

2021

Exploring the Design, Use and Impact of Companion Pet Robots and Automata for Older Adults and People with Dementia

Bradwell, Hannah L.

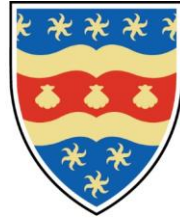
<http://hdl.handle.net/10026.1/17295>

<http://dx.doi.org/10.24382/1107>

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UNIVERSITY OF PLYMOUTH

Exploring the Design, Use and Impact of Companion Pet Robots and Automata for Older Adults and People with Dementia

by

HANNAH LOUISE BRADWELL

A thesis submitted to the University of Plymouth in partial fulfilment for the degree of:

DOCTOR OF PHILOSOPHY

School of Nursing and Midwifery

April 2021

Acknowledgements

I would first like to thank my Director of Studies, Professor Ray Jones, for taking a chance on me and giving me the opportunity to pursue a PhD. I have the most gratitude possible for Professor Jones, who has changed the course of my career and entire life for the better. I would also like to thank Professor Jones for his continual academic and personal support, guidance, teaching, expertise, and unwavering encouragement over the last few years.

I would also like to thank my supervisor Dr Serge Thill. Dr Thill has provided the invaluable quantitative, computational, mathematical and technological skills and expertise that my brain can struggle with, teaching me the true importance of cross disciplinary work, because in academia, researchers are only as useful as the skills in their 'circle' – not the skills they possess alone. Dr Thill has always been a provider of bright ideas, great discussion and speedy assistance.

My sincere thanks also goes to Dr Rhona Winnington, who has been a phenomenal giver of advice, guidance, qualitative expertise and emotional support. Dr Winnington always provided thoughtful and considered suggestions throughout our work, and helped me navigate data collection with vulnerable samples with a caring and person-centred manner. Dr Winnington continued to support me and my progression even from the other side of the world.

I have always said I could not have hoped for a better supervisory team, and this could not be truer, my supervisors are not only exceptional academics, but wonderful people, all bringing different viewpoints and ideas for a perfect mix of supervisory support. I will forever be grateful to my supervisors for all I have learned and gained from them, and without whom this thesis would not have been possible.

I would also like to thank my loving family, Mel and Oliver, for their love, patience, support and giggles through the stressful times, I love you both. Thanks also go to my wider family, for their love and encouragement on this journey. I'm also grateful to my friends, particularly Katie, Lauren and Josh, for always sticking by me. I cannot miss out my animals, my dogs Darcy and Evie, and cat Chiefy, for their kisses and nudges, and for forcing me to take breaks and get fresh air. Importantly, I would like to thank all of the collaborators and participants who made this work possible, particularly the older adults who shared their space, time and thoughts with me, some of whom are sadly no longer with us. And finally, all my thanks goes to God.

DEDICATION

Dedicated in memory of my Mother Michelle, Brother Luke and Aunt Linda. All most dearly loved and very sorely missed.

Luke Bradwell – 1996 - 2012

Michelle Bradwell – 1968 - 2018

Linda Bolton – 1959 – 2021

AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee. Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

Word count of main body of thesis: 80,000 (with tables/figures: 87,506)

Signed: *HBradwell*

Date: 17.04.2021

Abstract

Companion robots, socially assistive robots typically possessing zoomorphic features, have shown potential in the care of older adults and people with dementia. Previous research demonstrated reduced agitation, anxiety, loneliness and blood pressure for older adults, and reduced carer burden. However, many literature gaps and methodological flaws remained, and there was limited evidence of real-world adoption into health and care practice. In particular, most research involved Paro, the robot seal costing ~£5000, a prohibitive cost for most intended end-users. Furthermore, contradictory research results, robot failures and variable responses of older people suggested sub-optimal robot design.

This thesis therefore aimed to expand the knowledge base on companion robots for older adults, through collaborative action research, bridging the gap between research and practice with real-world benefit. The studies explored feedback in various settings from a collectively large sample of stakeholders essential for real-world implementation: older adults (with and without dementia), family members, care home staff and management, robot developers, health and care professionals and students. All types of stakeholder found companion robots acceptable. The value of user-centred design was demonstrated with significant differences between end-users and developers in perceptions of suitable robot design. Optimum robot design should include soft, furry, familiar, realistic embodiment, with large cute eyes, life simulation, lap-sized frame, interactivity and gaze direction and costing <£250. An effective infection control procedure was developed proven for bacterial infection of robot pets (with varying shell types), in care home settings. Ethical concerns on robot use, as reported in literature, were explored concluding that they were unlikely to pose real-world barriers. Finally, this thesis provides initial support that such affordable devices result in longer term wellbeing outcomes, such as reduced depression, anxiety and

agitation for older people. In conclusion, this thesis contributes knowledge on design, use and impact of companion robots for older adults, and the user-centred feedback has informed a new prototype robot pet.

Contribution to Knowledge

This thesis provides a comprehensive exploration of companion robot design, use and impact, with studies conducted within the United Kingdom and Ireland, focusing mainly on South-West England. The studies detailed in this thesis respond to identified literature gaps, and further previous work with methodological flaws. The studies focused on design have implications for future robot developments (in meeting user requirements more adequately and being more acceptable). The studies focused on robot use context will have implications for both future research and real-world implementations (in informing practicalities of robot affordability, robustness, battery life and required infection control procedures). The studies focused on impact of devices also have implications for future research and real-world implementations (in informing and supporting affordable and acceptable device selection with potential to improve wellbeing for older adults with widespread adoptions). This research has provided novel findings, from a total of 11 studies conducted using both qualitative and quantitative methods, resulting in 12 papers, eight of which have been published (or accepted/in-print), two manuscripts are under review and two are in preparation (summarised below).

Publications and knowledge dissemination

Published

1. Aguiar Noury, G.E., Bradwell H.L., Thill S, Jones R.B. (2019). User-defined challenges and desiderata for robotics and autonomous systems in health and social care

settings. *Advanced Robotics*, 33(7-8), 309-324.

<https://doi.org/10.1080/01691864.2019.1599728>

2. Bradwell, H.L., Edwards, K.J., Winnington, R., Thill, S. & Jones, R.B. (2019). 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. *BMJ Open*, 9(9), e032468.
<https://doi.org/10.1136/bmjopen-2019-032468>
3. Bradwell, H.L., Johnson, C.W., Lee, J., Winnington, R., Thill, S. & Jones, R.B. (2020). Microbial contamination and efficacy of disinfection procedures of companion robots in care homes. *PLOS ONE*, 15(8), e0237069.
<https://doi.org/10.1371/journal.pone.0237069>
4. Bradwell, H.L., Johnson, C.W., Lee, J., Soler-Lopez, M. & Jones, R.B. (2020). Potential transmission of SARS-CoV-2 via robot pets in care homes. *Available on ResearchGate*.
<http://doi.org/10.13140/RG.2.2.30353.45922>
5. Bradwell, H.L., Winnington, R., Thill, S. & Jones, R.B. (2020). Ethical perceptions towards real-world use of companion robots with older people and people with dementia: survey opinions among younger adults. *BMC Geriatrics*, 20(244).
<https://doi.org/10.1186/s12877-020-01641-5>
6. Bradwell, H.L., Winnington, R., Thill, S. & Jones, R.B. (2020). Longitudinal diary data: Six months real-world implementation of affordable companion robots for older people in supported living. *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction (HRI '20 Companion)*, March 2020; Cambridge, UK. pp 23-26. <https://doi.org/10.1145/3371382.3378256>
7. Bradwell, H.L., Winnington, R., Thill, S. & Jones, R.B. (2020). Poster presentation of Longitudinal diary data: Six months real-world implementation of affordable

companion robots for older people in supported living. *HRI'20: ACM/IEEE International Conference on Human-Robot Interaction Session: Late Breaking Reports*. April 2020. <https://www.youtube.com/watch?v=A3iUqdEcQpw>

Accepted – In Print

8. Bradwell, H.L., Aguiar Noury, G.E., Edwards, K., Winnington, R., Thill, S. & Jones, R.B. (2021). Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions. *Health Policy and Technology*.
9. Bradwell, H.L., Winnington, R., Thill, S. & Jones, R.B. (2021). Morphology of socially assistive robots for health and social care: A reflection on 24 months of research with anthropomorphic, zoomorphic and mechanomorphic devices. *RO-MAN 2021*.

Under Review

10. Bradwell, H.L., Winnington, R., Thill, S. & Jones, R.B. (2021). Prioritising design features for future companion robots aimed at older adults: Survey ranking results from relevant stakeholders (Under Review).
11. Bradwell, H.L., Edwards, K.J. Shenton, D. Winnington, R., Thill, S. & Jones, R.B. (2021). Acceptability and design preferences of older adults in care homes towards eight forms of companion robots: A user-centred design approach to informing future robot development (Under Review).

In preparation

12. Bradwell, H.L., Edwards, K.J. Winnington, R., Thill, S. & Jones, R.B. (2021). Eight-month, stratified, cluster randomised controlled trial: The implementation and impact of affordable companion robots in eight care homes throughout South West England before and during the COVID-19 pandemic (In preparation).

13. Bradwell, H.L., Winnington, R., Thill, S. & Jones, R.B. (2021). Overview paper: Key messages on the design, use and impact of pet robots and automata for older adults. (In preparation).
14. Fraser, F., Edwards, K., Page, T., Bradwell, HL. & Warren A. Digital health technology and occupational engagement. In Maclean, F., Warren, A., Hunter, E. & Westcott, L. (Eds.) *Occupational Therapy for Dementia*. Jessica Kingsley Publishers. In preparation.

Presentations

Jones, RB. Bradwell, HL. (2019) Alan Turing Institute – Robotics and AI for health and social care, October 2019.

Bradwell, HL. (2017). The use of therapeutic robot pets with older people and those with dementia, results from acceptability comparison research. University of Plymouth EPIC Project Conference – Lanhydrock Hotel, April 2017.

Wider Research Dissemination

AISB – The Society for the Study of Artificial Intelligence and Simulation of Behaviour 2021 – Invited as panel speaker for Anthro2021 to discuss robot morphology. April 2021

Research included in ERDF booklet:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/836957/Supporting_Local_Growth_2019_final.pdf

Relation of publications to chapters and studies included in this thesis:

Publication	Chapter and Study Publication Originates From
1	Chapter 3, Study 1
2	Chapter 3, Study 3
3	Chapter 4, Study 7a

4	Chapter 4, Study 7b
5	Chapter 4, Study 8
6, 7	Chapter 5, Study 10
8	Chapter 3, Study 2
9	Chapter 4, Study 9
10	Chapter 4, Study 6
11	Chapter 3, Study 4
12	Chapter 5, Study 11
13	Chapter 3, 4, 5, all studies

Impact

The body of work forming this thesis has additionally created real-world impact and implications. The studies included have gathered local, national and international media coverage, as documented in Appendix A. Additionally, the ideas resulting from this thesis on user-centred design of a robot pet have been implemented by collaborating development company, Robotriks, resulting in a new prototype robot pet. Furthermore, the investigation into infection control has informed implemented cleaning procedures in both research and real-world practice. Of note, the Joy for All company (producers of robot pets) were in contact to inform me they had adapted their recommended cleaning procedure, conducted additional laboratory tests and emphasised individual robot use in response to the infection control studies included in this thesis. Finally, the interest generated in robot pets throughout the course of this doctoral project has also resulted in a number of real-world robot implementations, as detailed in Chapter 5, demonstrating implications of the research on current social care practice.

Table of Contents

Acknowledgements	3
Abstract	5
Contribution to Knowledge	6
Publications and knowledge dissemination	6
Impact	10
List of Tables	14
List of Figures	15
Glossary and use of language	16
<i>Use of language</i>	16
<i>Abbreviations</i>	16
Chapter 1: Background	18
1.1 Introduction	18
<i>The Challenge</i>	18
<i>Defining Robots</i>	19
<i>Theoretical Approaches to Social Robots</i>	20
<i>Companion Robots</i>	22
1.2 Literature Review	23
<i>Wellbeing Outcomes</i>	24
<i>Selection Bias towards Paro and Lack of Comparison Studies</i>	28
<i>Contradictory Outcome Research</i>	32
<i>Importance of Appropriate Design</i>	34
1.3 Rationale	36
Aims and Objectives.....	50
Chapter 2: Ontology, Epistemology and Methodology	52
2.1 Ontology and Epistemology	52
2.2 Methodology	54
2.3: Analysis methods, validity and rigour	60
2.4 Structure of Project	64
Chapter 3: CAR Cycle 1 – Initial user-centred exploration	65
3.1 Study 1: Requirement of Socially Assistive Robotics (SAR) in Health and Social Care (H&SC) 66	
3.2 Study 2: Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions	67
<i>Study 1 and 2 reflection</i>	86

3.3 Study 3: Companion robots for older people: the importance of user-centred design demonstrated through observations and focus groups comparing preferences of older people and roboticists in South West England	87
<i>Study 3 reflection</i>	117
3.4 Study 4: Acceptability and design preferences of older adults in care homes towards eight forms of companion robots: A user-centred design approach to informing future robot development	118
<i>Study 3 and 4 reflection</i>	119
3.5 Study 5: Implementation model for companion robots in care homes: Initial insight into the understudied factor based on views of key stakeholders	120
<i>Study 5 reflection</i>	132
3.6 CAR Cycle 1 Reflection	133
Chapter 4: CAR Cycle 2 – Responding to new research questions	137
4.1 Study 6: Prioritising design features for future companion robots aimed at older adults: Survey ranking results from relevant stakeholders	137
<i>Study 6 reflection</i>	138
4.2 Study 7a: Microbial contamination and efficacy of disinfection procedures of companion robots in care homes	140
<i>Study 7a furthered</i>	163
4.3 Study 7b: Potential transmission of SARS-CoV-2 via robot pets in care homes	163
<i>Study 7a and 7b reflection</i>	166
4.4 Study 8: Ethical perceptions towards real-world use of companion robots with older people and people with dementia: Survey opinions among younger adults	167
<i>Study 8 reflection</i>	187
4.5 Study 9: Morphology of socially assistive robots for health and social care: A reflection on 24 months of research with anthropomorphic, zoomorphic and mechanomorphic devices	188
<i>Study 9 Reflection</i>	189
4.6 CAR Cycle 2 Reflection	189
Chapter 5: CAR Cycle 3 – User-based assessments	192
5.1 Study 10: Longitudinal diary data: Six months real-world implementation of affordable companion robots for older people in supported living	192
<i>Study 10 reflection</i>	210
<i>Study 11 pilot study</i>	212
5.2 Study 11: The implementation and impact of affordable companion robots in eight care homes in Cornwall England before and during the COVID-19 pandemic: an eight-month, stratified cluster randomised controlled trial	213
<i>Study 11 Reflection with Collaborators</i>	261
<i>Non-research robot purchases following completion of thesis studies</i>	262
5.3 CAR Cycle 3 Reflection	264
Chapter 6: Collaboration with Robotriks to develop new companion robot, COMpet	266

<i>Discussions between researchers and collaborators</i>	266
<i>Main Findings and recommendations for Robotriks based on the work presented in this thesis</i>	267
<i>Research Communications</i>	267
Chapter 7: Discussion	270
7.1 Key findings and knowledge contribution in relation to original aims	270
7.2 Implications for further research	275
<i>Brief commentary on potential for companion robots use in secondary care</i>	275
<i>Brief commentary on robots for end of life and palliative care</i>	277
<i>Brief commentary on companion robots for physiological wellbeing</i>	278
<i>Brief discussion on mechanism of robot impact</i>	280
7.3 Implications for robot design and development	282
7.4 Implications for health and social care practice	286
7.5 Implications for health and social care policy	288
7.6 Final thoughts	289
7.7 Conclusion	290
References	291
Appendices.....	330
Appendix A: Media coverage of PhD studies	330
Appendix B: Further examples of evidence from Study 2	331
Appendix C: F Further examples of older people’s and roboticists’ responses during focus group discussions in Study 3	338
Appendix D: Full table of themes and example evidence for free interactions in Study 4	343
Appendix E: Full table of themes and example evidence for focus groups in Study 4	349
Appendix F: Details of future research design ideas	363
Appendix G: MICRO checklist for Study 7a	368
Appendix H: Tables of further example evidence for Study 8	369
Appendix I: Study 9 in full (as accepted) Morphology of socially assistive robots for health and social care: A reflection on 24 months of research with anthropomorphic, zoomorphic and mechanomorphic devices	372
Appendix J: Full table of themes and example evidence for Study 10	391
Appendix K: Full summary of scale selection for Study 11 during pilot with collaborators	395
Appendix L: Full table of themes and example evidence for Study 11	398
Appendix M: Ethical approvals	419
Appendix N: Author contributions	423

