Morphology of socially assistive robots for health and social care: A reflection on 24 months of research with anthropomorphic, zoomorphic and mechanomorphic devices

Hannah L. Bradwell, Rhona Winnington, Serge Thill and Ray B. Jones

Abstract - **This paper reflects on four studies completed over the last 24 months, with social robots including Pepper, Paro, Joy for All cats and dogs, Miro, Pleo, Padbot and cheaper toys, including i) focus groups and interviews on suitable robot pet design, ii) surveys on ethical perceptions of robot pets, and iii) recorded interactions between stakeholders and a range of social robots. In total, up to 371 participants' views were included across the analysed studies. Data was reviewed and mined for relevance to the use and impact of morphology types for social robots in health and social care. Results suggested biomorphic design was preferable over mechanomorphic, and speech and life-simulation features (such as breathing) were well received. Anthropomorphism demonstrated some limitations in evoking fear and task-expectations that were absent for zoomorphic designs. The combination of familiar, zoomorphic appearance with animacy, life-simulation and speech capabilities thus appeared to be an area of research for future robots developed for health and social care.**

I. INTRODUCTION

One research area in Human Robotics Interaction is how best to support health and social care (H&SC) [1]. The H&SC sector is experiencing increasing pressure worldwide [2], with greater requirement for services [3] exacerbated by declining H&SC workforce numbers [4]. The use of assistive robotics as a supporting strategy has thus gathered particular interest [3]. In this paper, we are specifically interested in application of socially assistive robots (SAR) [5], robots designed to meet social and psychological needs [6], which have demonstrated promising health and wellbeing benefits [5]. Optimum design of such devices is however a source of debate, with aesthetic and behavioural features likely to impact device acceptability and thus ultimately use [7-9]. As noted by Fong et al. [10], embodiment and morphology helps establish social expectation, and will bias the subsequent interaction.

One aspect under discussion is the inclusion of natural features or characteristics of biological systems, so-called biomorphic design [11]. Such devices might, for example, have potential in evoking emotional and empathetic human responses [11]. Specifically, anthropomorphism is the attribution of human-like qualities and form to non-human objects [12], including physical appearance, movements, behaviours and speech [13]. Similarly, biomorphic devices may have features of biological origin, such as animal ears or noses [8], while zoomorphic devices may be completely identifiable as a known animal [2]. While unrealistic animal devices have been referred to as zoomorphic previously [8], here we distinguish between realistic and unrealistic animal forms, to best understand optimal morphology and explore any difference between realistically representing animal-form and simply including biological features on an otherwise unrealistic device. Biomorphic designs may create an intuitive interaction, which may relate to the biophilia hypothesis [14], which posits an innate inclination to affiliate with nature and living things [15]. Familiar cues may assist social robots in their specific purpose, creating social interaction, as humans are social agents attuned to interaction [16]. This may be particularly relevant in eldercare, as older people may feel anxious in the presence of a machine [17]. However, these designs face challenges such as an "Uncanny Valley" response [18], capability expectations [12], and ethical concerns, for example, on deception [19]. Mechanomorphism, meanwhile, is design congruent with mechanical, machine qualities [8].

In this paper, we consider the impact of a range of morphological designs and provide a comprehensive discussion based on evidence accrued with anthropomorphic, zoomorphic and mechanomorphic devices. In particular, this is in contrast with studying anthropomorphism in isolation, which limits understanding of the impact of this design method over alternatives. Previous anthropomorphic research has neglected to include such a spectrum of designs. One such example is the work of Salem et al. [13] who investigated impact of non-verbal gestures on perceived anthropomorphism. Participants perceived greater human-likeness, likeability, shared reality and future contact intentions when the robot made intentional mistakes in gesturing. This could support the role of empathy in successful human-robot interaction. However, further exploration of anthropomorphism and empathy is required, as empathy is also implicated in the Uncanny Valley theory [18], which suggests humanlike robots can evoke positive and empathetic emotional responses from human users, until a point is reached in the design being too humanlike (without being human), where response becomes intense repulsion [12]. This therefore identifies a potential issue of anthropomorphic design, where a balance is needed between evoking empathy or creating repulsion, and thus hindering interaction. Further concerns arise around expectations, as humanlike features may create expectations of unachievable

