soft-plastic shell
	Perfect Petzzz Dog	<ul style="list-style-type: none"> • Familiar • Life-like • Non-interactive • No noises • Life-simulation (breathing) • Soft-fur
3 – Mythical, unfamiliar option, human speech, completely inert option. Personalisable option.	Furby	<ul style="list-style-type: none"> • Unfamiliar • Not life-like (mythical) • Interactive • Non-animal noises (speech) • No life-simulation • Soft-fur
	Hedgehog	<ul style="list-style-type: none"> • Unfamiliar • Not life-like • Non-interactive • No noises • No life-simulation • Soft-fur

features of interest to ensure relevance with end-users as opposed to care providers.

Following completion, participants were debriefed.

Table 1: Key questions used to guide focus group discussions

Key Questions
<ol style="list-style-type: none"> 1. Which of the animals did you prefer? What is it about that animal that makes you like it? 2. Thinking of designing a new robot for older people, what possibilities and properties should a suitable pet robot have? (e.g. Look, feel, abilities) <ol style="list-style-type: none"> 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 <i>not</i> have? 4. How do you feel about a companion robot speaking? And have 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?

Robots starting positions at each station were randomised, from left to right, to avoid introduction of bias, Figure 2 shows an example interactions 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 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.



Figure 2: Interaction Station 2

Materials

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

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

Interactivity

The theme of interactivity emerged on 185 occasions through the codes: *interactivity*, *speech and talking*, *commanding the robot*, *fun*, *noises* and *interactivity lacking*. This theme strongly suggested 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 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. 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 be “*looking right at*” the participant (OP2, OP4, OP13, OP17). Most frustration was seen 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. On 11 occasions, participants confused the noises 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, 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, *"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 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, 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 reporting 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 suggested older people preferred soft, furry companion robots, but also favoured big eyes. Participants did prefer features making animals appear more realistic, although this is 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 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 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 a live animal occurs with possession, and has been shown in research to relate to 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 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*” (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 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 the number of older people and roboticists providing positive, negative or non-responses for each feature and the resultant level of difference or agreement

		Interactiv-			Person-			Life sim-	
		ity	Soft Fur	Talking	alised	Realistic	Familiar	Mythical	ulation
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
Roboticians 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 in opinions were 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 generally older people were more positive towards life simulation and more negative towards mythical design. Some participants did not respond to every feature, resulting in lower numbers of re-

sponses for some features. Table 2 shows familiarity, life-simulation and mythical design received lower responses, this could suggest these features were less important, and thus participants felt less inclined to comment. However, this could also represent the semi-structured nature of the focus groups, and that realistic, familiar or mythical design were all discussed in relation to key question 10.