List of Tables

Table 1: Summary of relevant research related to robot design or robot use and outcomes	38
Table 2: Summary of studies included in this thesis.....	47
Table 3: Iterative progress through CAR cycles, phases and user-centred design actions.....	59
Table 4: Content analysis themes mapped on to Almere Model Components.....	74
Table 5: Key questions used to guide focus group discussions	94
Table 6: The number of older people and roboticists providing positive, negative or non-responses for each feature and the resultant level of difference or agreement	102
Table 7: Examples of evidence from each group during focus group discussions	104
Table 8: Breakdown of participants to gender and stakeholder group.....	118
Table 9: Breakdown of participants from the five care homes	118
Table 10: Five design categories showing 42 features of interest included on questionnaires.....	138
Table 11: Participant demographics	138
Table 12: Showing i) the features ranked in order of importance, based on the number of times they were scored higher than the features presented alongside them	138
Table 8: Shell types of the robot animals and alternatives	148
Table 9: CFU/cm ² on each robot before cleaning and after cleaning at 48 and 120 hours incubated	154
Table 10: CFU/cm ² before cleaning, and after cleaning by a care staff member, at 48 hours and 120 hours incubation.....	155
Table 11: Responses to purchasing a device for an older relative (Q3)	176
Table 12: Responses to open question on general feelings towards companion robots for older people (Q4)	176
Table 13: Responses to open question on ethical concerns of companion robot use with older people (%) (Q5)	177
Table 14: Potential ethical issues scored on Likert-scales based on level of concern (1= not at all a concern – 7=very much a concern).....	178
Table 15: Themes with example evidence. Further evidence in Appendix J.....	199
Table 16: Demographic make-up of the participating homes.....	225
Table 17: Care staff summative estimation of impact of robot pets for each resident at 8 months (n=83).....	234
Table 18: Resident deaths in participating care homes from baseline to follow-up.....	236
Table 19: Baseline characteristics of residents who did, or did not, go on to interact with robots... 237	
Table 20: Baseline and four month scores for the control group and intervention group, for communication issues, challenging behaviour, neuro-psychiatric symptoms and occupational disruptiveness (ITT (n=63)). ITT analysis excludes the 20 residents who died but includes 63 who potentially had access to the robots.....	239
Table 21: Domains of the Neuro-psychiatric inventory at baseline and four months for the intervention and control group (minimum 0 – maximum 12).....	240
Table 22: Reported reasons for using robots in calendars (n=109).....	242
Table 23: Thematic Analysis of Qualitative Interviews and Calendar Entries.....	242
Table 24: Robot features relevant to morphology and anthropomorphism.....	379

List of Figures

Figure 1: CAR cycles (Kemmis and McTaggart, 2000).....	55
Figure 2: Key user-centred design activities (Daly-Jones et al., 2000).....	58
Figure 3 Devices available for interaction during exhibitions: Pepper, Padbot, Paro seal, Miro, JfA dog and cat, Perfect Petzzz breathing dog, handmade knitted hedgehog, mobile apps, Amazon Echo Spot, virtual reality equipment	71
Figure 4: Typical layout of interaction stations.....	72
Figure 5: Robots and toys at each interaction station, and the associated features for comparison..	93
Figure 6: Interaction Station 2	95
Figure 7: Choice of robot/toy for use with older people, shown by participant group.....	103
Figure 8: Mapping the relationship between older people’s unprompted opinions and focus group themes	107
Figure 9: Robots used from left to right, Paro, Miro, Pleo rb, JfA dog, JfA cat, Furby, Perfect Petzzz dog, Hedgehog.....	118
Figure 10: Question 1, preferred device	118
Figure 11: Question 2, reason for preference	118
Figure 12: Question 4, preferred feel of a new device	118
Figure 13: Question 6, features to avoid in new robot.....	118
Figure 14: Question 7, opinions on a new device speaking human language.....	118
Figure 15: Question 10, which device would participants keep for residents use	118
Figure 9: Devices residents interacted with, from left: Paro, Miro, Pleo, JfA pup, JfA cat, Furby, Perfect Petzzz dog, handmade knitted hedgehog.	124
Figure 10: Stakeholder preference for companion robot procurement	127
Figure 18: Demonstrating considerable variation in design of some of the available robot pets used in previous research. The devices shown on the right are included in this study.	137
Figure 19: Companion robots and toys available for interaction before questionnaire completion (from left, Paro, Miro, Pleo, JfA dog, JfA cat, Furby, Perfect Petzzz dog, Hedgehog).....	137
Figure 20: Percentage of responders selecting each animal as ii) preferred device for target audience, iii) most appealing eyes, iv) most appropriate size and v) animal with most appropriate volume and frequency of vocalisations	138
Figure 21: Showing vi) visual representation of free text feedback behind choice of preferred animal (word size relative to frequency).....	138
Figure 22: Showing vii) visual representation of free text feedback behind choice of most appealing eyes (word size relative to frequency).....	138
Figure 11: Eight robot and toy animals used in stage one.....	148
Figure 12: Cleaning procedure for use with socially assistive robots in care homes or other health and social care contexts.....	151
Figure 13: From left, Paro, JfA dog, JfA cat, Pleo.	174
Figure 14: The questionnaire	175
Figure 15: JfA dog, JfA cat.	197
Figure 16: Stepped wedge study design as originally planned.....	220
Figure 17: Study design as carried out as a result of the pandemic, showing the removal of quantitative data collection at 8 months and the ending of staff diaries at 4 months.	221
Figure 18: Example calendar for recording of activities	223
Figure 19: Interview schedule.....	224
Figure 20: Consort diagram of trial recruitment, allocation and analysis	227
Figure 21: Trial structure demonstrating Covid-19 impact.....	231

Figure 22: Normality histograms for primary outcome (NPI total) at baseline (top) and four months (bottom) for intervention (left) and control (right) groups	232
Figure 23: Resident in collaborating care home with JfA dog 'Benjamin'	264
Figure 24: COMpet, prototype robot internal structure	268
Figure 25: From left; Pepper, Padbot, (top row) Paro seal, Joy for All dog, Joy for All cat, Pleo rb dinosaur, (bottom row) Miro, Perfect Petzzz breathing dog, Knitted Hedgehog, Furby.....	379

Glossary and use of language

Use of language

Through chapters 3-5 within this thesis, I include all studies involved in this doctoral project.

The majority of studies (10/11) resulted in a publication, therefore, most studies are presented in the form of a complete paper, with additional narrative above and below the manuscripts for context in the thesis. This creates some repetition in study introductions, but each introduction contextualises relevant literature for the aims of that study. I first authored all studies (apart from Study 1 which is not included in full in this thesis), with additional authors providing i) supervision, ii) specific expertise (e.g. microbiology), or iii) a second researcher for validity of qualitative analysis. I led on design, data collection, analysis and write up of all included studies. Considering that much of the thesis has been published with co-authors, for consistency between chapters (and papers) I sometimes use 'we' as the pronoun, referring to myself as PhD candidate and Principal Investigator together with my supervisors (and in some cases other colleagues).

Abbreviations

- AAT – Animal assisted therapy
- ACC – Aerobic colony counts
- ADLs – Activities of daily living
- ATP – Adenosine triphosphate
- CAR – Collaborative action research
- CFU/cm² – Colony forming units per centimetre squared
- COSHH - Control of Substances Hazardous to Health
- EPIC Project – eHealth Productivity and Innovation in Cornwall and the Isle of Scilly

- F – Family members
- HRI – Human robot interaction
- IRAS – Integrated research application systems
- ITT – Intention to treat
- M – Mean
- MICRO – Microbiology investigation criteria for reporting objectively
- NHS – National Health Service
- NPI – Neuropsychiatric inventory
- OP – Older person
- P – Participant
- PRN – Pro re nata
- PSS – Product/service system
- R – Roboticians/Resident (specified in text)
- RCT – Randomised controlled trial
- REC – Research ethics committee
- RLU – Relative light units
- S – Staff
- SD – Standard deviation
- SME's – Small and medium sized enterprises
- UID – Unique identifiers
- UK – United Kingdom
- VC-IOE – Video-coding protocol-incorporating observed emotion

Chapter 1: Background

1.1 Introduction

The Challenge

The population world-wide is suggested to be undergoing a demographic shift, with life expectancy increasing, a greater proportion of the population is of retirement age and above (Abdi et al., 2018). This puts pressure on health and social care (H&SC) resources (Moyle et al., 2018), because human function deteriorates with age (Garçon et al., 2016).

The increasing burden creates a greater demand for services (Broadbent et al., 2009), which is problematic as health and social care is expected to struggle with service provision due to decreasing numbers of care workers (Abdi et al., 2018). Steptoe et al. (2015) suggested an increased need for research on maintaining wellbeing. Although medical advancements are providing extended physical functioning for older adults (Farrand et al., 2016), less research has focused on caring for psychological wellbeing of the aging population.

Improving wellbeing is essential for all older adults, but it is particularly relevant for those in residential care who are vulnerable to experiencing feelings of isolation and loneliness (Siniscarco et al., 2017). Improving psychological wellbeing is also a key outcome for people with dementia, which is a common condition for those living in long-term care facilities such as care homes (Moyle et al., 2017a), with 70% prevalence reported for care settings (Matthews et al., 2013). A chronic condition associated with aging, current estimates suggest 35 million people worldwide live with dementia, a figure projected to double by 2030 (Farrand et al., 2016). Types of dementia include Alzheimer's disease, vascular dementia, Lewy body dementia and frontotemporal dementia (Oh et al., 2019). The condition is associated with changes referred to as behavioural and psychological symptoms of dementia, or BPSD. High levels of BPSD can lead to impaired wellbeing for the individual,

and increase care provider burden and stress (Sheehan, 2012). Furthermore, BPSD is associated with institutionalisation (into residential care) and prescription of medications with serious side effects (Sheehan, 2012). The antipsychotics prescribed are often associated with increased risk of cardiovascular issues (Stoner, 2018), and mortality (Maust et al., 2015). As there is no cure for dementia, current research recommends focusing on non-pharmacological approaches to manage BPSD (Farrand et al., 2016; Pu et al., 2018a), including physical, psychological and psychosocial methods of improving wellbeing (Farrand et al., 2016). Antipsychotics should thus be reserved for severe symptoms failing to respond to non-pharmacological strategies (Tampi et al., 2016). Psychosocial interventions can also reduce care-provider stress, which can consequently increase positive interactions between an individual and carer (Sheehan, 2012). As a psychosocial strategy, interactive technologies receive considerable research interest due to the potential for improving physical and psychological wellbeing (McGlynn et al. 2017). The UK Government has provided support for research and innovation in technology to support the needs of the aging population, with particular emphasis on robotics and artificial intelligence for H&SC (UK Parliament, 2018).

Defining Robots

Robot refers to a machine that uses sensors and is capable of automatically carrying out complex series of actions, particularly if programmable by a computer (Ben-Ari & Mondada, 2018). The complex series of actions and use of sensors distinguishes robots from more simple automata, which cannot adapt their actions to their environment (Ben-Ari & Mondada, 2018). The definition of robotics is however complex, and many machines exist in the boundary between automata and robot. One sub-set of robotics with particular potential in H&SC is socially assistive robots (SAR) (Broekens et al., 2009), including social, service and rehabilitation robots (Frennert & Östlund, 2014; Moyle et al., 2017a). SAR are

often designed with features of either humans or animals, to promote perception as a social entity, examples include; Pepper, Paro, iCat, AIBO, Pearl and Care-o-bot, (Broekens et al., 2009; Pu et al., 2018). Such devices are usually autonomous robots developed to provide benefits including companionship, emotion-focused affective therapy, cognitive training, social facilitation and physiological therapy (Abdi et al., 2018). Despite the lack of formal definition of SAR (Bemelmans, 2012; Frennert & Östlund, 2014; Kachouie et al., 2014), Feil-Seifer and Matarić (2005) suggest these devices have the aim of aiding humans specifically through social interaction. In response to the identified challenges of the aging population, and potential for robotics as a supporting strategy, this thesis explores the use of social robots for older adults. This thesis also explores the role of various 'smart toys' (such as Joy for All cats and dogs), in delivering such benefits (Study 10 and 11; Picking & Pike, 2017), despite likely categorisation of these devices as automata rather than robots (Ben-Ari & Mondada, 2018). While these interactive devices do possess sensors and automatically adapt responses to environmental stimuli, the series of actions emitted are arguably not complex, yet the devices are aimed at aiding humans through providing a social entity.

Theoretical Approaches to Social Robots

Authors have previously discussed theoretical approaches to understanding and defining use of social robots (Sarrica et al., 2019). Using technological determinism leads to the perception technology is forward-thinking and a beneficial solution for the older user. However, from a social constructionist perspective, technological change is more complex, with social robots possessing different meanings and consequences for older adults dependent on social, economic and cultural contexts (Frennert & Östlund, 2014; MacKenzie & Wajcman, 1999; Lie & Sørensen, 1996), being more than a purpose-build machine (Sarrica et al., 2019). From a social perspective, technology is a social construction (Bijker, 2009),

being made and used by humans to reflect human values and ideas (Kaplan, 2009).

Technology itself does not determine the outcome for users, being inherently good or bad, but the meaning, use and thus subsequent outcomes of technology are socially constructed and chosen proactively by stakeholders. A complex network of users, researchers, developers, engineers and media thus create the meaning of social robots (Frennert & Östlund, 2014). The co-evolution of social robots in collaboration with older adults is therefore crucial for the adoption of such devices, as users are consumers who can actively affect the use and development of a device (Frennert & Östlund, 2014), with this social construction influencing outcomes, particularly important due to variation in perception of what constitutes a social robot based on stakeholder category (Sarrica et al., 2019). This approach forms a core mentality to this work, straying from technological determinism, where older adults are a problem requiring solution, and interactions are a one-way, technical process where technology determines the outcome. Based on the review by Frennert and Östlund (2014), the authors proposed identified research gaps which could improve the co-evolution of technology in collaboration with users, including requirement for studies with older adults as users of social robots, to understand their matters of concern and avoid stereotypical views of older people as a homogenous group of weak and frail individuals. The authors additionally noted requirement for participatory design research including all stakeholders and longitudinal studies to respond to literature gaps. This literature gap was further supported more recently by Hung et al. (2019), who noted the needs and experience of the user remain unexplored. This thesis responds to the identified gaps with inclusion of key stakeholders as a priority throughout. The social robots of interest in this work are companion robots.

Companion Robots

Companion robot is a term used for biomorphic or zoomorphic robots often visually and/or behaviourally representing animals. Such devices often have features of biological origin, including animal ears or noses, or may be completely identifiable as a known animal (Klamer & Allouch, 2010; Moyle et al., 2017a). These devices can be perceived (and are sometimes referred to) as robot pets, and they appear to hold potential for significant health and wellbeing improvements for older adults and those with dementia, particularly those living in long-term care (Kachouie et al., 2014; Pu et al., 2018). The theory behind companion robots, and the associated benefits, is animal assisted therapy (AAT) (Gustafsson et al., 2015). Benefits of AAT are possibly rooted in the *biophilia hypothesis*, suggesting an innate desire to interact with living beings or nature (Gustafsson et al., 2015), or the *social support hypothesis*, whereby animals provide and mediate social contact (Beck, 2003). An issue however with AAT for older people, particularly in care homes, is the risk of infection, allergies, danger and unpredictability of live animals, together with associated time and money expenditure (Soler et al., 2015). Furthermore, behaviour and mood changes associated with dementia could pose a risk to live animals, such as fear, aggression or over-attachment (Soler et al., 2015). In these contexts, the benefits of robotic alternatives is clear. This work therefore aims to provide a comprehensive exploration of design, use, implications and impact of companion robots upon older adults and those with dementia through studies with a range of stakeholders.

In the following sections, Chapter 1 provides a literature review of relevant works, to contextualise the studies completed for this doctoral project, highlighting the potential for companion robots to elicit wellbeing outcomes, the issue of a selection bias towards one platform in available literature, the prevalence of contradictory and inconsistent outcome

research and the importance of establishing appropriate design. Chapter 1 concludes with overall aims and objectives of the project. Chapter 2 focuses on the methodology employed for this project, including the use of collaborative action research in line with the requirements of social constructionism. Chapter 2 also details the pragmatic and mixed-method approach, and inclusion of user-centred design actions, congruent with collaborative research and social constructionism. Chapters 3-5 then detail all studies conducted as part of this doctoral project, occurring in three cycles of collaborative action research, first to explore initial user requirements from robots, secondly to respond to research questions identified in Cycle 1, and finally to explore wellbeing outcomes following user-centred selection of the most appropriate devices. Chapter 6 then details collaboration with robotics company Robotriks, and the creation of a user-centred prototype based on results from this project. Finally, Chapter 7 includes the overall discussion.