H.B & R.J.: EPIC Project, Centre for Health Technology, University of Plymouth, Plymouth, UK, hannah.bradwell@plymouth.ac.uk, 07975927341, ray.jones@plymouth.ac.uk. RW: Department of Nursing, Auckland Univ. of Technology, NZ, rhona.winnington@aut.ac.nz. ST: Donders Centre for Cognition, Radboud Univ. NL, s.thill@donders.ru.nl.

task capabilities [12]. It is possible zoomorphism as an alternative avoids this issue, lowering expectations as human-animal relationships are less complex than human-human relationships [10]. Discussion of zoomorphic versus anthropomorphic devices is therefore warranted.

While taking account of various designs is important, so too is considering the spectrum of stakeholders. Understanding optimum design based on perceptions of target users is essential, as devices must be accepted by those intended to use them [7,8,9]; yet perceived requirement for support can vary across H&SC stakeholder groups [8]. Understanding reasons for acceptance and rejection from a range of relevant stakeholders [3] would thus allow better informed robot design. Previous research has explored aesthetics with relevant H&SC stakeholders; for example Pino et al. [20] explored SAR acceptance among healthy older adults, older adults with mild cognitive impairment and informal carers. Robots discussed included human-like, mechanical human-like, android, animal-like and machine-like. Results suggested mechanical human-like design was preferential, although this meant some inclusion of anthropomorphism, it was felt robots should indeed be recognisable as robotic. Least preference was found for human-like and android aesthetics. However, the sample size was relatively small (25 participants), and there was interaction with only one robot (Robulab 10), while others were demonstrated via booklet or PowerPoint. This lack of opportunity to appreciate all design aspects through direct interaction may have limited participant ability to provide fully informed opinions [21]. The results of Heerink et al. [22], somewhat contrast Pino et al. [20], with 36 care home staff suggesting 'looks like a real life pet' as required for a robot pet. This would support realistic zoomorphism, however, this study only considered one stakeholder group (care staff), and only zoomorphic devices, perhaps explaining the drift in preference from recognisably robotic [20].

While zoomorphism may negate issues of expectations, this design method has been heavily criticised for issues of deception. Some authors suggest designing robots to be perceived as animals is unethical, with beneficial use relying on delusions as to the real nature of the interaction [19]. This is particularly relevant for social robots aimed at those with dementia [23]. Considering challenges faced with both anthropomorphic and zoomorphic design, a possible alternative is use of animacy, that is, use of autonomous movement to evoke emotional response, even to objects or items as simple as geometric shapes moving on a screen [12]. Thus, there may be an argument for robots with mechanoid design, but employing animacy in order to evoke the empathetic response required for social interaction. Linked with animacy is the use of life-simulation features, including breathing, warmth, heartbeat [24], and any other feature indicative of 'being alive.' In contrast to conscious movements and speech, these features are involuntary, physiological expressions that may increase perceptions of a device being alive [25].

Overall, thus, although embodiment, morphology and anthropomorphic design have been extensively studied [7], there is difficulty in drawing general conclusions, with contradictory findings, and individual and contextual variables impacting any broad understanding. In this paper, we discuss how different morphological designs (anthropomorphic, zoomorphic and mechanomorphic) may be perceived by H&SC stakeholders based on evidence from four studies with such devices. Our research contributes to a broader understanding of design impact on perceptions of H&SC stakeholders and goes beyond the scope of previous work largely focused on anthropomorphism alone.