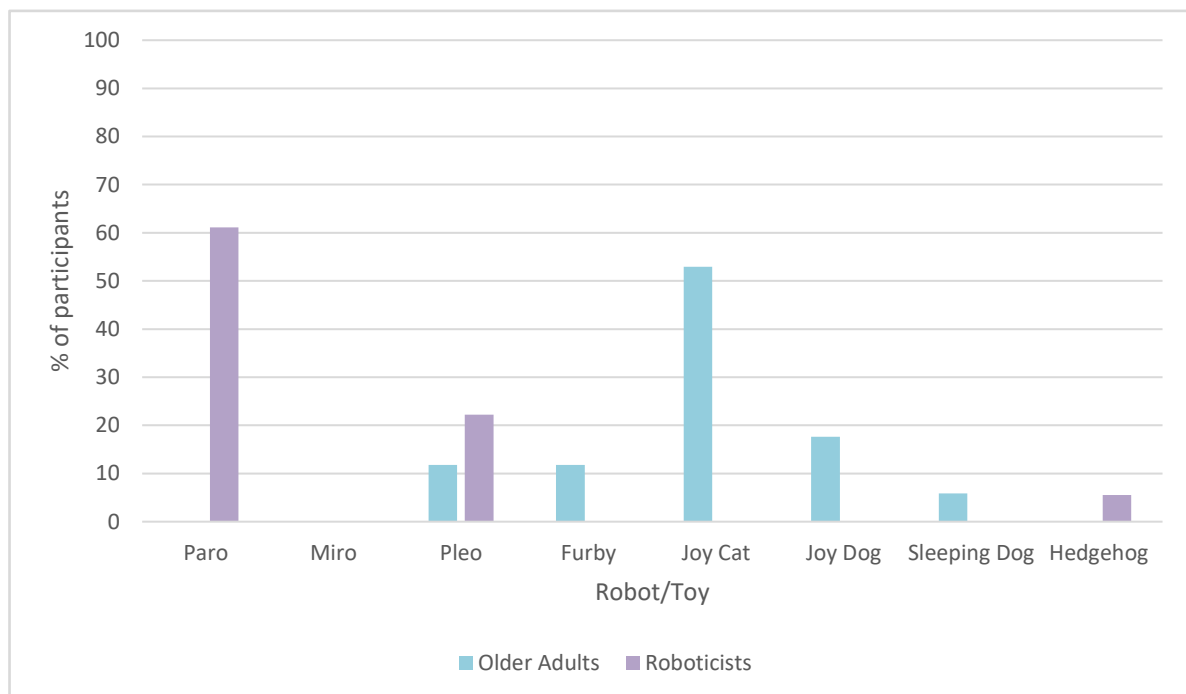


Figure 3: Choice of robot/toy for use with older people, shown by participant group

The most preferred animal among older people was the Joy for All cat, with 9/17 (53%) participants selecting this animal (figure 3). 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 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 robot-icists.

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

Theme	Example Evidence	
	Older People	Robotocists
Interactivity	<p>“If you’re sat there on your own, you want some reaction” (OP6)</p> <p>“That one [Joy for All cat] is almost perfect, but perhaps if you could say, do you want to play, and then it could then do something, a little bit more interactive” (OP13)</p>	<p>“I think something passive, that doesn’t make a lot of sounds, it could be stressful, too much [sic] You could have a sack that’s warm and purrs” (R3)</p> <p>“I think it should have high level interaction, because it would keep the interaction longer as well, if you just have a pet like this with one or two features, it’s done, it’s limited” (R9)</p>
Soft fur	<p>“Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder” (OP5)</p> <p>“Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle” (OP13)</p>	<p>“I don’t think so, because it isn’t cleanable, if you wanted something to cuddle you could just buy a stuffed toy” (R14)</p> <p>“Nice and furry, you could kinda cuddle it” (R18)</p>
Talking	<p>“[animals] don’t talk, there are sounds that creatures make” (OP6)</p> <p>“For older people living on their own in particular, we all talk to ourselves anyway, you don’t feel so stupid if you talk to something that responds to you” (OP13)</p>	<p>“from a technological point of view, speech should be left out of the equation, especially with elderly people, and people with dementia, they wouldn’t have expressions or fully structured sentences which would get frustrating if the robot didn’t understand” (R1)</p>

		<p>"I can see the appeal, [sic] a rudimentary conversation might be quite nice, as long as you didn't feel like a twit doing it" (R11)</p>
Personalisation	<p>"If it was knitted, it wouldn't be able to move its eyes and mouth" (OP5)</p> <p>"It's quite a good idea, yeah I do, someone who's got a particular animal"</p> <p>"We were talking about colours, I like that one, she's always had black cats, it would be nice to have a choice of different colours" (OP13)</p>	<p>"That might ruin the illusion I'd say" "if you've eaten like a chicken, if you've seen the actual process, you would not feel so good about it [sic], when you see the finished product without knowing how, it's sometimes better" (R2)</p> <p>"It would be amazing, it would give it a personal touch, it's like having a new [smartphone] and getting a new cover, people love that" (R10)</p>
Realistic	<p>"For someone who's always had animals, they feel that loss, so for them, something realistic that they could interact with" (OP1)</p> <p>"as long as it's got big eyes and attractive I don't mind" (OP17)</p>	<p>"It would make more sense" (R1)</p> <p>"No [sic] if it's not realistic, you wouldn't be hoping it would be a real dog so" (R16)</p>
Familiarity	<p>"because they [cat and dog] are more domesticated animals, whereas a seal you wouldn't have a seal in your home" (OP1)</p> <p>"I think if you'd had a cat or a dog, it would be better to have something you could relate to" (OP12)</p>	<p>"for the elderly it should be something familiar" (R2)</p> <p>"I think because of uncanny valley it doesn't have to be something that we are used too" (R7)</p>
Mythical	<p>"That's a generation thing, kids would love it but not here" (OP1)</p> <p>"Maybe in five years time.." (OP16)</p>	<p>"I also think something super unrealistic like the Furby would be creepy as well, it's so bizarre you could be turned off by it, it's weird, a baby seal, you're not accustomed to the animal so whatever it does is just cute" (R8)</p>