1.2 Literature Review

This section first aims to establish the current knowledge base around companion robots for older adults. This section does not, however, aim to provide an exhaustive review of related literature (due to availability of such reviews elsewhere (Abbott et al., 2019; Abdi et al., 2018; Bemelmans, 2012; Broekens et al., 2009; Hung et al., 2019; Kachouie et al., 2014; Pu et al., 2018a; Koh et al., 2020a; Koh et al., 2020b)). This section instead sets the basis for the following work included in this thesis, which aims to respond to the literature gaps and methodological flaws identified in currently available literature. Each of the studies detailed in Chapters 3-5 additionally begins with its own literature review relevant to the aim.

According to literature, at present, the most well researched companion robot is Paro, the robot seal (Jung et al., 2017; Pu et al., 2018). Paro is an advanced interactive robot, developed in Japan, to deliver benefits of animal therapy for people living in long-term care

settings. Paro was developed with light, tactile, audition, temperature and posture sensors, and adapts its behaviour and response to the environment and specific interaction of the user (e.g. responds differently to stroking than hitting, and recognises its name, praise, greetings and direction of audio). Paro also possesses some artificial intelligence, in learning to adapt behaviours to the specific user (e.g. repeating noises or behaviours that result in stroking), and can learn to respond to known voices (Paro, 2014). The use of Paro for individuals in care homes or with dementia appears very well studied (Kachouie et al., 2014). In a relatively recent scoping review, authors identified a number of health and wellbeing outcomes in response to interacting with Paro or alternative devices (Abbott et al., 2019).

Wellbeing Outcomes

There is a wealth of wellbeing research within long-term care facilities for Paro. Notably, Jøranson et al. (2015), conducted a cluster-randomised controlled trial (RCT) with 60 residents of nursing homes. Participants were aged 62-95 and had a dementia diagnosis or cognitive impairment. A usual-treatment (no intervention) control group was compared to an intervention group, who received 30-minute group sessions with Paro, twice a week for 12 weeks. The authors measured agitation, depression and medication use, and found statistically significant improvements for both agitation and depression for the intervention group in comparison to the control group, from baseline to follow-up (three months after intervention), with agitation and depression in the intervention group decreasing whilst increasing for those in the control group.

Further research suggested interaction with Paro could result in more adaptive stress response (Saito et al., 2003). The authors introduced Paro to 30 patients in an aged care health facility four days a week, for three weeks. Morning urine samples were collected at

three stages (baseline, 1 week and 2 weeks) and assessed for bodily stress response. Results suggested excellent adjustment ability to stress following implementation of the robot. An additional outcome was a reduction in nursing staff stress, contributing to reported reduced care-provider burden (Saito et al., 2003; Wada et al., 2004). Furthermore, Liang et al. (2017) reported Paro significantly improved affect and communication between older adults and day care staff. The study involved a pilot, block RCT comparing Paro intervention with standard care (usual activities such as quizzes, bingo, music), in dementia day care units. The study involved two to three, 30-minute sessions a week, over six weeks, and ongoing access to Paro in participants homes. Observations and time sampling suggested Paro significantly improved affect and social interaction with staff. Additionally, previous research by Petersen et al. (2017) demonstrated Paro could reduce psychoactive and analgesic medication use. This outcome is particularly relevant due to the detrimental impact of pharmacological treatments (Sheehan, 2012; Sullivan et al., 2014). Further research has even suggested potential decreased blood pressure resultant from robot interaction (Robinson et al. 2015). Twenty-one residents of a residential care facility had blood pressure measures taken before, during and after interaction with Paro, with results showing significant decrease in blood pressure from baseline to during interaction, with an increase seen following robot withdrawal.

Further research with Paro in long-term care settings was conducted by Bemelmans et al. (2015a), with 91 individuals with dementia. The authors conducted a within-subjects comparison to assess short-term effects and therapeutic applications. Observations were conducted, and participant behaviour and moods were measured using validated scales. In total, participants experienced 10 or more interactions with Paro. Results demonstrated significant therapeutic effect. Robinson et al. (2013), also explored psychosocial impacts of

Paro for 40 residents of care/hospital settings, in an RCT. The intervention group received one hour group sessions with Paro, twice a week for 12 weeks. The intervention group showed significant decreases in loneliness compared with the control group.

Some research has focused on the communication effects of the device, with Wood et al., (2015), exploring the use of Paro, a plush toy (Paro off) or Pleo the robot dinosaur to mediate social interaction between 114 unacquainted female members of the public. Results suggested Paro had the strongest social mediation effect. Kidd et al., (2006), similarly found care home residents reported more social interactions with Paro than a plush toy (inactive Paro).

Additional interesting outcomes have been found in response to pain. Pu et al. (2020), conducted semi-structured interviews with 11 participants with dementia and chronic pain from three residential care settings. The participants interacted with Paro five days a week for six weeks, in 30 minute sessions before completing an interview. While participants did self-report therapeutic benefits to mood and relaxation for pain relief, the design of Paro was criticised due to its weight, vocalisations and characteristics. A limitation of this study, and studies above (Bemelmens et al. 2015; Saito et al., 2013), however, is limited robot interactions and short time frames.

In perhaps the most rigorous work with Paro, Moyle et al. (2017a) report on a cluster RCT, exploring the use of Paro to improve dementia symptoms. In total, a very large sample of 415 participants in 28 long-term care facilities took part. Nine sites received Paro as an intervention (15 minute sessions, 3 times per week for 10 weeks). Ten sites received a plush toy as comparison (Paro switched off for same intervention dose), and 9 sites were randomised to usual care. Authors assessed coded video observations and completed validated measures of agitation. The agitation measure suggested no significant difference

between groups for agitation, although video evidence suggested Paro was more engaging than the Plush toy and improved pleasure more than usual care. However, despite the strong scientific rigor of this work, the intervention dose was minimal (15 minutes, 3 times a week), and the study duration was again relatively short. I argue that to understand the impact robot pets may have for older people, research should seek to replicate real-world use, rather than highly controlled intervention doses such as here, which lack ecological validity and demonstrate efficacy of robot interventions, rather than potential effectiveness, which is discussed further in Chapter 5, Study 11.

Some of the earlier work available with Paro is from Wada et al. (2004), who reported on three months of robot assisted therapy for depression in older people in aged care facilities. Wada et al. (2004) discussed the usefulness of robots in place of real animals for therapy in care homes and hospitals, suggesting live animals have known therapeutic effects but also risks of negative effects (allergy, bites, infection, scratches), and suggest they have supported robot assisted therapy as a solution since 1996. During their study, they introduced Paro to older people and their carers, and collected data from 10 participants on depression symptoms over 14 weeks. No significant changes were seen, but authors suggest scores showed a decreasing tendency after 8 weeks. This highlights the importance of longitudinal work to explore robot impact, rather than reliance on short-term trials. A further issue with the high prevalence of short-term studies is potential novelty effect. Although the work of Wada et al. (2004) suggests robot benefits may become more prevalent over longer periods, Sparrow and Sparrow (2006) conversely suggested companion robots may only provide an entertaining and amusing novelty. The authors were sceptical on how long devices remain entertaining, and how involving the relationships between the devices and users are in practice. Broadbent et al., (2009) also reported on

previous companion robots which lost the interest of users after just one month. Thus, for a valid understanding of robot potential, more longitudinal studies are desperately required.

Selection Bias towards Paro and Lack of Comparison Studies

While it is clear there has been a wealth of research on the use of Paro, published reviews on companion robot work demonstrate a clear selection bias towards this device (Kachouie et al., 2014; Pu et al., 2018). A few studies report on the impact of alternative devices, particularly Joy for All (JfA) devices. These devices are less sophisticated than Paro, possessing only touch and sound sensors, but are considerably more affordable as a result (~£100 vs ~£5000). The devices differ from Paro as they use a familiar animal embodiment approach (familiar cats and dogs vs unfamiliar seal). At present, the research available with alternate devices is usually from small, short-term studies, and often in community or hospital settings. One such example being Hudson et al. (2020), who explored the effect of JfA cats and dogs on the loneliness of community dwelling older adults. Results from 20 interviews with older adults who had received a JfA device suggested older adults were open to adopting the robot pet, with strong evidence in support of the robots being integrated into daily life. Participants named their devices, and incorporated interactions into their usual routines. Participants additionally forged new connections, introducing friends and family to their pets. Participants acknowledged the devices were different to live animals, but valued the reminiscence of real pets, and researchers found a relationship between high levels of engagement and perceived realness of the pet. Positive outcomes included comfort, a social presence and feeling of calm from interacting with devices, thus, participants felt the robots had a positive impact on their experience of loneliness. While this study does contribute towards the limited literature available with alternatives to Paro, the focus only on loneliness is relatively narrow, and the data relies on qualitative

interviews, which although rich and insightful, allow for limited general conclusion on effect. Additionally, the participants are community dwelling older adults, creating limited generalisability to care home residents, who have comparatively poorer health, mental wellbeing and cognitive abilities (Moore et al., 2019), which is likely to impact their experience of robot pets.

Further research with JfA devices also focused on community-dwelling older adults is Pike et al. (2020), who investigated general effects of JfA cats. Analysis of qualitative results suggested the devices could provide distraction and improved communication and connections. Interestingly, four of the 12 participants rejected their cat, due to dislike, resistance or lack of interest. For those that accepted the cat, the stimulated communication appeared to be a profound result, with no evidence of novelty effect, as improvements lasted over three months. No specific symptom or outcome was studied, perhaps limiting the sensitivity of this research to any outcomes, and limiting the validity of reported benefits through lack of validated measure or scale. In prior community based work by the same authors, Pike et al. (2020) explored effects of a JfA robot cat for six individuals with dementia living in their own homes. Interviews with the older adults and their families again highlighted some cases of robot rejection, but also incidences where the cat initiated conversation between participants, family members and carers. The incidences of robot rejection in these studies are interesting, and further research would be of value with alternative populations to explore any difference in acceptance, or indeed perceived requirement, of robot pets based on the individuals level of isolation, independence and cognitive impairment.

Tkatch et al. (2020), investigated the use of JfA robot pets to combat loneliness, again for community-dwelling older people. Two-hundred and seventy one participants were

recruited through a prior loneliness survey collected via a health insurance company. The authors conducted loneliness, quality of life, purpose, resilience and optimism metrics at baseline, before receiving a dog or cat robot of their choosing. Metrics were repeated at 30 days and 60 days. Results demonstrated significant improvements in loneliness, mental wellbeing, purpose, resilience and optimism after one month. However, this study relies on self-reported benefits, creating potential for positive reporting bias. The research also lacked a control group for comparison. This study again focused on generally-healthy, community dwelling older adults, as with the above community based studies. The difference in life experience and challenges between care home residents and community dwelling older people is reflected in the choice of optimism, resilience and purpose metrics by Tkatch et al. (2020), rather than measures for BPSD, agitation, isolation and other care specific metrics as seen in research with Paro in care settings (Moyle et al., 2017a; Jøranson et al., 2015). The large sample is a strength of the work, which indeed supports the potential for JfA devices in producing wellbeing outcomes.

Within hospital settings, Brecher (2020) assessed use of the JfA cat for terminal restlessness through a case study suggesting some benefits during the end-of-life phase. Brecher (2020) reports aggression reduced, and staff and relatives felt limited medication was needed during active dying. The cat remained present even during the individual's final 24 hours of life, with family reporting a respectful and peaceful death. Further hospital based work conducted with the JfA cat includes a study by Schulman-Marcus et al. (2019), who recruited 20 patients with delirium from an intensive care unit, and provided a JfA cat for three days before completion of a feedback survey by the patient, family and healthcare staff. Sixty-five percent of patients, relatives and staff agreed the cat had a calming effect and 70% felt the devices did not interfere with provision of clinical care. The large majority (95%

patients/family, 72% staff), felt such devices could be useful for patients in the future.

Despite the small sample size and very short time frame, this study provides some support for the potential of affordable robot pets in clinical settings, however, results again have limited generalisability to residential care settings.

There are some additional studies reporting use of JfA animals specifically in residential care, but as yet appear not to be formally published in journals, instead made available on institutional websites or in poster sessions. Marsilio et al. (2018), report on 11 participants with dementia in long-term care settings who interacted with JfA pets. Results suggested significant reduction in agitation scores, significantly increased oxygen saturation and no changes in heart rate or use of psychotropic medication over 6 weeks. Although limited information is available on the intervention dose in this work, the small sample size and short time frame are limitations of the study. McBride et al, (2017) also provided JfA pets to 33 residents of a long-term care facility with severe impairment. Social workers encouraged robot therapy during their visits, 2-3 times per week. Qualitative reports suggest some evidence for improved communication and calming effect. However, two of the residents rejected the robot, with one stating it was for children, and the other resident with psychosis became disturbed by the cats vocalisations.

The cases of robot rejection, and incidences of negative response such as the above disturbance, raise a further topic of enquiry for robot pets, their design. The below section demonstrates how companion robot literature currently presents contradictory outcomes, with research finding contrary evidence to many positive reports, highlighting inconsistency in reported wellbeing outcomes. In fact, researchers have warned against overly optimistic reports of wellbeing effects, particularly for Paro, as many older studies originated in Japan (the founding country) (Misselhorn et al., 2013), with many authored by Paro's creator, Dr.

Takanori Shibata. Thus, below is provided some evidence of less positive wellbeing outcome research below, suggesting inconsistency is reported Paro effects.

Contradictory Outcome Research

In one example of Paro research with contradictory results, Pu et al. (2020), conducted a pilot RCT with 43 people with dementia and chronic pain, which evaluated the effect of Paro on pain and BPSD, in three long-term care facilities. Participants randomised to the Paro intervention (30 minute sessions, 5 days per week), had significantly lowered observed pain than those in usual care (based on researcher-rated observational pain behaviours).

However, there were no significant differences in staff-rated perceived pain, agitation, anxiety and depression, nor regularly scheduled medication. The improvements noted by the researcher were additionally entirely subjective, and not supported through care staff ratings, who would arguably have known residents better. Of course, these results contrast those discussed previously, demonstrating reductions in depression and agitation (Jøranson et al., 2015).

Furthermore, the cluster RCT conducted by Moyle et al. (2017a), also found no significant effect on agitation on the validated scale, and authors concluded the only benefits of Paro over a plush toy were limited to engagement. Additionally, while Robinson et al. (2013), did report a decrease in loneliness, they found no significant improvement for depression; and separate research (Thodberg et al., 2016) compared live dog visits to Paro sessions over 6 weeks, and found no improvement for depression with either intervention. While many factors, such as use context, individual variability and intervention method may have influenced the disparity between studies, it appears the benefits reported from Paro interactions are inconsistent.

Further to inconsistent wellbeing outcomes, it appears Paro, and indeed other devices such as the JfA cat and dog, suffer from high variance in responses of older people. As already discussed, some research with JfA pets reports on a third of participants (4/12) rejecting the device, as they did not like cats, robots or any interventions (Pike et al., 2020). Research assessing suitability of Paro for a dementia unit suggested it required adaptations to be acceptable for this context; for example, the vocalisations can be distressing (Robinson et al. 2013 suitability). Finally, reflections on the large RCT by Moyle and colleagues reported considerable variation in responses to Paro, with some participants refusing to interact with Paro entirely (Moyle et al., 2017b).

Birks et al. (2016, pg1) also found variable responses to Paro, with a key theme from their results being “a therapeutic tool that’s not for everybody.” The authors noted some participants responded to the seal with outright dismissal, and care staff reported only ‘50 per cent are really interested.’ Participants displaying negative responses were thought to be more cognitively able. The authors also reported on the negative responses of family members, one of whom felt a resident carrying the seal looked like ‘a complete idiot.’ There were also occasions of negative responses among care staff, who disliked the seal or even believed it could be monitoring them. This demonstrates requirement for research assessing acceptability among staff, who will ultimately be responsible for facilitating robot interactions. The negative responses of family members in Birks et al. (2016) also highlights the importance of exploring ethical perceptions of these devices, as discussed further in Chapter 2, Study 8.

The clear disparity in wellbeing results, and variance in older person’s responses to Paro and other such devices would suggest the literature still lacks agreement on how best to design

such robots to promote widespread acceptability and consistent responses for this population.

Importance of Appropriate Design

The issue with the contradictory outcome research above is consolidated by reports of a number of devices in this sector failing, with commercially produced robots experiencing lack of uptake in the health and care sector (Broadbent et al., 2009). Attaining the optimum design for companion robots is essential in realising their full potential, the importance of design for a platform to be successful cannot be overstated, as appropriate design promotes acceptability amongst end users (Fink, 2012; Klamer & Allouch, 2010; Heerink et al., 2010). In contrast, inappropriate design may result in devices falling into disuse or not delivering expected benefits (Forlizzi et al., 2004), ending up a cost to society. Aesthetic and behavioural features are largely influential in predicting device acceptability and thus ultimately use (Fink, 2012; Klamer & Allouch, 2012; Heerink et al., 2010). Robot embodiment and morphology helps establish social expectation, thus influencing subsequent interactions (Fong et al. 2003), and yet despite the importance, definitive results have still been lacking. Currently, a range of robot pets are available, with a number of varied embodiments, shell types and features, yet no consensus exists on appropriateness of each design for this context. This is discussed further in Chapters 3 and 4, Study 3, 4, 6 and 9, with Study 6, in particular, detailing the clear lack of consensus in robot pet design at present.