II. METHODS

For this reflective work, we (re)analysed data from four of our studies on companion robot acceptance for insights relevant to morphological design. Two studies (1&3) have been published already albeit with a different focus, with the remaining two (2&4) providing novel material. The previous analysis and reporting of studies 1 and 3 focused on the results attained, whereas this paper will focus on morphology. Studies 2 and 4 are previously unreported. Data and results from all studies was therefore mined for insights into impact of morphological design. The selected studies provide views from a large range of H&SC stakeholders; professionals, students and businesses of relevant disciplines, service users, older people in supported living, care home staff and resident relatives.

A. Robots

Our studies included devices with varying degrees of anthropomorphic, zoomorphic, mechanomorphic features, human speech, life-simulation and animacy [12] (Fig. 1, Table 1).

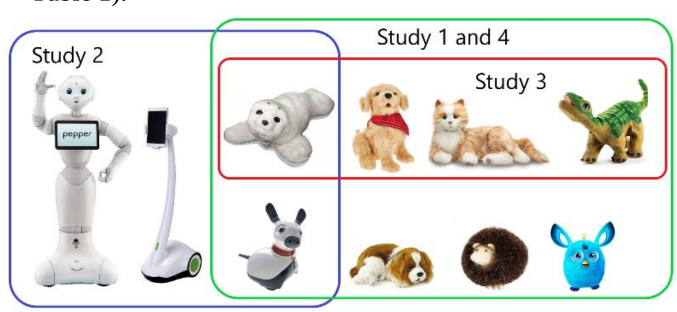

Figure 1: From left; Pepper, Padbot, (top) Paro seal, Joy for All dog, Joy for All cat, Pleo rb dinosaur, (bottom) Miro, Perfect Petzzz breathing dog, Knitted Hedgehog, Furby

	Pepper	Padbot	Paro	Joy for All Dog	Joy for All Cat	Pleo rb	Miro	Perfect Petzz Dog	Hedgehog	Furby
Biomorphic	✓		✓	✓	✓	✓	✓	✓	✓	✓
Anthropomorphic Humanoid	✓									
Zoomorphic			✓	✓	✓			✓	✓	
Animacy	✓	✓	✓	✓	✓	✓	✓			✓
Mechanomorphic	✓	✓					✓			
Anthropomorphic Speech	✓									✓
Life-simulation				✓	✓			✓		

Table 1: Robot features relevant to morphology and anthropomorphism

Table 1 includes the authors' perception of each device in terms of related morphological design. Devices which in some way resemble a biological form have been assigned a biomorphic categorisation. For this reason, realistic animals (e.g. Joy for All cat), and unrealistic 'animals' (e.g. Miro), are all categorised as biomorphic, for inclusion of features potentially perceived as biological in origin (e.g. rabbit-like ears on Miro). However, the zoomorphic category has been used only for devices realistically depicting known animals, for this reason, devices such as Miro, Furby and Pleo are excluded, lacking an embodiment that provides a realistic zoomorphic morphology, being cartoonish or mythical in design. Anthropomorphoc speech has been indicated for devices emmitting recognisably human words.

B. Studies Included

Study 1: Comparison of companion robot design preferences between older people and roboticists [24]. Design: Collaborative action research with key stakeholders. Aim: To compare perceptions of older adults (as end-users) and roboticists (as developers) towards suitable robot pet design for older people, to establish importance of user-centred design. Settings: One supported living complex for older adults, one robotics research centre event. Participants: 17 older people (5 male, 12 female, aged 60-99), 18 roboticists (10 male, 8 female, aged 24-37). Robots: Paro. Miro, Pleo, Joy for All Dog and Cat, Furby, Hedgehog, Perfect Petzzz dog. Procedure: Older people and roboticists separately interacted in groups of between two and four with eight companion devices with varying degrees of biomorphism. Robots were displayed on three tables (with 2-3 robots on each table), with participants spending 10 minutes at each table. Free interaction was encouraged, with researchers present to answer questions. Data collection: Interactions were filmed and participants subsequently shared design perceptions in focus groups which were also recorded. Focus group questions included; favourite animal, reason for preference, required features for a new companion robot, features to avoid, thoughts on appearance, life-simulation and feel. Data analysis: Interactions and focus groups were transcribed and analysed with content analysis.