		“The mythical Furby looks right because you’ve got no expectations, so you cannot do it wrong, you cannot break expectations” (R13)
Life simulation	<p>“Warmth under belly to keep your knees warms!” (OP1)</p> <p>“If it was breathing, it would be almost a real cat, and again, it’s a soothing thing” (OP14)</p>	<p>“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)</p> <p>“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)</p>

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 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.

Themes from older peoples
unprompted free interactions

Themes from focus groups

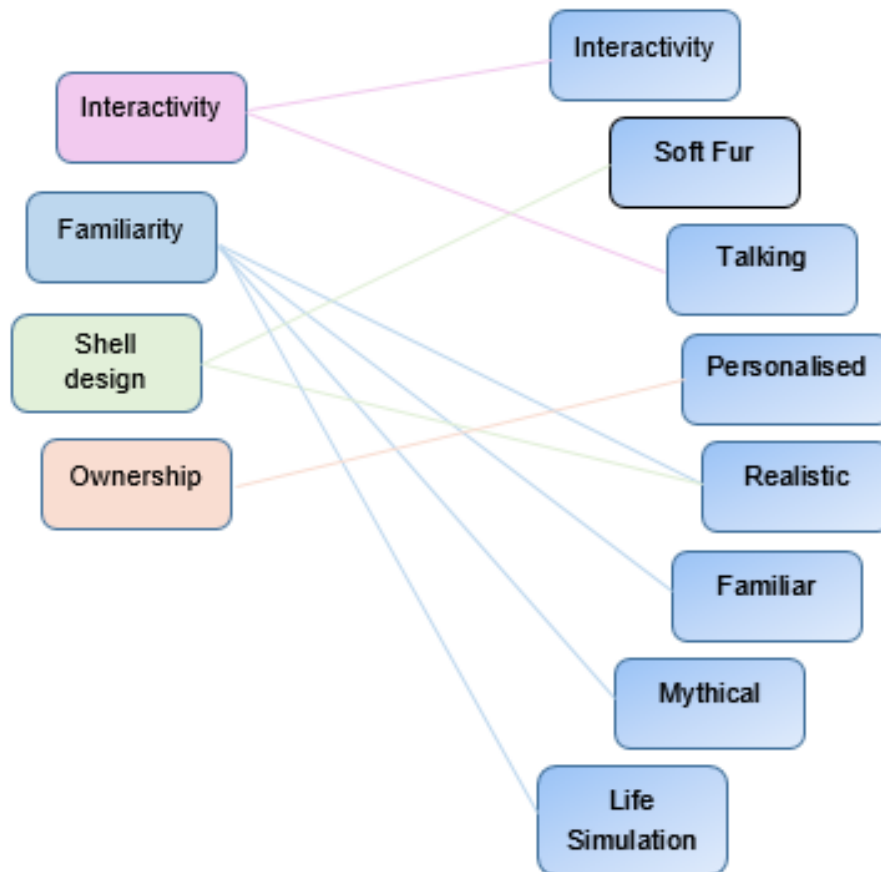


Figure 4: Mapping the relationship between older people's unprompted opinions and focus group themes.

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 devices 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 supports the focus group theme of talking, where 12/17 (71%) older people felt positively towards robot speech.

The 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 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 could alternatively be suggested participants did not necessarily distinguish between realistic and familiar, as realistic, unrealistic and mythical were the words used within the Key Questions.

The shell-type theme, and clear preference for soft fur during older peoples' free interactions, is 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 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 feature 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.