Over the last ten years, <10 studies appear to have considered robot pet design for older people, one key study being Heerink et al. (2013), who gathered care staff opinions on appropriate features for a robot pet. However, the study lacked Paro for comparison, Paro is important to include as the most well researched device of this type. The data collection on

design requirements focused on the perceptions of care staff, some of whom had no first-hand experience of robot pets. The importance of engaging multiple stakeholder groups is, therefore, a key motivator for the work throughout this project (Bedaf et al., 2018), as a person's stakeholder category can influence their technology acceptance (Pino et al., 2015). This may be due to differences in perceived requirements for support across patients, caregivers and professionals (Orrell et al., 2008). Indeed, Bedaf et al. (2018), demonstrated older adults to be more accepting of a robot than their caregivers or relatives.

Pino et al. (2015), explored perception and acceptance of social robots, but with older adults themselves, along with informal carers and people with mild cognitive impairment. Twenty-five participants completed a survey, and seven took part in a focus group. Focus groups received a demonstration of one robot (RobuLAB10) and a PowerPoint of other available devices, including humanoids and machine-like robots further to robot pets. Participants discussed various SAR platforms, and suggested design should ensure devices are recognisably robotic. The results did demonstrate participants felt they were more likely to use SAR in the future, than the present, perceiving themselves as too able. People with cognitive impairment did demonstrate a higher perceived usefulness, again strengthening the importance of including a range of stakeholders in acceptability and design research, as current level of need strongly relates to technology acceptance and thus will influence appropriate SAR design. A limitation of this work however is the use of passive materials (PowerPoint/booklet) to inform participant opinions of SAR, as this limits participant ability to assess robot capabilities (Jung et al., 2017). A strength of the work is the inclusion of multiple stakeholder groups, and the discussion of general SAR (including humanoids and machine-like robots) is useful for all subtypes of SAR in understanding acceptable base designs (e.g. degree of machine-likeness).

While some other studies exploring SAR design are available, these are described in more detail throughout this thesis. Based on the design studies to date, considerable literature gaps remained, responded to here, through multiple design focused studies with a range of stakeholder groups and live demonstrations of several example robots.

1.3 Rationale

The literature review above has identified discordance with regards to reported wellbeing outcomes for robot pets, further to a selection bias towards Paro in outcome research, without understanding of Paro's particular suitability for older adults. Considering the prohibitive price of Paro, and evidence of negative responses towards the seal, it is imperative alternative devices are considered. To this regard, however, the literature still lacks consensus on appropriate design for a robot pet for older people, with Frennert and Östlund (2014) suggesting older adults are implicated in the design (being the ultimate user), but not involved. Indeed, a relatively recent (2019) scoping review noted research gaps in this field, including that the users' needs and experience remain unexplored (Hung et al., 2019), and as such, is a challenge responded to in this work. The review also noted theory should be used to guide future robot implementations (Hung et al., 2019). A further recent review suggests despite all the research interest, little is known about factors affecting robot implementation in real-world practice (Koh et al., 2020a). The works produced as part of this thesis should aid in this regard, by informing; context of use, optimum design of robots (including embodiment, feel, aesthetics, interactivity, behaviours, features, size), infection control procedures, ethical considerations and purchasing models (including appropriate price). Of note, infection control and ethical concerns were also literature gaps noted by Hung et al (2019). Further to the literature review above, a summary of relevant research focused on companion robot design or wellbeing outcomes is

available in Table 1 **Error! Reference source not found.**, accompanied by notes on methodological limitations and literature gaps. Table 2 then details the studies conducted as part of this doctoral project, with notes on the methodological issues and literature gaps each study responds to.

Table 1: Summary of relevant research related to robot design or robot use and outcomes

Paper	Study Focus and findings	Time frame, interaction time	Sample size	Technology	Population	Notes
Studies related to robot design or acceptability						
Heerink et al. (2013)	Design of companion robot for older adults. Furry skin, response and quiet mechanics important.	One hour group session, one minute per robot per person	36 care staff	WowWee Seal toy, Pleo, FurReal Friends cat, Robotic bear,	Care staff	+ More than one device for comparison + Alternative devices, - No Paro for comparison, - Relied mainly on carers opinions, - Some carer opinions on feature design were uninformed by experience
Jones et al. (2008)	Exploring impact of zoomorphic features and behaviours. Neither behaviour or appearance impacted perceived performance.	Unknown	30	Roomba vacuum	Unknown, general population	- Device not designed as a companion, - Unspecific sample, - No ecological validity, lab based - Limited generalisability to care homes,
Klamer and Allouch, (2010)	Acceptance and use of social robot by older people. Enjoyment and playfulness important for acceptability. No improvement in health conditions.	10 days	3	Nabaztag	Older people living in own homes	+ Alternative device, - Small sample size, - Short time frame, - Limited generalisability to care homes,
Lazar et al. (2016)	Design of robot pets for older adults. Rejected idea of robot pets for loneliness, some friction around robotic	Unknown	41	Zoomer plastic dog, WowWee seal and Koala, Penbo penguin, Chatimals	Independent older adults	+ Included perspective of older adults, + Alternative devices, + Range of devices, - All unfamiliar/unrealistic,

	companions. Desired to care for robotic pets.			hamster, Fijit Friends Willa		<ul style="list-style-type: none"> - No devices for this audience were used, brightly coloured, pink/purple children's toys, - Limited generalisability to care homes,
Odetti et al. (2007)	<p>Acceptability of robot pets for older people.</p> <p>Acceptance of AIBO was limited and unstable.</p>	One short session	24	Aibo	Older adults with mild cognitive impairment living independently	<ul style="list-style-type: none"> + Opinions of older adults, + Alternative device, - No devices for comparison, - Short interaction time, - Limited generalisability to care homes
Pino et al. (2015)	<p>Attitudes of older people towards SAR (not just pets).</p> <p>Intention to use SAR lower at present than in future</p>	1.5-2 hours	25 in survey, 7 in focus group	RobuLAB 10 (pictures of Kompai, Pearl, Mamoru-kun, Eve, Telenoid, Nexi, Geminoid, iCat and Paro)	Older adults with mild cognitive impairment, caregivers and health older adults, all living independently	<ul style="list-style-type: none"> + Opinions of older people, - Only one robot demonstrated - Passive materials such as PowerPoint presentation as experience of SAR, - Limited generalisability to care homes
Robinson et al. (2013)	<p>Acceptability and improvements of healthcare robots.</p> <p>Paro interacted with more than Guide, SAR must be simple and easy to use. Paro's sounds need modifying.</p>	1 hour	10 people with dementia, 11 relatives and 5 staff	Paro and Guide	Secure dementia facility	<ul style="list-style-type: none"> + Two devices for comparison, + Multiple stakeholder groups input, - Family dictated resident interaction, - Short interaction,
Wu et al. (2016)	<p>Attitudes of older adults towards assistive robot, including companion robots.</p> <p>Participants felt too able to benefit from robotic assistance.</p>	N/A	20	None	Older adults with mild cognitive impairment living independently	<ul style="list-style-type: none"> - No robots demonstrated for informed opinions, - Limited generalisability to care homes,

Studies related to robots achieving wellbeing outcomes						
Bemelmans et al. (2015a)	Effect of Paro on wellbeing of people with dementia. Improvements in mood and goal attainment.	10 + interactions per participant	91 care home residents	Paro	Care home residents and care staff	+ Use of validated measures, + Large sample, - Only Paro,
Birks et al. (2016)	Experiences of therapists Support therapeutic benefit of Paro, but not suitable to everyone.	30-40 minute sessions, daily for 4 months	3 therapists	Paro	Therapists of older people	- Only Paro, - Small sample size, - Only views of professionals, not end-users
Brecher (2020)	Robot cat for terminal restlessness. Perceived as supporting in peaceful and dignified death.	~2 weeks	1 end-of-life patient	JfA cat	Reflection of clinician treating end of life patient	+ Alternative robot + Novel research question, Case study only - Short time frame
Gustafsson et al. (2015)	Reaction of people with dementia, and experience of care givers. Reduced agitation, improved quality of life.	7 weeks	4 people with dementia, 3 relatives, 11 care givers	JustoCat	Care givers and people with dementia in care home	+ Alternative robot, + Validated measures, - Short time frame, - Small sample size, - Only views of professionals, not end-users
Hudson et al. (2020)	Robot pets to alleviate loneliness for self-reported lonely individuals. Robots have potential for reducing loneliness, particularly for those living alone.	60 days	20	JfA Cat, JfA dog	Community dwelling older adults	+ Alternative devices, - Limited generalisability to care homes, - Short time frame

Jøranson et al. (2015)	Robot assisted group activity effect on agitation and depression. Significant reduction in agitation and depression.	Group activity, 30 minutes twice a week for 12 weeks	53	Paro	Nursing home residents with dementia	+ Control group + Validated scales, - Somewhat short time frame, - Structured interaction lacks ecological validity - Only Paro
Jøranson et al. (2020)	Robot pet group sessions for sleep with residents with dementia or cognitive impairment. Improvements in agitation and depression.	Group activity, 30 minutes twice a week for 12 weeks	60	Paro	Nursing home residents	+ Cluster RCT + Objective measures of sleep-wake patters - Only Paro
Jung et al. (2017)	Care giver perceptions of Paro potential. Paro noises overstimulating, good perceived potential to provide distraction and promote conversation.	N/A	9 healthcare providers	Paro	Care providers in geriatric psychiatry	- Only Paro, - 4 participants had no experience of Paro, - Video used for uninformed participants, no live demonstration, - Only views of professionals, not end-users
Kramer et al. (2009)	Comparing human, animal and Aibo interaction. Live dog and Aibo stimulated social interaction more than human. Aibo looked at more.	1 interaction with robot per participant	18 residents	AIBO	Care home residents with dementia	+ Alternative device, + Comparison of robots with humans and animals, - Short time frame
Liang et al. (2017)	Wellbeing outcomes from robot interaction.	30 minute group sessions, 3 times a week for 6 weeks	30 dyads (care recipient and carer)	Paro	People with dementia at day care and at home	+ Physiological outcomes, + Validated measures, + More ecological validity - Limited generalisability to care homes, - Short time frame

	Improved affect and communication with staff.					- Only Paro
Marsilio et al. (2018)	Robot cat for agitation and quality of life. Reduction in agitation and increase in oxygen saturation. No change in heart rate.	6 weeks	11 residents	JfA cat	long-term residential care residents with dementia	+ Validated measures, + Alternative device, - Pre/post measures (no control) - Short time frame, - Small sample size
McBride et al. (2017)	Robot animals for isolation. Nonverbal people speaking. No one harmed devices.	30 days	33	JfA cat and dog	Residents with severe impairment	+ Alternative devices - Short time frame - Limited information, poor reporting of data collection or analysis
Moyle et al. (2016)	Feasibility, effectiveness and tolerability of robot. Participants raised issues with CuDDler. Pet size, weight and shape important.	5 weeks	5	CuDDler	Residents with dementia	+ Alternative device - Short time frame, - Small sample size
Moyle et al. (2017a)	RCT comparing Paro to plush toy for engagement and wellbeing outcomes. Paro arm participants more engaged. No difference in agitation.	15 minutes, 3 times a week, for 10 weeks	415	Paro	People with dementia in long-term care	+ Robust design, + Validated measures + Very large sample, - Short time frame, - Only Paro - Highly controlled, low ecological validity
Moyle et al. (2017b)	Reflections on cluster-RCT with Paro.	10 weeks	5 residents	Paro	Long-term care residents with	- Short time frame, - Only Paro,

	Response can vary between participants and for the same participant at different times.				diagnosis of dementia	
Moyle et al. (2018)	Care staff perceptions of Paro compared with plush toy. Staff preferred Paro, potential to improve quality of life.	10 weeks	20 care staff	Paro	Long-term care facilities	- Short time frame, - Only Paro, - Focus only on opinions of professionals
Petersen et al. (2017)	Physiological and wellbeing outcomes from robot interaction. Decreased stress, anxiety, psychoactive and pain medication use.	20 minutes, three times a week, for 12 weeks.	61	Paro	Patients in secure dementia unit	+ Control group, +Physiological measures, + Validated measures - Only Paro, - Highly controlled, low ecological validity
Picking et al. (2018)	Effect of robot interaction, acceptability and impact. Robots accepted and provided positive outcomes.	Unknown	6 older people with mild-moderate dementia living at home	JfA cat	People with dementia living independently	+ Alternative device, - No measures, limited evidence, - Small sample size, - Limited generalisability to care homes,
Pike et al. (2020)	Effects and acceptability of robot cat at home. Robots accepted and provided positive outcomes for distraction, communication and connections.	3 months	12 people living at home	JfA cat	People with dementia living independently or sheltered housing	+ Alternative device, - No measures, - Small sample size

Pu et al. (2020)	Effect of robot interaction on pain and wellbeing. Lower researcher observed pain, but not staff observed pain. Lower medication use.	30 minute interaction, 5 days a week for 6 weeks	43 people dementia and chronic pain	Paro	Long term care residents	+ Validated measures, + Control group, - Short time frame,
Pu et al. (2019)	Perceptions of Paro in relation to pain and mood. Positive attitudes towards Paro for pain and mood improvements but voice, characteristics and weight criticised.	30 minute interaction, 5 days a week for 6 weeks	11 people with dementia and chronic pain	Paro	Long term care residents	- Small sample size, - Short time frame,
Robinson et al. (2015)	Physiological outcomes from robot interaction. Blood pressure and heart rate reduced over time.	10 minute sessions	17	Paro	Residential care facility residents	+ Physiological measures, - Small sample size, - Short time frame,
Robinson et al. (2013)	Psychosocial effects of a companion robot. Significant decreases in loneliness.	One hour, twice a week for 12 weeks	40	Paro	Residential care facility residents	+ Validated measures, - No control group
Saito et al. (2003)	Robot use for stress reduction. More adaptive stress response.	Four days a week for 3 weeks	24	Paro	Nursing home residents	+ Physiological outcomes, - Short time frame, - Only Paro
Tkatch et al. (2020)	Robot cat and dog for loneliness, purpose,	60 days	Health, community-dwelling	JfA cat and dog	Community dwelling older adults	+ Validated measures, - No control group, - Limited generalisability to care homes

	resilience, optimism and wellbeing. Decreased loneliness, improved mental wellbeing, resilience, purpose in life.		older adults			
Wexler et al. (2018)	Robots for delirium, loneliness and falls. Less delirium, loneliness and fewer falls.	Duration of hospitalisation	Hospitalised patients	JfA cat and dog	Hospitalised patients	+ Alternative devices, - Limited generalisability to care homes - Limited information on intervention dose/duration

Table 1 provides a non-exhaustive summary of much of the key research on design, acceptability, use and impact of companion robots, identifying some of the methodological issues and research gaps present. As displayed in the table, much of the design related research is limited by small samples, often consisting of a single stakeholder group. Lazar et al. (2016), noted few studies directly involve older adults, and when involved, it was usually only for end-stage design (usability), or through proxies such as caregivers. Indeed, the studies above involving older adult participants rely mainly on independently living older adults, rather than care home residents or people with dementia, despite appearing to be the intended end-user (Abbott et al., 2019). Studies focusing only on care providers and families may ignore the voice of end-users, who have been shown as more accepting of robots than their carers or relatives in prior work (Bedaf et al., 2018).

The robot design studies included in Table 1 often lack a range of companion robots for comparison, an issue highlighted by Kachouie et al. (2014). Many of the studies rely on a single, often unfamiliar, device (e.g. Paro, Roomba), sometimes with a hard shell (e.g. Nabatzag, Aibo).

The lack of alternative devices to inform participants of a range of shells, embodiments, features and abilities limits the learning to be gained on optimum design. As Table 1 demonstrates, much wellbeing outcome research is dominated by a selection bias towards Paro, being the single most studied robot of this type (Moyle et al., 2017a). Many studies also report on short time frames, which may be problematic due to potential novelty effect.

The longer, more rigorous studies again focus on Paro, with debate surrounding the value of measuring impact through highly controlled interventions (e.g. 30 minutes, 3 x a week), which is not necessarily reflective of real-world use. This is discussed further in Studies 10 and 11. The current literature includes a number of literature gaps, for example, work is lacking into practical factors of real-world implementation (Koh et al., 2020a), such as affordability, robustness, infection control and procurement models.

The studies undertaken as part of this thesis have therefore been included in Table 2 to demonstrate how each study responds to some of these key issues raised, thus contributing towards this field of research.