Study 2: Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions (previously unreported). Aim: To explore acceptability and design requirements of social robots among decision makers and implementers in health and social care, as 'higher-level' acceptability of social robots is required for the purchase, implementation and maintenance of devices, prior to specific enquiry with direct end-users. Settings: Eight eHealth events across Cornwall, South West England. Robots: Pepper, Miro, Padbot, Paro. Participants: 223 H&SC stakeholders including 108 professionals, 34 service users, 24 students of relevant disciplines, 20 related businesses, and 37 who did not declare their category. Procedure: Events involved 40 minute technology exhibitions where participants could engage in free interactions with two zoomorphic robots, one humanoid and one mechanomorphic telepresence robot. Data collection: Interactions were filmed. Data analysis: Audio of interactions was transcribed and analysed using content analysis. Acceptability was assessed through mapping of themes onto Almere Model constructs, full results were mined for data relevant for morphological design.

Study 3: Ethical perceptions towards real-world use of companion robots with older people and people with dementia: Survey opinions among family members [26]. Design: Cross-sectional survey. Aim: Ethical concerns on robot pet use have been discussed in literature, however limited work was available exploring ethical perceptions among relevant stakeholders, such as family members who may pose a barrier to implementation should ethical concerns be present. Setting: Robot interaction station at Science Gallery exhibition. Robots: Paro, Joy for All Cat and Dog, Pleo. Participants: 67 younger adults (average age 28, range 18-65, SD 10.99), most of whom had an older adult relative (53/67), some with a relative with diagnosis of dementia (11/67). Procedure: Stakeholders interacted with four robot animals with biomorphic features, before completing a survey of ethical concerns. Data collection: Surveys queried robot preferences, dislikes, likelihood to purchase, and degree of concern for; reduced human contact, carer convenience, privacy issues, inequality of access, deception, infantilisation and potential for harm. Data analysis: We mined the data from this study with the perspective of impact of embodiment on ethical perceptions, in order to explore and understand a potential barrier to real-world use.

Study 4: Care home management, staff and resident relative interviews (previously unreported). Design: Collaborative action research. Aim: To explore perceptions of stakeholders in the care of older adults towards design of robot pets. Settings: Five care homes. Participants: 29 care home staff, 10 resident relatives. Robots: Paro. Miro, Pleo, Joy for All Dog and Cat, Furby, Hedgehog, Perfect Petzzz dog. Procedure: Care home staff and resident relatives observed residents interacting with eight robot animals with varying levels of biomorphism, life-simulation or anthropomorphism (speech), before completing interviews.

Data collection: Interviews were filmed and questions included; favourite animal, reason for preference, required features for a new companion robot, features to avoid, thoughts on appearance, life-simulation and feel. Data analysis: Interviews were transcribed and analysed using deductive thematic analysis.

III. RESULTS

Study 1

We compared older adults and roboticists views towards companion robot design based on direct interactions, we focus here on older people's perceptions, although the full comparison is available [24]. With reference to animacy, the highly sophisticated responses of Paro were underappreciated by older adults, who felt the seal was *"on strike*," while preference was shown towards the Joy for All devices "*you've done more with that cat than I got to do.*" During focus group discussions, five older people responded positively towards life-simulation features, with no older people responding negatively. Animacy and life-simulation appeared to assist in preference, purring and breathing were discussed as *"soothing,"* and making participants "*feel comforted."*

Interestingly, despite Study 1 devices being mainly zoomorphic, older people expressed a desire for human speech, both during free interactions and focus group discussions. During free interactions, participants stated; "*talk to me good boy," "it's the company [...] I talk to the furniture! [...] if you live alone you often don't hear voices," "I like to talk to things [...] I think I just like to hear a voice*" and *"I wish you could talk, yes I wish you could talk."* The lack of verbal response from non-speaking robots was met with disappointment. During focus groups, 12 older people responded positively to inclusion of human speech, and five responded negatively. Responses suggest speech may answer an emotional need caused by loneliness and *"living on their own."*