Personalisation 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 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 cited as beneficial (4, 26); however the extent of its use in companion robot development is currently minimal. This study has demonstrated, through direct comparison, the importance of implementing user-centred design in the development of companion robots targeted at older people, due to large differences in design preference between end-users and potential developers. The results therefore justify additional effort for the reportedly difficult process of integrating user requirements into design (29), and may aid with 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 min-

imal use of this process. However, rather than damaging illusions, adopting user-centred design may actually ensure devices receive adequate acceptability to promote use (25, 39). Future development of robots utilising a user-centred approach 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 the reported potential benefits of companion robots for older people, those with dementia and their family and care team (10-15). Results of our study would 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 lack of available companion robot comparison studies (40) and apparent selection bias towards Paro in research (9). Further to highlighting the value of user-centred design, this study provided initial insight on end-user design requirements.

Regarding robot abilities, older people strongly preferred an interactive device, for the purpose of providing companionship, fun, and reducing loneliness through responsiveness. Interactivity was also a strong preference for our group of roboticists, however some 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 responsiveness of Paro may be unnecessary. Despite having fewer technological abilities, the Joy for All cat was perceived as most interactive. This appeared to result from a 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 older adults had continuous interest 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 (41) who 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, 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 (42). 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 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 (43). Komatsu and Yamada (44) demonstrated participants relate 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. While this would suggest animal sounds would be most acceptable for animal robots, our results indicated positive attitudes towards speech capabilities for provision of company. Frennert and Ostlund (33) found 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 results be replicated in wider samples. It is possible, however, that this feature will be evaluated differently 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 when robots failed to look towards the user. Gaze following may increase social relevance of the robot. This may be particularly true when eye movement is intentional rather than random (45). While the

pre-programmed movements of the Joy for All cat were positively evaluated, intentional gaze following would perhaps be an improvement for optimal social companionship. de Graaf et al. (46) noted the importance of improving sociability for robot acceptance, and therefore this addition of apparent social behaviour could improve acceptability further.

Regarding the outer shell, most older people preferred soft, cuddly fur. Our group of roboticists generally agreed, although both groups raised concerns regarding hygiene in comparison to a hard shell. This corroborates previous findings that care providers preferred soft, cuddly fur on robots aimed at their older service users (34, 47). On the contrary, other results have reported older people's preference for mechanical design on a robot (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 implied a robot should indeed be recognisable as robotic (28). Robinson et al. (21) also reported a family member demonstrating stigma towards his father interacting with soft-toys, suggested a potential gender barrier 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 companion robots aimed at this market. 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 (47), 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 (47) 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. Previous research focusing on opinions of care providers revealed criticism towards Pleo for lack of familiarity (34). In contrast, the intentionally unfamiliar Paro (42) is the most often utilised companion robot in research (9), and research on older adult perceptions towards robot pets did not produce familiarity as a result (32), however this may result from the lack of familiar options available for comparison. The end-users in our research suggested that, additionally to Pleo, Paro was also considered too unfamiliar. The strongest preference was seen towards the most familiar animals, the Joy for All cat and dog, for being more relatable and congruent with the contexts in which older people lived. The unfamiliar forms appeared incongruent and infantilising, perhaps ex-

plaining the tension Lazar et al. (32) noted 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) to avoid negative schemas, or the robot failing to meet expectations (42). Research suggested older people complained about the feel and behavior of a robot cat in comparison to real cats (48). However, this initial research was conducted 19 years ago, and it is therefore likely that currently available robotic cats are more realistic than the Tama OMRON Corp cat available at the time. The majority 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 (42), and unsurprisingly selected Paro as their preferred companion robot. It is likely the roboticists appreciate the advanced technical capabilities of Paro, but this study would suggest 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 (42), this theory seems to resonate poorly with end-users, having potential negative impact on preference.

The preference for realistic and familiar robots may result from relatability, with older people perhaps having personal experience of cats and dogs, due to prevalence of ownership of these species (49). 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 (42), 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 (50). Reminiscence therapy uses memories, feelings and thoughts from the past to facilitate pleasure (51). 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 (52). This is not surprising given their field of interest, and it is possible the uncanny valley theory and related literature had influenced roboticists' perceptions on robot design, 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 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 is however longer than, for example, previous research, where participants only interacted with each robot for one minute (34).

We did also use smaller group sizes than 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 use of qualitative, free interaction transcriptions also increases confidence in 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, 47). 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

This study has 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 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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