Table 2: Summary of studies included in this thesis

Study	Study Focus	Time frame	Sample size	Technology	Population	Strengths and Limitations
1	Requirement of SAR in H&SC. Qualitative observations of interactions with SAR.	8 x 40 minute exhibitions	223	Paro, Pepper, Padbot and Miro	H&SC professionals, service users, relevant students and businesses	+ Responds to limitations of previous SAR acceptability work (small samples, limited live demonstrations of robots, one stakeholder group) + Large sample size, + Multiple devices for comparison, + Multiple stakeholder categories, - Short interaction time
2	SAR Design recommendations for H&SC. Qualitative observations of interactions with SAR.	8 x 40 minute exhibitions	223	Paro, Pepper, Padbot and Miro	H&SC professionals, service users, relevant students and businesses	+ Responds to limitations of previous SAR acceptability work (small samples, limited live demonstrations of robots, one stakeholder group) + Large sample size, + Multiple devices for comparison, + Multiple stakeholder categories, + Live SAR interaction in response to literature limitation, - Short interaction time
3	Importance of user-centred design for companion robots. Qualitative observations and focus groups.	Total of 30 minutes of interactions for each participant	17 older adults, 18 roboticists	Paro, Miro, Pleo, JfA Dog, JfA cat, Furby, PP dog, Handmade Hedgehog	Potential end-users (older adults living in supported living), and potential developers (roboticists)	+ Novel research question, + Responds to literature limitation of older people being implicated but not involved in robot pet design, + Responds to limitation of past work using robots not designed as companions, + Demonstrates market for robot pets with more able older adults, + Comprehensive comparison of robot pets with 8 devices - Short interaction periods, - Not generalizable to care home residents,

4	Acceptability and design preferences for robot pets among care home residents, resident relatives and care staff	Up to 60 minutes total interaction time per participant	65 total, 26 residents, 29 staff members and 10 family	Paro, Miro, Pleo, JfA Dog, JfA cat, Furby, PP dog, Handmade Hedgehog	Care home residents, relatives and care staff	<ul style="list-style-type: none"> + Comprehensive comparison of robot pets with 8 devices + Responds to literature limitation of older people being implicated but not involved in robot pet design, + Responds to limitation of past work using robots not designed as companions, <ul style="list-style-type: none"> + Multiple stakeholder categories, + Relatively large sample size for qualitative care home study + Responded to literature limitation of not randomising presentation order, <ul style="list-style-type: none"> - Short interaction time, - Only care home residents with capacity
5	Exploring an Implementation Model for Real World Use of Robot Pets with Key Stakeholders	1 - 3 hours of observing residents interact	29 care staff and 10 family member	Paro, Miro, Pleo, JfA Dog, JfA cat, Furby, PP dog, Handmade Hedgehog	Care staff and resident relatives	<ul style="list-style-type: none"> + Responds to literature gap on practicalities of real-world adoption <ul style="list-style-type: none"> + Novel research question, + Comprehensive comparison of robot pets with 8 devices, + Perspectives of 2 stakeholder groups implicated in real-world purchases, <ul style="list-style-type: none"> - Small sample size, - Short observation period
6	Prioritising design features for future companion robots through feature ranking survey	20 – 30 minutes interaction for each participant	119 events at 9 H&SC events	Paro, Miro, Pleo, JfA Dog, JfA cat, Furby, PP dog, Handmade Hedgehog	H&SC professionals related to dementia, psychiatry, gerontology, aged care	<ul style="list-style-type: none"> + Novel research questions on appropriate price, size, weight, eye design, in response to literature gaps on these features, + Responds to literature requirement to prioritise robot pet features, <ul style="list-style-type: none"> + Large sample size, - One stakeholder group, but range of relevant professionals, - Short interaction,
7a and 7b	Microbial contamination on companion robots and potential transmission of SARS-CoV-2	20 minutes of interaction with 4 residents for each robot	8 older adults assisted in replicating use of robots	Paro, Miro, Pleo, JfA Dog, JfA cat, Furby, PP dog, Handmade Hedgehog	Microbial contamination samples	<ul style="list-style-type: none"> + Responds to literature gap on adequate infection control exploration, + Comprehensive range of devices to compare infection control, <ul style="list-style-type: none"> + Some generalisation for other SAR in care settings, + Responded to previous methodological limitations of microbial sampling, <ul style="list-style-type: none"> + Novel considerations of robot use during pandemic, - Relatively small number of samples,

8	Ethical perceptions	20 – 30 minutes of interaction per participant	67 younger adults	Paro, Pleo, JfA Dog, JfA Cat	Younger adults as family members of older people	+ Responds to literature gap on ethical concerns as a possible barrier, + Novel research question, - Only one stakeholder group, - Short interaction time,
9	Morphology of social robots	No data	364 participants	Pepper, Padbot, Paro, Miro, Pleo, JfA Dog, JfA Cat Furby, PP Dog, Handmade Hedgehog	Younger adults, care home staff, H&SC staff and services users, H&SC or technology students and businesses	+ Relatively novel research method to provide generalised design guidance, + Inclusion of large range of stakeholders, + Large range of SAR, + Novel and practical contribution, - Reflective work
10	Longitudinal use of affordable companion robots	6 months of robot use	~ 100 older adults in supports living	JfA Cat and JfA Dog	Supported living and dementia care residents	+ Responded to literature gap on limited availability of research with affordable robot pets, + Responded to literature gap on limited availability of longitudinal robot pet studies, + Explored novelty effect, + Ecological validity - Limited generalisability to care homes,
11	Impact of affordable robot pets, cluster RCT	8 months	83 older adults, 8 care staff	JfA dog, JfA cat	Care home residents, care home staff	+ Responded to literature gap on limited availability of research with affordable robot pets, + Responded to literature gap on limited availability of longitudinal robot pet studies, + Ecological validity, + Longitudinal use, + Rigorous care home study, + Validated quantitative wellbeing outcomes, + Qualitative impact through interviews and diary observations + Novel contribution of robot pet impact during pandemic and lockdown, - Proxy-report scales may have produced positive bias, - Not possible to blind respondents - Impact of Covid

Aims and Objectives

This research aimed to provide a comprehensive exploration into the design, use and impact of companion robots for older people and people with dementia living in care homes, due to the potential benefit the devices can bring to this population.

In particular, the objectives were to:

- Assess requirement and acceptability of socially assistive robots in health and social care generally,
- Establish necessity and value of user-centred design in the companion robots field, based on research suggesting older people are implicated but not involved in design, together with the issues of robot failure and rejection documented to date,
- Compare a range of companion robots and alternatives, to respond to this identified literature gap, and compare device acceptability and preferences by end-users and relevant stakeholders likely to influence real-world adoption and use,
- Understand user-requirements, and perceptions of all key stakeholders, based on limitations in current literature (including older people, relatives, care staff, roboticists, relevant health and care professionals, businesses, and students), to inform user-centred design of affordable and improved devices,
- Feed user-centred research results into development of a new robot, to reflect user-requirements more accurately,
- Develop understanding of context for real-world companion robot implementation, a further identified literature gap (including suitable purchase costs and procurement models, further to exploring ethical concerns, longer-term 'real-world' use and practical factors such as robustness and infection control),

- Explore effectiveness of affordable and acceptable robot pets in achieving health and wellbeing outcomes through user-based assessment with older adults, responding to limitations of previous short-term, highly controlled studies focusing mainly on the unaffordable Paro.

Chapter 2: Ontology, Epistemology and Methodology

2.1 Ontology and Epistemology

Ontology is concerned with the nature of reality, and epistemology is concerned with the methods of obtaining valid knowledge. Researchers hold philosophical positions of ontological and epistemological approach, influencing their perceptions and understanding of reality, and methods of conducting research (Parvaiz et al., 2016). There are several paradigms present in research, with common opposing ends being positivism and interpretivism, with associated quantitative and qualitative methods respectively (Parvaiz et al., 2016). This research, however, adopts a pragmatist approach, selecting methods perceived best suited to each individual aim (Morgan, 2014). Justifying a mixed method approach in research can be difficult (Parvaiz et al., 2016), however mixed-methods research has recently gained momentum (Timans et al., 2019), and the relevance of pragmatism to this field has provided confidence in selection of this approach. Health and care generally provide a challenging environment for innovation, due to the complexity of the sector, making pragmatism suitable in light of flexibility of research approach, sensitivity to context, focus on applied knowledge and value placed on different knowledge forms (Long et al., 2018).

Farbus' (2004) thesis commented previously on enabling researchers to select most appropriate methods for each aspect of a theory without confinement to a particular set of methods associated with a single epistemology. Farbus (2004, p. 54), argued "research should be less about taking epistemological sides and more about using the methods and theories that are best for achieving our research aims." For pragmatic researchers, debating laws on ontology and epistemology are of less significance than the research question itself, which should be the central focus (Creswell, 2003; Mackenzie & Knipe, 2006; Parvaiz et al.,

2016). Philosophically, pragmatism goes beyond merely problem solving, and moves away from abstract concerns to focus on human experience, and the implications of experiences on our beliefs (Morgan, 2014). This approach is particularly evidence in Study 8, where philosophical concerns on robot ethics are explored among real-world stakeholders, going beyond the abstract concern to assess human experience and beliefs.

Although divergent from traditional alignments, the pragmatic paradigm became common in research practice, and in doing so rejects forced choice (Creswell, 2003). In contrast, positivism often implies deductive reasoning for confirmatory research on well-established theory, whilst interpretivism often uses inductive reason, to develop theory (Parvaiz et al., 2016). Pragmatist researchers, however, typically employ 'abductive' reasoning and sway between both reasoning processes (Parvaiz et al., 2016). This approach is appropriate for the field of companion robot research, where much literature exists (Kachouie et al., 2014; Pu et al., 2018a), however variation in results convey difficulty in deducing predictable patterns. This thesis therefore presents a mix of confirmatory and exploratory outcomes. For pragmatic researchers, "the mandate of science is not to find truth or reality, the existence of which are perpetually in dispute, but to facilitate human problem-solving" (Powell, 2001, p. 884). It is therefore not the primary concern of this thesis to continue the debate of ontology and epistemology, but to acknowledge the problem facing our population; increasing life expectancy, inadequacies of wellbeing for older adults, issues with isolation and loneliness, decreasing numbers of human care staff, and then endeavour to assist with the problems and challenges, through the most appropriate methods available.

2.2 Methodology

This project used a collaborative action research (CAR) approach and mixed-methods design, whilst also incorporating principles of user-centred design, due to the particular relevance with the aims of this thesis. Action research generally is thought to bridge the gap between research and practice (Nichols, 1997). It has been suggested social science research often fails to influence practice (Nichols, 1997), however, CAR is thought to decrease this divide by fully involving stakeholders in every stage of the research process. This is particularly relevant for companion robot research, as the prohibitive price of Paro has limited likelihood of real-world implementation, outside of research (Moyle et al. 2018, user-centred). In contrast, I aimed here to conduct collaborative research with an increased chance of instigating real-world impacts and implications for practice, and the involvement of key stakeholders was key in this regard. CAR occurs in cycles of four stages; *planning, acting, observing* and *reflecting* (Figure 1) (Kemmis & McTaggart, 1988). Each cycle is considered a phase, which then informs progression into the next phase. This process is demonstrated for this project in Table 3, and the overall project can be seen in Section 2.3. Importantly, stakeholders were engaged in the planning phases of this process, informing methodological choices, further to actively engaging in data collection and subsequent reflection to inform later research questions.

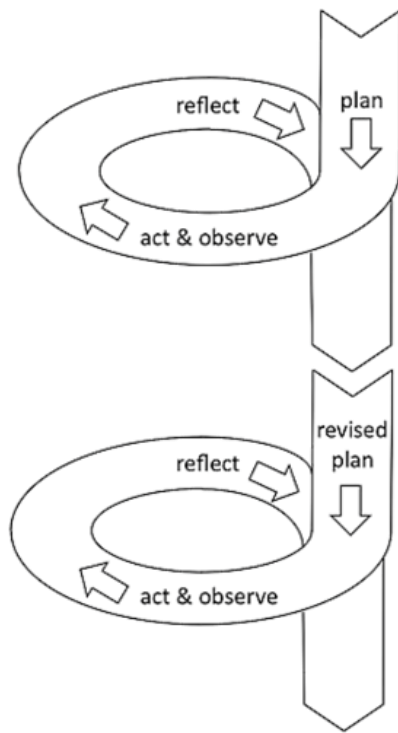


Figure 1: CAR cycles (Kemmis and McTaggart, 2000)

Demange et al. (2012) suggested collaboration between researchers and stakeholders was a motor of innovation. Research questions can actually arise from the input of professionals in the field (Bryant, 1995), rather than the researcher alone. This has been evidence in this thesis, with many subsequent research questions and studies directly resulting from collaborators input in earlier studies (for example, Study 7a exploring infection control resulted from hygiene concerns of stakeholders during Studies 4 and 5). Three key stakeholder groups were identified to become collaborators:

- Older adults and care home residents,
- Care home staff and management,
- Residents' relatives.

These three groups are directly implicated in future implementation of companion robots, either through being end-users, or responsible for assisting in use, purchase or maintenance. In line with CAR cycles (Nichols, 1997), these collaborators were engaged in

forming research questions (planning), collecting data (act and observe) and reflecting on research results. While these three stakeholder groups were chosen as collaborators, wider stakeholder groups have been included as participants through the studies included in this thesis, including H&SC professionals beyond care staff and roboticists as developers of companion robots. These additional stakeholder groups are less influential in the real-world adoption of devices, but are clearly relevant within the wider context.

CAR is not, however, without its challenges, some authors report doctoral students are advised to avoid CAR for their doctoral methodology, due to the complexity of enacting CAR in practice (Jiang, 2019). In particular, recruiting collaborators and participants can be more challenging than for other methodological approaches, as collaboration is usually longitudinal and cyclical in nature, requiring longer-term engagement than cross-sectional methods (Jiang, 2019). Alternative approaches include quasi-experimental designs, where participants are passive to the research process without active involvement, or ethnographic approaches, where participants are observed without interference (Jiang, 2019). In contrast, CAR actively involves stakeholders in the research process and as a result, is consistently cited as bridging the gap between theory and practice (Jiang, 2019). CAR can lead to feedback of results directly in to practice (Nichols, 1997). This improves likelihood of real-world implications, a priority due to the apparent lack of real-world implications for robot pet research to date.

As CAR tends to be pragmatic in nature (Bryant, 1995), it sits well within the pragmatism paradigm. The mixed-methods approach is also appropriate within the pragmatist paradigm. This project has given use and value to both quantitative and qualitative approaches when they are perceived as most appropriate, often combining both methods within a single study to gain empirical insight, additional to depth of understanding (Johnson et al., 2007).

In recent years, mixed-methods research has become recognisable and commonplace among the social scientific field (Timans et al., 2019). The flexibility allows for meeting the needs of the thesis overall and the studies within it. This intuitive approach to methodology is one of the appeals of pragmatism (Creswell, 2003). Molina-Azorin and Cameron (2010) suggest mixed-methods often provide broader perspectives than mono-method designs, and appear to have most popularity in psychology, sociology and health sciences disciplines. The use of mixed-methods can address the limitations of each individual method alone, with the weaknesses of each method offset by the other (Molina-Azorin & Cameron, 2010). Using different methods therefore, if results provide mutual confirmation, allows more confidence in valid results. Tashakkori and Teddlie (2010) suggest mixed-methods are superior in ability to answer confirmatory and exploratory questions simultaneously. This is relevant in companion robot research, a field in which much literature is available, and yet many conclusions require confirmatory research due to limited stakeholder involvement, small sample sizes, or issues of validity. Despite the prevalence of companion robot research, there are also literature gaps requiring exploratory questions, some of these include implementation models, comparison studies, and practical considerations, including hygiene, limited within the literature (Dodds, 2018; Koh et al., 2020a; Kachouie et al., 2014).

The aim of informing economical and improved companion robot design means this project also follows user-centred design methods. User-centred design links well with CAR, as a collaborative process, where end-users become collaborators engaged in all phases of a product development (Daly-jones et al., 2000). Similarly, in CAR, stakeholders are involved in all phases of the research (Nichols, 1997). Both CAR and user-centred design acknowledge that stakeholders can contribute expertise from their own perspectives (Daly-jones et al., 2000; Nichols, 1997). The user-centred design process is shown in Figure 2.