With reference to embodiment, older people much preferred life-like, familiar, realistic forms. During focus groups, 12 and four older people responded positively to realistic and familiar design respectively, with one and zero responding negatively. Life-like, realistic, zoomorphic design appeared superior in invoking emotional responses, particularly through prompting reminiscence of previous pets that older people *"feel that loss"* of. The familiar zoomorphic forms allowed older people to feel they could better *"relate"* to devices, while mechanoid or mythical devices (Miro, Furby, Pleo), were perceived as infantilising*; "a toy," "suitable for a child."*

Summary:

- Older people preferred realistic, familiar, zoomorphic design over mechanomorphic or mythical.
- Older people were open to speech, an anthropomorphic feature that may encourage social interaction, even when contextually misplaced in a zoomorphic embodiment.
- Older people responded well to animacy and life-simulation, with features increasing the life-likeness of devices provoking engagement and positive discussion.

Study 2

We analysed interactions of H&SC stakeholders with a range of robots and mapped our subsequent themes onto Almere Model constructs [9] to assess acceptability of various robot designs. We then mined full results for insight specific to morphology. The Almere Model acceptability constructs impacted by anthropomorphic or biomorphic design were; Social Presence, Perceived Sociability and Anxiety. These were demonstrated through provision of evidence towards these themes in the transcripts of interactions.

Interestingly, we found evidence for the construct of Social Presence (sensing a social entity), for all three devices with biomorphic design, including anthropomorphic Pepper, zoomorphic Paro and mechano-biomorphic Miro, while no evidence for Social Presence was found for the completely mechanomorphic Padbot. Despite the apparent animacy Padbot presents (appearing to move autonomously), the lack of biomorphic features appeared to drastically reduce perceived Social Presence. In contrast, biomorphic devices evoked empathetic responses*; "are you [Miro] having a bad day?" "Pepper are you happy?" "[Participant squeezes Paro's flipper, Paro vocalises] Oh no! He didn't like that" "[witnessed flipper squeeze] did you just nip him then!"* Such responses were recorded 17 times. There were also 89 counts of participants gendering robots, compared to 35 counts of objectifying. Interestingly, gendering again only occured in reference to biomorphic devices; *"he [Miro] loves me," "he [Pepper] is dancing," "I want to hug him [Paro],"* while mechanomorphic Padbot received no evidence of gendering; *"it [Padbot] is amazing."* The descriptions applied to Padbot, while positive, were more functional than emotional, relating to ability. The biomorphic devices were far more capable of invoking empathy and emotional responses such as *"love,"* and appeared more engaging and interesting to participants.

For the construct of Perceived Sociability (ability for a system to perform sociable behaviour), we found positive regard for the verbal communication abilities of Pepper. Despite comprehension, appropriate response and voice recognition issues, participants enjoyed conversing with Pepper; *"he's very polite."* Mistakes in Pepper's speech and responses were actually perceived positively, and perhaps endearingly, often met with laughs, humour and empathy. For all three biomorphic designs, participants interacted in a manner indicative that they believed the robot understood them, talking to them, commanding them and engaging as you would a living entity; *"be a good boy [Miro]."* However, there was no evidence for Perceived Sociability for Padbot, the mechanoid.

Of further interest, of all robots involved, evidence of Anxiety presented only towards Pepper, the only anthropomorphic humanoid present. This anxiety in part resulted from fear of damaging the robot, potentially due to the perceived expense of such a device. However, there were additional incidences of fear and distrust towards Pepper such as *"it's worrying to have a conversation with a robot," "what springs to mind is that sci-fi movie, taking over the planet, going rogue [sic] making mistakes [Pepper]," "spooky eh?" "I'm almost kind of scared of it," "it's just too fast, technology is too fast these days," "old parents, they will freak out," "Pepper is scary, no it's cute, I have to get used to it.. if you turn the lights out I'm not sure," "you could have nervousness about interacting with him," "I couldn't touch it," "it's a bit too scary I can't"* and *"I was a bit cautious."* In total, there were 16 counts of fear presented towards Pepper, and zero for any other device. Hesitation was demonstrated towards Pepper, who appeared to encourage less physical engagement than Paro or Miro, but more than Padbot. Pepper also received a limited number of comments suggesting additional task expectations, which were not expected of the zoomorphic or mechanomorphic forms; *"my friend said can he do the hoovering?" "a cup of tea?" "hoovering?"*

Summary:

- Biomorphic design (including both anthropomorphic/zoomorphic) increased the Social Presence of a device, increasing incidences of emotional response and interaction, while mechanomorphic design created function-based response.
- Biomorphic design appeared more important than animacy, as despite apparent animacy, Padbot did not evoke the emotional response achieved by biomorphic devices.
- Biomorphic design made gendering much more likely to occur.
- Speech was positively evaluated, and mistakes were met with empathy and humour.
- There was some evidence that anthropomorphic design increased task expectations more than zoomorphic or mechanomorphic.
- Biomorphic design appeared to strongly enhance Perceived Sociability, and encouraged engagement as a result, with participants more likely to interact with a device as they would a living entity than for devices without biomorphic features.
- Mechanomorphic and zoomorphic designs were superior for avoiding negative fear/anxiety, which was present for the anthropomorphic device.

Study 3

Study 3 focused on ethical implications of robots designed with life-like qualities, of particular relevance is the suggestion zoomorphic (or indeed anthropomorphic, although there was no anthropomorphic device on display), can create deception and be infantilising. These are embodiment concerns often cited for robots used with older people. We directly assessed prevalence of these concerns among stakeholders, surveying level of concern towards robots for; reducing human contact, being deceptive (appearing like animals when they are not), being infantilising, being used for carer convenience, causing injury or harm, impacting privacy or having impaired equality of access due to cost. Infantilisation and deception are the ethical concerns most associated with robot embodiment. On a scale of 1 (not at all a concern) – 7 (very much a concern), infantilising and deception received mean scores of 3.45 (SD 1.70) and 3.44 (SD 1.61) respectively, being ranked as less of a concern than equality of access (M=4.72, SD=1.75) (due to robot costs and socioeconomic status) and robots being used for carer convenience (M=3.98, SD=1.58) . It would appear the use of zoomorphic embodiment did not form a barrier to use on ethical grounds, with the majority of participants reporting they would purchase a device for older relatives (58%).

Summary:

- Deception and infantilisation with zoomorphic design did not appear to be the most important ethical issue for younger adults as stakeholders in older relatives care.
- The Joy for All cat was chosen most often as the device participants would purchase purchase for an older relative.

Study 4

Care home managers, care staff, activity coordinators and resident relatives discussed companion robot design for care home residents, after observing residents interacting with a range of devices. One feature discussed was inclusion of speech, an anthropomorphic characteristic. Results were mixed, some stakeholders felt it could be beneficial; *"it shows social interaction, communication is very important," "they [residents] might be able to express their feelings more."* Furby was very engaging, and this appeared to result from use of human speech, which prompted seemingly automatic responses from not only residents but also cognitively intact staff and family members. The mythical, colourful design of Furby was disliked, seeming *"like a child's toy,"* but the speech ability appeared to mitigate issues in design. Cognitively intact staff couldn't resist engaging with the speaking Furby, even halting discussions with the researcher to respond to the device; Furby: *"Electric sheep!"* Staff member: *"oh! Electric sheep, never heard of that before [laughs]."* The interaction appeared to be pleasurable and promote laughter, despite Furby speaking nonsense. Others felt the practical issue of deafness in older age would impair usefulness of a speaking robot; *"deafness is a huge problem," "a lot of them [residents] are deaf or struggle to understand."* Some staff and family also noted that speech from an animal may be *"confusing"* or *"weird"* due to contextual incongruence, with animal appropriate sounds seen as more appropriate.