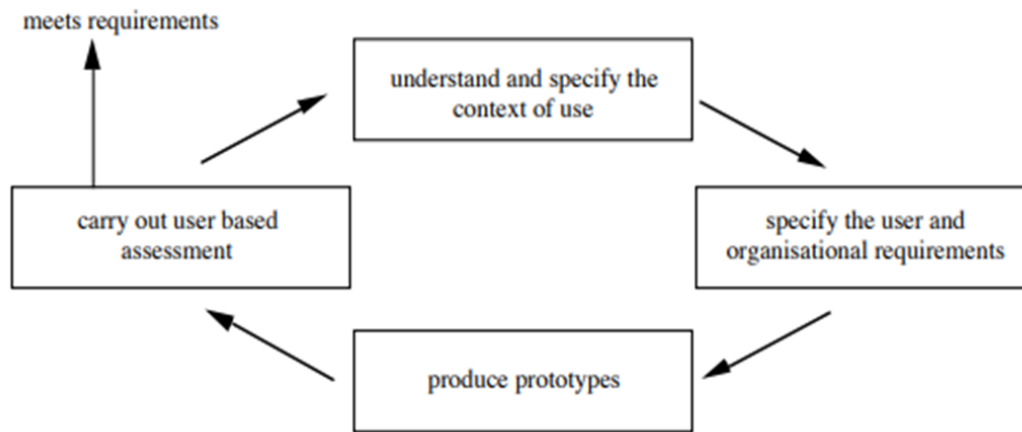


Figure 2: Key user-centred design activities (Daly-Jones et al., 2000).

In brief, the studies in this work relate to these activities as below:

- Understand use context: Study 1, 2, 5, 7a and 8,
- Specify user and organisational requirements: Study 1, 2, 3, 4, 5, 6 and 9,
- Produce prototype: Optimum available robot selected from Studies 3, 4, 6 and 7 and original prototype produced detailed in Chapter 5,
- Carry out user based assessment: User based assessment of optimum available robot in Study 10 and 11.

In Chapters 3-5 of this thesis, each study includes an explanation of which CAR process and which user-centred design activity it responded to, but the process is visualised in Section 2.4, demonstrating how outcomes from each study informed the subsequent work.

Following each completed study and CAR cycle, I aimed to feed user-centred feedback into design of a new prototype robot, through collaboration with a robotics company, Robotriks.

The design recommendations provided to Robotriks are detailed in Chapters 3-5, and the resultant prototype is described in Chapter 6. It should be noted, while CAR and user-centred design present in cyclical models, the real-world practice of both is more iterative and complex (Jiang, 2019). While this thesis involved three CAR cycles, the studies within those cycles iteratively moved between *planning/acting/reflecting* phases and user-centred design actions as required (Table 3).

Table 3: Iterative progress through CAR cycles, phases and user-centred design actions

CAR Cycle	Study	CAR phase	User-centred design action
1	1 + 2	<i>Planning</i> future research by establishing requirement and acceptability of SAR	<i>Understanding use context</i>
	3	<i>Planning</i> by establishing value in user-centred design for remainder of project, And <i>planning</i> Study 4 with collaborators	<i>Specify user requirements</i> <i>Inform prototype</i>
	4	<i>Acting and Observing</i> to collect data on <i>user requirements</i> <i>Planning</i> future research questions	<i>Specify user and organisational requirements</i> <i>Inform prototype</i>
	5	<i>Reflect</i> on interactions in Study 4 to inform implementation model <i>Planning</i> future research questions	<i>Understanding use context and specify user and organisation requirements</i>
<p>Cycle 1 supported the value of user-centred design. Cycle 1 also established initial robot acceptability and requirement, further to exploring <i>user and organisational requirements</i> and <i>understanding of context</i>. <i>Reflection</i> on results from studies in Cycle 1 informed studies in Cycle 2.</p>			
2	6	<i>Act and Observe</i> to explore the robot design and cost research questions raised in Cycle 1	<i>Specify user and organisation requirements</i> <i>Inform prototype</i>
	7a	<i>Act and Observe</i> upon hygiene research questions raised in Cycle 1 <i>Plan</i> hygiene procedure for use in Cycle 3	<i>Understanding use context</i>
	7b	<i>Reflecting</i> on prior work for implications during pandemic	<i>Understand use context</i>
	8	<i>Act</i> to explore ethical research question raised in Cycle 1 and <i>Reflect</i> with collaborators	<i>Understanding use context</i>
	9	<i>Reflect</i> on prior work (Cycle 1 and 2) to summarise design recommendations	<i>Specify user and organisation requirements</i>
<p>Cycle 2 was responsive to results of Cycle 1, exploring unanswered research questions raised by collaborators in Cycle 1. Reflection of all results to date (Cycle 1 and 2) informed selection of robots best matching <i>user and organisational requirements</i> and <i>context of use</i> for employment in <i>user-based assessments</i> (Cycle 3).</p>			
3	10 + 11	<i>Plan</i> Study 11 with collaborators <i>Act and Observe</i> real-world assessments of selected devices Final <i>Reflection</i> with collaborators	<i>User based assessments</i>
<p>Cycle 1 and 2 informed selection of most suitable robots for <i>user-based assessments</i>, and Cycle 3 responded with two studies exploring longitudinal, real-world use and impacts of these devices.</p>			

2.3: Analysis methods, validity and rigour

Analysis methods

Due to the mixed-methods approach to this doctoral project (Timans et al., 2019), analysis methods throughout this thesis have involved both qualitative and quantitative approaches. The qualitative analysis used consists of thematic analysis and content analysis. Braun et al. (2019), detail the process of thematic analysis, a form of analysing qualitative data, often in health and social sciences. Although thematic analysis has received some criticism in the past, perceived as lesser than phenomenology, ethnography or grounded theory (Nowell et al., 2017), it is now recognised as an appropriate analysis method in its own right (Braun et al., 2019). The sub-type of thematic analysis used was reflexive, in generating codes from explicit content, which evolve and adapt through considerable analytic work, to produce themes, representing an understanding of meaning across a dataset (Braun et al., 2019). Analysis was inductive, as researchers had predetermined aims to inform robot design and assess experience.

Our qualitative analysis also involved content analysis, which has a shared history with thematic analysis (Braun et al., 2019). Content analysis follows similar processes to thematic analysis, involving coding and categorising of textual information, however the frequency of occurrence is of additional importance (Vaismoradi et al., 2013; Elo & Kyngäs, 2008). Content analysis was selected for studies where it was deemed advantageous to have numerical understanding of the thematic patterns, further to the purely qualitative themes, particularly in informing user-requirements for robot design decisions, to ensure most generalisable robot appeal.

Descriptive and statistical analysis was also employed, in line with the mixed-method approach. Again, statistical analysis of survey results on optimum design allowed for

qualitative insight into desirable robot features to be quantified, allowing prioritisation of design features for robot developers. Further to quantitative analysis of design requirements, Cycle 3 of the CAR involved non-parametric analysis of psychometric scales to indicate wellbeing effects of robot use (Sheehan, 2012).

Validity and Rigour

Qualitative analysis was undertaken by two researchers, with initial codes compared and subsequent themes co-produced based on researcher agreement for both thematic and content analysis. The process of reflexive coding can evolve throughout analysis, with initial codes being split, combined or re-named as researchers develop conceptualisation of the data (Braun et al., 2019). Coding is open and iterative, and themes are not identifiable until patterns emerge in the codes, as conceptually founded patterns require critical depth of engagement with content (Braun et al., 2019). Neither thematic nor content analysis removes researcher subjectivity, however, the agreement of two researchers aids in the validity of a compelling interpretation of data (Braun et al., 2019). It is possible to quantify the agreement of two researchers using Cohen's kappa, however such level of control removes the reflexive nature of thematic analysis, discarding flexible principles, subjectivity and reflexivity (Braun et al., 2019). Consensus coding (without kappa analysis) does not reduce replicability of findings or impair rigour, but does allow for exploratory research. Additionally, authors have reported scepticism in reporting inter-coder reliability, failing to demonstrate objectivity of codes, showing only that two people can apply similar subjective interpretation to data (Vaismoradi et al., 2013).

Each of the studies conducted for this doctoral project provides explanation of the qualitative method undertaken, and full tables of initial codes and themes are provided within the appendices. This disclosure is essential in ensuring readers can determine the

credibility and trustworthiness of results (Nowell et al., 2017). Specifically, disclosure of full tables of evidence allows for confirmability (Nowell et al., 2017). The use of two researchers for agreement also improves credibility, as does the oversight of established researchers (the supervisory team), (Jiang et al., 2019), and the fact a number of the studies included in this work have already received peer-review for publication.

Regarding the quantitative analysis reports, the use of psychometric scales combined with qualitative data for assessment of wellbeing effects of robot interactions increases validity of conclusions, reducing subjectivity and allowing enhanced precision (Sheehan, 2012). The primary outcome scale selected in Study 11 of this project was the NeuroPsychiatric Inventory (NPI) nursing home version. The nursing home version has received limited discussion in literature, varying from the original NPI scale only through re-naming of the family disruptiveness score to the occupational disruptiveness score, increasing relevance in the care settings. The NPI tool has reasonably good content validity and internal consistency, with good test-retest and interrater reliability, although parametric tests are not deemed appropriate due to the scoring method (Lai, 2014).

Additional strengths of the studies conducted for this doctoral project include the high ecological validity of Studies 10 and 11, which report on longitudinal robot implementations in real-world care settings, under likely real-world adoption contexts. Additionally, Studies 1, 2, 3, 4 and 5 involved either video or audio recording of robot interactions and qualitative discussions. Recorded footage of robot interactions more accurately reflects the experiences under analysis than traditional observational notes (Asan & Montague, 2014). Furthermore, footage can be reviewed after the event to validate observations, missed information is reduced, and analysis can be conducted by multiple researchers, limiting observer bias, and improving overall quality of the analysis (Jones et al., 2015). In Studies 10

and 11, which are longitudinal in nature, I additionally report on experience sampling of staff observations of robot implementations. The experience sampling method (data collection triggered by an experience occurring), allows for ecologically valid appraisal of subjective experiences, and is reported to yield comprehensive views of activities likely to be difficult to assess using cross-sectional questionnaires, or interviews which can suffer from memory strains and aggregation (Verhagen et al., 2016). Supplementing post-study interviews with experience sampling of observations is therefore a strength of Studies 10 and 11, increasing validity of reported observations.

2.4 Structure of Project



Chapter 3: CAR Cycle 1 – Initial user-centred exploration

In the following chapters (3-5), all studies involved in this doctoral project are included. The majority of studies (10/11) have resulted in a paper for publication. For this reason, most studies are presented as complete papers, with some additional narrative provided above and below the manuscripts for context in the thesis. This creates some repetition in study introductions, but each introduction contextualises relevant literature for the aims of that study. All studies (apart from Study 1), were first authored by HB, with additional authors providing i) supervision, ii) specific expertise (e.g. microbiology), or iii) a second researcher for validity of qualitative analysis. I led on design, data collection, analysis and write up of all included studies, with the exception of Study 1 which has not been included in full in this thesis. As much of the thesis has been published with co-authors, for consistency between chapters (and papers) I sometimes use 'we' as the pronoun, referring to myself as PhD candidate and Principal Investigator together with my supervisors (and in some cases other colleagues). This thesis remains my work, just with the usual supervisory input.

In Cycle 1 of the CAR, Study 1 and 2 first began with establishing 'higher-level' acceptability of SAR, before moving to specific enquiry with end-users and care stakeholders (Studies 3, 4 and 5).

For Study 1 and 2, we thus first took the opportunity to explore any requirement or desire for SAR in H&SC generally. For any social robots to be accepted into practice, there needs to be acceptability among stakeholders to support their procurement and use. Gathering this 'higher-level' approval towards robot use in the sector is essential before more narrow research focuses, on robot pets for care homes. Even good acceptability of robots by older people in care homes would be hindered during procurement and implementation if

decision makers in H&SC were not first open to the idea of robots as tools within their sector and workplace (Moyle et al., 2016). Thus, Study 1 and Study 2 contribute to the *Understanding of Context* factor of user-centred design (Daly-Jones et al., 2000).

3.1 Study 1: Requirement of Socially Assistive Robotics (SAR) in Health and Social Care (H&SC)

(Collaborative work with Gabriel Aguiar, published Advanced Robotics)

This PhD project has been conducted alongside the University of Plymouth's EPIC project (Ehealth Productivity and Innovation in Cornwall and the Isle of Scilly), which aims to facilitate a sustainable eHealth sector in Cornwall (University of Plymouth, 2017). During workshops held by EPIC in 2017, initial research was conducted on views of relevant stakeholders in H&SC towards robotics within their sector.

Workshops were attended by 223 participants, including H&SC professionals, services users and students. During workshops, participants were able to engage with a range of SAR. Two papers have resulted from this research. The first paper for which G. Aguiar Noury is lead author, identified the challenges faced in health and social care with potential robotic solutions. This article is published in the Journal of Advanced Robotics although not included in full in this thesis (Aguiar Noury et al., 2019). A notable outcome was stakeholders acknowledging a key challenge in H&SC for providing social support and companionship, and noting potential value of robotics in meeting this need. This requirement related particularly to older and isolated individuals, and demonstrated possible usefulness for companion robots in responding to this challenge.

The second paper to result from these workshops formed Study 2, for which I was the lead author. This full paper is available below, and is currently under review. Once Study 1 had

confirmed a valid challenge for H&SC stakeholders related to social support and companionship, we next considered the acceptability of robots in meeting this challenge, and also began general enquiry into design requirements. While this study again looked at SAR more broadly than robot pets alone, the insight gathered is important for designers of robot pets and understanding the broader context of robot pet use, alongside other types of available SAR, who together could respond to a range of unmet needs in adult social care.

3.2 Study 2: Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions

(Accepted, Health Policy and Technology, accepted manuscript below following 12 month embargo, published version available from Health Policy and Technology).

Authors: Hannah Louise Bradwell*, Gabriel E. Aguiar Noury, Katie Jane Edwards, Rhona Winnington, Serge Thill and Ray B. Jones.

Introduction

Socially assistive robots: Health and social care (H&SC) faces increasing pressure (Moyle et al., 2017b), due to aging populations (Abdi et al., 2018) together with increases in dementia (World Health Organisation, 2019) and loneliness (Valtorta & Hanratty, 2012). Technology (Maguire et al., 2018), including socially assistive robots (SAR) (Broekens et al., 2009), may help address these pressures. SAR is a subfield of robotics including social, service and rehabilitation robots. The exact definition of SAR has been debated (Moyle et al., 2017c; Frennert & Östlund, 2014). SAR sometimes possess features of humans or animals (e.g. Paro (Moyle et al., 2017c)), to be perceived as a social entity (Broekens et al., 2009; Pu et al., 2019), and are usually autonomous robots aimed for benefits such as companionship, effective therapy, cognitive training, social facilitation and physiological therapy (Abdi et al., 2018; Winkle et al., 2018). However, others argue telepresence robots (e.g. Padbot),

assisting in social interaction through facilitating human-human contact should be included (Moyle et al., 2017c). Despite the lack of formal definition of SAR (Frennert & Östlund, 2014; Kachouie et al., 2014; Bemelmans et al., 2012), all SAR aid humans specifically through social interaction (Feil-Seifer & Matarić, 2005). Various ‘smart toys’ (e.g. JfA pets) may also produce wellbeing through social interaction (Study 10 and 11; Picking & Pike, 2017). Successful adoption however, depends on acceptability from end-users (Fink, 2012; Klamer & Allouch, 2010; Heerink et al., 2010). In this paper we adopt a compromise definition of SAR focussing on four devices; Pepper, Paro, Miro, and Padbot. Such an approach is reflective of van Wynsberghe’s (2013) interpretive flexibility, where a robot’s definition depends somewhat on context of use.

Acceptability research: A number of SAR have failed in this sector (Broadbent et al., 2009) and while detailed outcome-based studies among end-users are important they can also be time-consuming, expensive and may be made redundant if policy makers and influencers have negative attitudes to the technology. We need, therefore, an improved understanding of acceptance or rejection across a broad range of relevant stakeholders to inform design (Pino et al., 2015; Wu et al., 2014; Whelan et al., 2018). Assessing acceptability may be approached in different ways and we draw upon previous research (Frennert & Östlund, 2014; Klamer & Allouch, 2010; Broadbent et al., 2009; Forlizzi et al., 2004; Wu et al., 2014; Odetti et al., 2007; de Graaf et al., 2017).

The implementation of SAR in H&SC requires a network of people, organisations, users, scientists, engineers and designers to ensure design meets the requirements of those involved in adoption, purchasing and implementation in this sector. So acceptability research needs to engage with the ‘right’ stakeholders. Research such as de Graaf et al. (2017), who recruited a large sample of participants from the general Dutch population, is

informative but not so relevant to the British H&SC sector where we need to understand the views of our stakeholders, such as service providers, patients and service-user groups (Whelan et al., 2018; Odetti et al., 2007; Heerink et al., 2013).

Relying on conceptualisation, booklets and videos as examples of SAR instead of direct robot interaction has limitations in ascertaining stakeholder views, an issue with some prior work (Pino et al., 2015; Jung et al., 2017; Wu et al., 2014). Some studies are limited by demonstrating only one device (Odetti et al., 2007), and some studies assess acceptability through general observation (Odetti et al., 2007) rather than basing assessment on formal models (Pino et al., 2015; Heerink et al., 2013). Pino et al. (2015), included a range of stakeholders, used the Almere model (Heerink et al., 2010), which assesses older adults' acceptance of assistive social technology, but mainly used PowerPoint and booklet exposure to images, videos and descriptions of SAR, with only one prototype robot being demonstrated.