Participants also discussed morphology. Strong preference was demonstrated for familiar, realistic, zoomorphic design; *"something they're used to."* Use of unfamiliar forms, bright colours, or unrealistic design were all seen as infantilising; *"for children, the ladies may feel offended if they think it's something for a child, but they're all open to soft animals."* The zoomorphic animals again appeared to prompt the most empathetic response, staff members reported that residents spoke to zoomorphic devices, asking *"oh what's the matter darling,"* and were more likely to talk *"to the animals as if they were real."* Staff believed zoomorphic design better promoted interaction, perhaps more adequately activating a pre-existing interaction schema based on memories with live animals than mechanomorphic design; *"they are ready to treat them as natural beings."* In contrast to previous research suggesting stakeholders felt devices should be clearly robotic, our stakeholders felt older adults, with limited technology experience, would be *"put off"* mechanomorphic designs, being unsure how to engage, as they are with other *"technology they are not used to."* The use of animacy was highly praised, and particular praise was provided for life-simulation features such as *"breathing," simulated "warmth," "heartbeat"* and *"purring,"* potentially increasing the perception of the device being a social entity; *"it shows you there's a presence there."* Zoomorphic design was also spontaneously compared to anthropomorphism used in human-baby robots, and perceived as superior for acceptance across genders.

Summary

- There were mixed opinions on speech, which appeared engaging and entertaining, but split opinion in providing social contact or appearing confusing from an animal.
- Positive opinions on life-simulation, which may have increased social presence.
- Mechanomorphic devices may have invoked negative response in older people with limited technology experience, strong dislike for machinelike robots, and strong preference for naturalistic, realistic, zoomorphic form.

IV. DISCUSSION

Biomorphic design is preferred over a mechanomorphic one. The reported perceptions of up to 371 relevant stakeholders on SAR design for H&SC, in general, strongly support inclusion of biomorphic features. Anthropomorphic and zoomorphic designs appeared to influence human behaviour through better engagement and emotional/empathetic response, increasing perceived sociability, perceived social presence, tendency to gender and preference. Our results support avoidance of mechanomorphic design for SAR aimed at this market. Stakeholders additionally felt mechanomorphic appearance would negatively impact interaction for older people specifically, due to limited experience with technology, as suggested previously [17]. Technophobia is a known barrier with older people, who grew up without computers, and are now expected to accept a variety of new eHealth interventions [27]. Thus, use of SAR that is aesthetically distant from computers and machines is likely advantageous for older people.

Ethical concerns voiced by stakeholders differ from those in the literature. Of note, there were also no incidences of spontaneous ethical concerns reported among our large sample of stakeholders. Sparrow [19] suggested realistic animal aesthetics were misguided and unethical due to users needing to 'delude themselves' to interact with the biomorphic machines. Our Study 3 results suggested limited concerns among younger adults as stakeholders in older relatives care, who were more concerned about prohibitively high costs of robots limiting access than with infantilisation and deceit. There has been little prior work exploring ethical perceptions with relevant stakeholders previously, and further work will be required to explore incorporating user perceptions in ethical design. While ethical concerns did not pose a barrier to implementation for the participants in our study, further ethical analysis is required to explore the mismatch between ethicists and real-world stakeholders.

Speech is well received even when limited. The anthropomorphic feature of speech received support across the studies. Although some responses were mixed, the majority of opinions were positive. Interestingly, issues in conversational fluency with Pepper did not appear to impair acceptability. Rather, verbal mistakes appeared endearing and prompted empathetic responses from participants. This result is congruent with the finding of Salem et al. [13], that participants perceived greater human-likeness in a robot that made gestural mistakes. The squeals of Paro in response to rough handling also provoked comparable empathetic response. It appears the anthropomorphic characteristics of mistake-making and pain reaction induce empathetic responses from human users that increase tendency towards anthropomorphism. Both have an apparent positive impact on acceptability through evidenced engagement and enjoyment.

Anthropomorphic design is not a universal solution. Some limitations towards acceptability of anthropomorphic design were noted in comparison to zoomorphic design, with reference to evoking a negative emotional response (anxiety/fear). This response may impair device acceptability [9]. It could therefore be suggested that anthropomorphism is not always appropriate for user engagement. While biomorphic design in general does appear to cue familiarity and thus aid interaction [7,13,16], the anthropomorphic form appears occasionally to cue negative schemas of sci-fi humanoids. A further issue with anthropomorphic design previously cited is increased expectations [12]. We noted a few occasions of additional task expectations of Pepper. Life-simulation as a form of animacy also received support, being engaging and increasing perception of social presence. Generally, animacy has been suggested to deeply involve users emotionally [12], and thus may have provided a solution to invoking an emotional response and encouraging interaction without relying on anthropomorphism. However, our results demonstrate very little interest in Padbot (mechanomorphic design with animacy) over alternative products with biomorphic design. Padbot was responded to more as a product with useful application, while more emotion was elicited in response to biomorphic robots, which were treated as living beings and provided with genders.

Sociability. Perceived sociability of robots appeared positively responded to in our research, somewhat contrasting limited appreciation for social companionship reported previously by de Graaf et al. [28]. Further previous research also found discomfort of robot use for social tasks [29]. While some participants in our studies noted robots should not replace humans entirely, a concern highlighted in previous research [30], the overriding feeling across all four studies was of positive regard for socially assistive devices that could improve wellbeing and ease the current strain on resources.

Strengths and Limitations. A strength of this study is the large range of stakeholders and range of SAR and alternative devices considered. This provided perceptions based on informed comparisons between products with varying levels of morphological features, including humanoid anthropomorphism, zoomorphism, mechanomorphism, life-simulation and animacy, or indeed absence of such features. Our informed discussion of morphology for a particular target group, based on a large body of previous data, that was collected and re-analysed together for new intelligence, provides a novel and practical contribution. A limitation of the data analysis is that data was mined for the purpose of this paper, to provide understanding of morphology for this target group. It is likely evidence related to anthropomorphism appeared more relevant to the researcher than if this analysis had been conducted without a specific aim to explore perceptions of anthropomorphism. The devices included also provide such a range of variables (e.g. size, colour) beyond morphology, further work in this area will be required to explore these specific variables across devices with the recommended biomorphic design. A further limitation of this work is the lack of full-android devices considered, meaning we cannot contribute towards the Uncanny Valley debate [16], or on the impact of degree of anthropomorphism. However, reflection on the results would suggest the imagined purpose of the robot impacts the desired life-likeness, with robot pets likely to be more acceptable with life-like designs. The impact of Uncanny Valley perhaps then relates to memories, expectations and control. Perhaps people expect substitute pets to be familiar, triggering memories of real animals, while the purpose of telepresence or more general purpose humanoids is not to cue memories of living-beings they are substituting.

V. CONCLUSIONS

Due to interest in human-speech across the studies, and apparent lack of concern for contextual incongruence between animal-form and talking, it is possible a combination of the anthropomorphic feature of speech and zoomorphic embodiment would be an interesting area for future robot development and research, specific to H&SC. Although all biomorphic designs (anthropomorphic/zoomorphic/biomorphic) seemed to provide greater social presence, zoomorphic design (realistic animal form) appeared superior in avoiding negative fear response and task expectations. It would appear advantageous to avoid mechanomorphic design for this user-group, due to limited engagement and lack of emotional response. The combination of familiar, zoomorphic appearance, animacy, life-simulation and speech is an area for future social robot research for H&SC settings.

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