Context: Our work was carried out in the context of the University of Plymouth's EPIC project (University of Plymouth, 2017) aiming to develop the market for health products (including SAR) and to help develop Small to Medium Enterprises (SME's) located in Cornwall, South West England.

Aims: Understanding acceptability for each stakeholder group individually is the optimum approach for designing specific devices (Study 3), however, we aimed to raise awareness of SAR and to get an initial 'broad' understanding of perceptions, acceptability and any general issues needing addressing when considering H&SC contexts. In this paper we aim to provide an overall acceptability assessment across a broad range of stakeholders in Cornwall, gathered via live demonstrations of multiple SAR rather than passive materials, together with analysis based on an acceptability model. We distil the resulting insights into

consequences for future robot designs aimed at H&SC that developers may wish to consider.

Methods

Events and participants

We organised eight locality events across Cornwall UK offering real-world interactions with SAR to a broad spectrum of H&SC stakeholders who may influence policy and practice in the adoption of SAR. H&SC professionals may make purchase decisions, lead SAR interventions, and also impact perception of technology, positively and negatively (Broadbent et al., 2009). H&SC students represent future healthcare professionals. Their inclusion, although often ignored, is essential to capture sustainable needs and requirements, with future professionals predicted to support an even greater burden of population disability (Guzman-Castillo et al., 2017). Service users are target end-users in this context, while, SME's focused on eHealth and health technology represent current or future providers.

Researchers identified and approached current and future H&SC professionals from disciplines including domiciliary care, residential care, primary and secondary care, pharmacists, mental health, and health related charitable or formal organisations, including local Council representatives. Invitations were sent via email. Three universities with presence in the county advertised online to students. Service users were recruited through online and newspaper advertisements, support groups and public engagement events. Members of SME's relevant to health, eHealth and technology were also identified and invited via email. Participants who did not specify their category at registration were recorded as 'others.'

In total, 223 participants, 108 H&SC professionals, 34 services users, 24 students, 20 SME's and 37 'others,' were recruited using this convenience sampling.

Ethics

Favourable ethical approval was granted by the Faculty Science and Engineering Ethics Committee at the University of Plymouth.

Devices for interaction

We selected four SAR with potential application in H&SC: an expensive humanoid robot (Pepper), a telepresence robot ('Skype on Wheels') (Padbot), and two companion robot animals; Paro, a relatively expensive cuddly animal, and Miro, an entertaining floor-based robot (Figure 3). The selected four provide examples of varied functionality, aesthetics, features and abilities for comparison and comment, rather than an exhaustive selection of SAR.

Alternative animal devices were available in our exhibitions, including the JfA cat and dog, Perfect Petzzz sleeping dog and a knitted hedgehog. However, data recording focused on interactions with 'undisputed' robots (Pepper, Paro, Miro and Padbot).

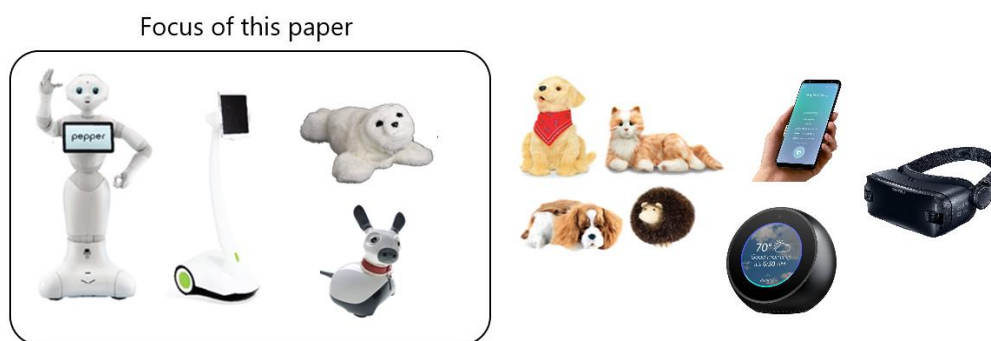


Figure 3 Devices available for interaction during exhibitions: Pepper, Padbot, Paro seal, Miro, JfA dog and cat, Perfect Petzzz breathing dog, handmade knitted hedgehog, mobile apps, Amazon Echo Spot, virtual reality equipment

Figure 4 shows a typical interaction station. Interactions with apps, virtual reality and smart speakers were often located elsewhere within the room, but were not included in this

research. Miro generally roamed autonomously on the floor, whilst Pepper and Padbot were stationed on the floor with one researcher (GAN). Paro was available on a table, supported by another researcher (HB). The alternative animal devices were displayed alongside Paro.

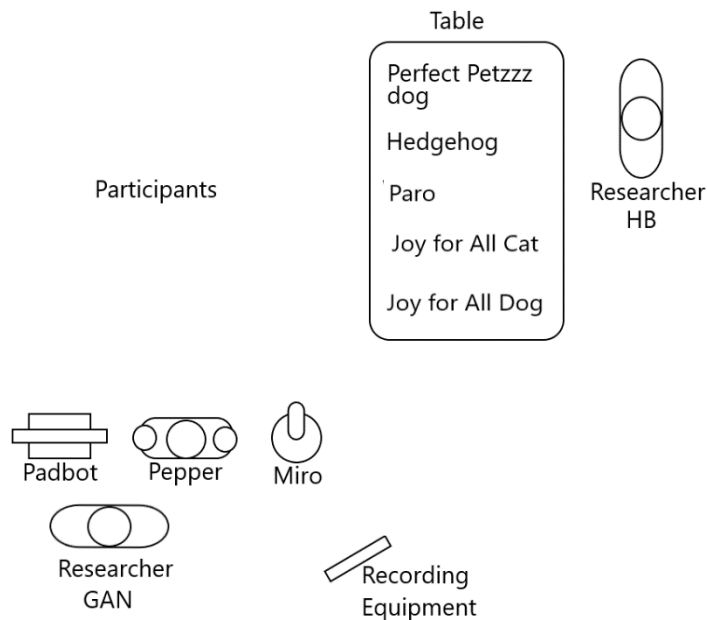


Figure 4: Typical layout of interaction stations

Procedure

The eight events comprised a buffet lunch and access for 40 minutes to a technology exhibition, followed by round table discussions. This paper reports on the exhibition. Two researchers (GAN, HB) operated stations where SAR were available for participants, in groups or individually, to approach, engage and discuss. Researchers demonstrated robot abilities, allowed participant interaction and answered questions. Interactions were video recorded, audio transcribed and collated with field notes. Participant identities were not known for analysis. While numbers within stakeholder groups could be calculated from registration details, participants were anonymous in video footage and notes, thus analysis

is conducted across all stakeholders, rather than between stakeholder groups. From recordings we estimate three-quarters (i.e. 160-170 people) interacted with the SAR.

Data recording equipment

Video recording equipment captured interactions between participants and robots. The camera was located at the interaction station supported by GAN, focusing on participant interactions with Pepper, Miro and Padbot. Some interactions with Paro at the second station are picked up in the periphery of data recording (Figure 4) but field notes captured additional comments, particularly about Paro.

Data analysis

We used the Almere model constructs for analysis of acceptability. This was created to measure acceptance of social robots with older adults (Heerink et al., 2010), thus the focus on elder care and social robots specifically was felt more appropriate than alternative, more general models (Momani et al., 2018). Our study involved observations of real-world robot interaction to assess acceptability based on unprompted opinions, so we did not use the questionnaire provided by the Almere model authors (Heerink et al., 2010) but instead followed other studies (Pino et al., 2015; Whelan et al., 2018) in using the constructs as a guide.

Transcripts were collated with field notes, both of which underwent content analysis, by two researchers (GAN, HB). Content analysis was selected for inclusion of frequency of theme occurrence (Vaismoradi et al., 2013), and involves systematic coding and categorising of text (Mayring, 2000). As prescribed by Elo and Kyngäs (2008), researchers undertook data immersion, coding, grouping codes, generating categories, and reporting, with a focus on manifest content. Identified themes were analysed for relation to Almere Model constructs,

to assess the degree to which collected evidence suggested acceptability. Researchers created tables displaying Almere Model constructs, related themes and evidence. From this we identified issues or design concerns among H&SC stakeholders that require addressing for implementation in this field.

Results

The four SAR seemed acceptable to our stakeholders as supported by the themes mapped on to the Almere constructs (Table 4). Participants saw potential in their use but raised practical issues for consideration. Below we explore this further. (Additional evidence regarding each Almere construct is available in Appendix B, discussed in the text below as Tables A-J).

Table 4: Content analysis themes mapped on to Almere Model Components

Almere Model Components	Themes (frequency)
Attitude towards technology	Likeability (24) Aesthetics (24) Intelligence (7)
Perceived usefulness	Comparison to known products (17) Mobility (13) Potential use (77)
Perceived ease of use	Ease of use (55)
Perceived enjoyment	Enjoyment (15) Humour (151)
Trust	Usability (18)
Intention to use	Ownership (17) Potential use (77)
Perceived adaptiveness	Adaption (5)
Anxiety	Fear (16) Damage (3)
Social presence	Anthropomorphism (17) Gendering (89) Objectifying (35)
Perceived Sociability	Friendliness (15)

Note: Frequencies represent the number of comments made providing evidence for each theme.

Attitude towards technology

This Almere construct refers to positive or negative feelings towards application of SAR, including making life more interesting, and being a good idea (Heerink et al., 2010). Our content analysis related themes were likeability, aesthetics and intelligence (Table A). The themes demonstrate predominantly positive attitudes towards the robots and their use, including aesthetics being *“friendly,”* responsiveness being *“clever,”* and evidence for likability. Many participants referred to ‘loving’ the robots, *“I love him [Miro],”* within seconds of beginning their interaction. Evidence for the intelligence theme in particular suggests SAR were perceived as ‘a good idea.’ The gaze following of Paro and Pepper was felt beneficial for companionship, *“it’s brilliant, for a companion, I feel like he’s looking right at me.”* One participant suggested she *“would visit [hospital] just to see”* Pepper, thus supporting potential for robots making life more interesting. However, some negative attitudes were evidenced through the aesthetics theme, some participants desired a soft shell, warm feeling and less robotic appearance to Pepper; *“change how hard it is, like if it was softer.”* Only one participant reported robots should be recognisably robotic.

Perceived usefulness

This construct is belief the system would be assistive, measured through participants feeling SAR would be useful to them (Heerink et al., 2010). Overall, our evidence supported this construct well (Table B) through participants identifying many potential uses for SAR and comparing robots to known products. Spontaneously discussed potential uses included; telehealth, delivering exercise classes and supporting physiotherapy, social support,

reducing loneliness/isolation, maintaining independence, providing entertainment, and medication or mindfulness reminders.

Limitations noted included Pepper's voice recognition with negative comparisons to other devices; *"it can't understand me, the Xbox has to learn me as well because I have a regional dialect."* This was a recurring concern as the limitations around voice recognition and accents could impair *Perceived Usefulness* in H&SC settings. Another limitation was mobility, with concerns around flooring irregularities in H&SC environments such as care homes, where carpets, rugs or steps may be more common than in hospital settings. Mobile SAR such as Padbot, Miro and Pepper could thus benefit from adaptation with *"bigger wheels"* for example, as suggested by one participant.

Therefore, although strong support was found for *Perceived Usefulness*, current limitations on voice recognition and mobility require practical improvements for successful implementation in a variety of H&SC contexts. These limitations were absent for Paro (who is portable but not mobile or verbal), and thus animal-based SAR may be more readily applicable

Perceived ease of use

This construct is the degree to which one believes use would be free of effort. More detailed evidence (Table C) suggests good support for this construct, *"that's nice and easy [Miro's app]"*; however concerns arose for Pepper, with participants commenting on the quantity of menu options and requirement for training; *"how long does it take [to] learn, [...] oh it's a bit too scary [...], do you need quite a lot of training?"* Generally, however, participants observed basic demonstrations (turn device on, use linked app), and then appeared comfortable and equipped enough to use robots with ease. This is a positive contributor towards acceptability.

Perceived enjoyment

Perceived Enjoyment refers to feelings of joy/pleasure associated with SAR use (Heerink et al., 2010). Themes which linked with this construct were enjoyment and humour (including laughing in response to SAR), due to the pleasure evidenced in both themes (Table D). All SAR provoked laughter and giggling during interactions, *“I think he’s [Pepper] wonderful actually [laughs] he makes you laugh.”* Evidence demonstrates clear enjoyment, pleasure and joy; *“he [Pepper] just cheered me up,”* thus strongly supporting this construct.

Trust

Our theme of usability (Table E) related to the Almere construct of Trust, defined as belief a system performs with personal integrity and reliability. Numerous questions were raised suggesting required *Trust* improvements, including battery life, *“if it [Paro] died, it could be unsettling for care home residents,”* further to accent interpretation, and internet connection. Due to concerns on battery life, *“standby”* modes and autonomous charging at *“homing stations”* were suggestions made to enhance reliability and therefore *Trust* in the system.

Intention to use

Our related theme to this construct was ownership (Table F), mainly representing occasions when participants mentioned taking/acquiring a robot for personal or occupational use, therefore representing *Intention to Use*; *“we could have him [Paro] in the staffroom,” “now I have to take it [Miro] home.”* Incidences were limited, however, referring back to *Potential Uses* could provide further support for this construct, as participants suggesting applications for robots could indicate an intention to use, should they have been able to.

Perceived adaptiveness

This Almere construct is the perceived ability of a system to adapt to a user's needs. Our theme of adaptation, although only present on five occasions, provided some evidence of participants querying adapting SAR to meet specific requirements (Table G), such as Pepper being adapted *"for somebody with dementia," "do you program it to what the persons needs are?"* Interestingly, such queries related only to Pepper, perhaps perceived as more easily adaptable due to the tablet and available apps.

Anxiety

This construct relates to systems evoking anxious or emotional reactions. Our related themes, damage and fear occurred three and 16 times respectively. Damage was felt relevant, as fear of damaging a device would likely provoke a negative response, *"[gentle touch] I didn't want to be too.. you know [Pepper]."* The evidence for damage related only to Pepper (Table H), perhaps due to participant anxiety on damaging a device perceived as expensive. Methods of reducing fear of damage may require further consideration for implementation in H&SC (Heerink et al., 2010). Paro was praised for feeling *"robust"* with the padding and fur, perhaps providing confidence in use and reducing *Anxiety* related to potential damage. Evidence for the theme of fear was also limited only to Pepper, *"it's worrying to have a conversation with a robot [Pepper]."* Whilst the majority of participants interacted with robots without displaying any anxiety, multiple incidences of fear were recorded for a few individual participants. Some evidence demonstrates preconceptions of robots, driven by media representation; *"what springs to mind is that sci-fi movie, taking over the planet, going rogue [...] making mistakes [Pepper]."* The damage and fear themes demonstrate possible barriers to acceptability of SAR for H&SC stakeholders. However, on balance, evidence for these themes is less prevalent than other themes. Nevertheless, the points raised should still be considered to reduce *Anxiety* and improve acceptability further.

Social presence

This relates to the experience of sensing a social entity when interacting with a system. Our theme supporting this construct was anthropomorphism, and the related theme of gendering/objectifying (Table I). Evidence of anthropomorphizing suggests participants attributed feelings to robots, even empathising with devices, *“are you having a bad day? [Miro].”* This supports participants feeling they were in the company of a social entity (Heerink et al., 2010), as would participant tendency towards gendering robots, *“she must be a girl with those eyelashes [Paro].”* There were 89 occasions of gendering, compared to 35 counts of objectifying. Viewing the robots as objects could provide evidence against *Social Presence*, whilst projecting a gender could suggest the robot is perceived as a being rather than a thing (Wu et al., 2014), therefore capable of social presence. Interestingly, all evidence for *Social Presence* was directed towards SAR with anthropomorphic or biomorphic design (Pepper, Miro, Paro), whilst Padbot received no evidence for anthropomorphism or gendering.

Perceived sociability

Finally, this construct refers to perceived system ability to perform sociable behaviour, measured through participants’ beliefs robots would be pleasant to interact with, talk to and be nice, further to feeling understood by the device. Our related theme was friendliness (Table J), including evidence of SAR perceived as nice, with a positive regard for sociable device interactivity, *“he’s very polite [Pepper].”* Participants often interacted in a manner indicative of believing the robot understood them, talking to them, commanding Paro and Miro, and engaging SAR as you would a living entity, *“be a good boy [Miro].”* The evidence also somewhat supports Pepper being a pleasant conversational partner, even considering conversational issues, participants appeared to find language mistakes endearing rather

than frustrating. The amusement gained suggests the available SAR were pleasant to interact with, although again evidence was lacking for Padbot.

Discussion

Acceptability of social robots among stakeholders

Based on the interactions of 160-170 stakeholders, the four SAR appear generally acceptable to H&SC policy makers and implementers, future implementers (students) and end-users. The variety of suggested potential applications demonstrates an open attitude for implementation of SAR in H&SC and strong potential for further robot development. This contrasts with the limited appreciation of social companionship reported by de Graaf et al. (2017) that may be a reflection of their use of a general population sample. Indeed, research with older people, care professionals and informal carers in the Netherlands, UK and France demonstrated requirement for development of robot social skills and behaviour (Bedaf et al., 2016), and some evidence suggests robot persona is a greater determinant of acceptability than embodiment (Huijnen et al., 2011). Our stakeholders suggested medication and mindfulness reminders, social support, reducing loneliness, maintaining independence, and entertainment as applications in line with the work of Pino et al. (2015). Telehealth, exercise and physiotherapy were additional uses seen in our study, with reminders, prompts and rehabilitation support also discussed in application of Pepper previously (Winkle et al., 2018). However, there were issues raised that designers and developers need to consider for general applicability to H&SC.

Design considerations

Our results would support use of soft, friendly aesthetics like Paro rather than 'robotic' aesthetics. Pino et al. (2015) reported mechanical human-like robots to be preferred, with both anthropomorphic and mechanical features. In contrast, soft/furry animal aesthetics

were felt most desirable for older people based on a review by Broadbent et al. (2009). The participants in our study generally desired less robotic aesthetics, contrasting Pino et al. (2015) with only one participant suggesting SAR should clearly resemble robots. This difference may be explained by our larger sample, wider range of stakeholders, and/or more hands on interaction. Furthermore, evidence for the construct of *Fear* was limited only to plastic-robotic Pepper, perhaps due to media representations of humanoids. Broadbent et al. (2009) suggested robot exposure most prominently comes from media depictions such as films and television. Support for this explanation arose in the current research. Softer aesthetics may thus receive a better reception in H&SC.

This study also supports use of anthropomorphic or biomorphic features to increase social presence. Broadbent et al. (2009) noted robot appearance was important for acceptability, and de Graaf et al. (2017) reported improving sociability as a key aim. Our study suggests including soft, friendly anthropomorphic and biomorphic design features would be desirable for aesthetic and tactile acceptance, distancing design from media influenced schemas of rogue mechanical humanoids. Sparrow (2006) suggested previously animal aesthetics were misguided and unethical, requiring deceit and delusion. However, we saw no ethical concerns on deceit raised. Although this indication does not provide sufficient comment on robot-ethics, our evidence would suggest rather than being misguided, adopting anthropomorphic or biomorphic design, further to soft shells, could enhance acceptability. Our results also suggest anthropomorphic or biomorphic design enhanced social presence, with no evidence for *Perceived Sociability* seen for the only SAR lacking such features (Padbot).

Additionally, adopting an androgynous design may avoid gender stereotype expectations. Previously the Broadbent et al. (2009) review suggested there is insufficient research to suggest an optimum gender for a robot. However as noted by Sjøraa (2017), applying a gender can be necessary to discuss the device. Our study suggests maintaining androgynous design may be advantageous, allowing participants to assign a gender of their choosing, due to the considerable debates on gender for our demonstrated SAR. Further support for androgynous design comes from research finding robots projecting 'uncommon' gender roles elicited more basic responses from users through perceptions of lesser knowledge than their gender role allowed, for example a female mechanic being perceived as less skilled than a male (Powers et al., 2005). Androgynous robot designs could therefore decrease misconceptions on robot ability resultant of social stereotypes on gender norms. This consideration could be particularly important when considering H&SC contexts, due to potential gender norms of doctors, nurses and carers (Stephens et al., 2016).

A further consideration noted was for improved voice recognition and accent interpretation, with issues raised regarding conversational fluency, accent interpretation and noisy environments. Pending advancements in voice recognition software, a potential solution is using other human-robot interfaces. Successful human-robot interaction would be key in ensuring usefulness of robots in H&SC. While technical issues appeared endearing to participants here, issues faced during real-world implementation would likely cause frustration. Indeed, van Maris et al. (2020) reported recently on older adults struggling to understand human speech from Pepper in longitudinal work, and subsequently blaming themselves for their poor hearing, which may have negative repercussions. Another considerations likely to become relevant in real-world H&SC settings is improved mobility for uneven floors, carpets and rugs, particularly for SAR to be implemented across a range of

H&SC contexts. Design considerations to account for varied and uneven floor surfaces seems a feasible alteration to improve acceptability specifically for this sector.

This study also identified importance of better perceived robustness of devices, to alleviate fear of damage. Devices might also aim for a long battery life or autonomous charging, as suggested by our stakeholders, to remove potential distress of a device 'dying.' Autonomous charging may also support ease of use. Generally, our evidence supports ease of use for the robots demonstrated, particularly for Paro and Miro, however some concern was shown towards usability of Pepper, with the quantity of options on the tablet appearing overwhelming for some. Options could be streamlined on app-based SAR dependant on intended setting to improve perceived ease of use. Improvements in verbal communication would also reduce the need for tablet based interaction with multiple apps.

Although the above recommendations are based on stakeholders' perceptions of the example robots, they provide important insight for designers into requirements of future robot developments. The data has identified potential uses developers may target robots at, design flaws in current robots to avoid, and improvements to be included to ensure usability specific to H&SC contexts. As identified previously by Broadbent et al. (2009) features of the end-user will also affect acceptability, including; age, needs, technology/robot experience, cognitive ability, education and culture. It may also be appropriate for future research to explore how well recommended features translate across different types of SAR, for example, research may explore if the preferential soft-fur embodiment is appropriate on a telepresence robot further to a robot pet. There were incidences of our participants requesting Pepper felt 'warm' or 'softer' to touch, thus this could be an interesting study.

Strengths

Our study addressed previous methodological limitations including; i) passive materials rather than live robot demonstration, ii) general observations without basis on acceptability model, iii) limited stakeholders included in small samples and iv) assessing acceptability with only one device. We gathered opinions from a larger number and wider range of participants than previous studies. Previous research has focused individually on end-users (Odetti et al., 2007), or primarily carers (Heerink et al., 2013), with other stakeholder groups such as students of relevant disciplines and related businesses appearing underrepresented. The physical demonstration of various types of SAR is a further strength of our study, allowing more comprehensive attitude formation from participants than acceptability research focused on only one type of SAR, such as an animaloid (Odetti et al., 2007). Finally, the live demonstration and hands-on interaction participants gained with the robots created more informed opinions and attitudes than demonstrations of robots through PowerPoints or booklets (Pino et al., 2015; Jung et al., 2017).

Limitations

The two external factors in the Almere model that impact acceptability and use, social influence and facilitating conditions, could not be included within our technology exhibition context. Heerink et al. (2010) also acknowledge moderating factors absent from the model, specifically age, gender, voluntariness and computer experience. These factors likely influence real-world implementation and demonstrate the need for further research. It would have additionally been interesting to assess design recommendations from each stakeholder group separately, and for stakeholders of different ages, however this was not possible with the data we collected. Although this limits understanding of design specific to each stakeholder group, robots first need designing for acceptability to service providers, purchasers and decision makers before they can enter real-world use. This paper thus

provides insight for a foundation design of SAR aimed at H&SC settings, such as care homes and hospitals, where implementation faces unique and specific challenges.

A limitation of the current study is the short interaction period, only 40 minutes at each event. It is possible there was a novelty effect present during these initial interactions (Kachouie et al., 2014; Sparrow & Sparrow, 2006). Research has suggested acceptance measured over longer periods of use allows for familiarisation and more informed attitudes towards the device, more predictive of actual use (Heerink et al., 2010; Broadbent et al., 2009). It is possible some variables may have a large effect on acceptability initially, but could have less impact following use over a longer period of time (Odetti et al., 2007). For this reason, some of the factors identified in the current research as impairing acceptability may not be an issue following real-world implementation and use, such as the theme of fear, which may have partially resulted from unfamiliarity with robots, and would thus ease over time. It is also possible additional barriers could arise unwitnessed during short interactions, or factors facilitating acceptance short-term are less relevant during real-world use. Furthermore, the evidence found in the transcripts supporting the concept of *Trust* is somewhat limited, and perhaps would be better established through interventional studies in real-world H&SC contexts. The group-interaction dynamics during exhibition could also have impacted results, through influences such as social desirability, conformity and collective effect. This method did however allow for data among a larger sample than much previous work in this area.

Conclusion

Our results suggest key stakeholders in the H&SC sector are open to the use of SAR in their field, as demonstrated by evidence in support of components of the Almere model of acceptability obtained from live interactions of a large sample of stakeholders with example

SAR, furthering previous research by responding to methodological limitations. The variety of potential uses identified particularly suggests participants saw potential for devices in this field. However, to be of most use, the general view suggests further design considerations were required. Improvements that could help ensure usefulness included: (i) improved mobility for uneven floors and carpets, (ii) improved voice recognition and accent interpretation, (iii) better ease of use (some concern for Pepper's usability), (iv) enhanced robustness and battery life or autonomous charging, (v) soft, friendly aesthetics (eg. like Paro), (vi) anthropomorphic or biomorphic design (non-robotic) to improve friendliness and social presence, (vii) androgynous appearance. The design considerations suggested need to be further explored in more detailed studies with end-users.

Study 1 and 2 reflection

Studies 1 and 2 were essential for the *Planning* phase of collaborative action research, in actively seeking H&SC stakeholder perceptions on i) requirement for social robots and ii) acceptability and design considerations on a broad level. The positive responses of participants supports the potential for companion robots and other forms of SAR to be implemented into H&SC practice. Study 2 also highlighted the particular acceptability of robots with animal embodiments, which of course is the SAR subtype of most interest here, further to demonstrating the two robot animals were perceived as easy to use, encouraging for future implementations and commencing Study 3. Of consideration, Study 2 did highlight the importance of robustness for robots to be useful in H&SC settings, alongside other design considerations, which was explored directly in Study 10 and 11. As 'higher-level' acceptability of robots for H&SC had now been attained, the project focus moved to robot pets specifically.

Study 3 involved exploring robot pet perceptions with older adults themselves, starting initially with older adults residing in supported living, and thus more independent than older adults residing in care homes. The decision was made by the research team to work with more independent older adults initially, to contribute towards the CAR approach, in order to attain older peoples' feedback (as collaborators) on the research method before completing a similar study with more vulnerable older people in care homes. Study 3 therefore contributed to the CAR phases of *Acting and Observing* (in attaining initial older adult perceptions) and *Planning* (in informing the design of Study 4). Regarding the user-centred design activities contributed towards, Study 3 allowed for *specification of user requirements*. The aim of Study 3 was also, in itself, to explore the value of user-centred approaches for companion robot design, as there was no previous work to this regard available. Study 3 therefore explored the value of taking a user-centred approach early in the doctoral project, and the results justify the use of this method throughout the thesis.

3.3 Study 3: Companion robots for older people: the importance of user-centred design demonstrated through observations and focus groups comparing preferences of older people and roboticists in South West England

(Published BMJ Open – CC BY-NC doi:10.1136/ bmjopen-2019-032468).

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Background

Life expectancy, and thus proportion of the population at retirement age or above, is increasing worldwide (Abdi et al., 2018). As human function deteriorates with age (Garçon et al., 2016), this creates a greater demand for services (Broadbent et al., 2009) while the numbers of health and social care workers decreases (Abdi et al., 2018), putting pressure on

health and social care resources (Moyle et al., 2018). Steptoe et al. (2015) suggested a growing need for research on maintaining wellbeing: while supporting physical functioning is often addressed, the psychological health of the aging population has received less attention (Farrand et al., 2016). Assistive robotics, whether rehabilitation or social robots (Broekens et al., 2009), could help in this respect and alleviate some pressure on health and social care resources (Broadbent et al., 2009).

Here, we consider companion robots – a subset of social robots often designed congruent with animal aesthetics and behaviours (Broekens et al., 2009; Moyle et al., 2013) that alleviate issues of traditional animal assisted therapy (Soler et al., 2015), including reducing risks for the animals themselves (Soler et al., 2015; Pu et al., 2019). A prominent example is Paro, the robot seal (Pu et al., 2019). Research has suggested numerous benefits of interacting with Paro, including reduced agitation and depression in dementia (Jøranson et al., 2015; Wada et al., 2005), more adaptive stress response (Saito et al., 2003), reduced care provider burden (Saito et al., 2003), and significantly improved affect and communication between dementia patients and day care staff (Liang et al., 2017). Paro may additionally reduce psychoactive and analgesic medication use (Petersen et al., 2017), and even decrease blood pressure (Robinson et al., 2015).

These positive results have however been questioned (Misselhorn et al., 2013). A comparison between an active Paro and an inactive one found benefits of the active robot were limited to engagement (Moyle et al., 2017a). One study (Robinson et al., 2013) found no significant improvement for depression (seeing a significant decrease only for loneliness); another (Thodberg et al., 2015) compared live dog visits to Paro sessions over 6 weeks, and found no improvement for depression with either intervention. Research assessing suitability of Paro for a dementia unit suggested it required adaptations; for example, its

vocalisations can be distressing (Robinsn et al., 2015). Finally, a large randomised controlled trial (RCT) found considerable variation in responses to Paro (Moyle et al., 2017a).

While this disparity may result from individual variability, it is also possible robot design factors may be impairing wider acceptance. Similar differences have been observed for other devices; for example, research on AIBO has both shown good acceptability (Odetti et al., 2007), and found it encouraged less interaction than a soft toy (Tamura et al., 2004). Meanwhile, a review of acceptability towards robots used in aged care suggests a number of robots have failed (Broadbent et al., 2009).

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 (Heerink et al., 2010). Furthermore, using robots in contexts they were not designed for can perpetrate negative perceptions of them and reduce acceptability (Moyle et al., 2018), which may explain some of the conflicting results on robot companions. User-centred design, in general, thus requires designers to have a deep understanding of those they design for, and to involve them in all stages of the process (Chammas et al., 2015).

Considering perceived requirement can vary between stakeholder groups (Orrell et al., 2008), as can technology acceptance (Pino et al., 2015), design requirements likely differ between varied groups of end-users, for example those with physical impairments (Green et al., 2000), children (Sandoval & Penaloza, 2012), or older people. Research should thus be specific to the aim of each robotic system. Generally, integrating user requirements and experiences into design can be difficult (Green et al., 2000). One challenge noted by Chammas et al. (2015) is the acceptance, recognition and incorporation of user-centred design in practice. Therefore, considering potential additional effort required, evidence

establishing the value of this approach might help encourage designers to adopt this type of methodology.

While little appears to be currently known about how older people perceive robots (Wu et al., 2014), one study explored meaning behind robotic pets with 41 independent older people (Lazar et al., 2016), finding robotic pets could provide social entertainment and interactions. While functional support was appealing, the fiction of robotic comfort was a potential tension (Lazar et al., 2016). Participants reported preference for soft fur and suggested play features as an improvement, currently absent from available companion robots. A limitation was the use of unfamiliar, often brightly coloured, child-orientated pets, restricting the range of features participants could inform perceptions on.

More generally, while older people and people with dementia are implicated in companion robot design, they are often not involved (Frennert & Östlund, 2014), even given a clearly identified need for ensuring devices adequately meet the needs of the end-users (Moyle et al., 2018). Instead, older people are often assigned stereotypical needs (Frennert & Östlund, 2014). When they are involved, it is usually through care providers, and at the end of the design process (Lazar et al., 2016).

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

Methods

Design

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

Patient and public involvement

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

Participants and settings

In total, 35 participants collaborated: 17 older people (5 male, 12 female, age range 60-99 years), and 18 roboticists (10 male, 8 female, age range 24-37). Older people were recruited at a supported living complex 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 moved through three interaction stations where participants

engaged in free interaction with a selection of robots or toys. Each station provided a different range of robot/toy features, aesthetics and abilities (Figure 5), and was filmed using two cameras. Non-interactive toys and devices with varying sophistication were included as comparison to the high sophistication levels of robots such as Paro. Paro and Miro were both setup as standard 'out of the box.' Participants spent 10 minutes at each station, with researchers present to assist and answer questions.









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

Figure 5: Robots and toys at each interaction station, and the associated features for comparison

After free interaction with all available robots and toys, participants engaged in semi-structured focus group discussions, guided by Key Questions (Table 5). Questions were informed by previous research (Heerink et al., 2011), amended only to include more features of interest and ensure relevance with end-users as opposed to care providers. Finally, participants were debriefed.

Table 5: Key questions used to guide focus group discussions

Key Questions
<ol style="list-style-type: none"> 1. Which of the animals did you like? What is it about those animals that makes you like them? 2. Thinking of designing a new robot for older people, what possibilities and properties should a suitable pet robot have? (e.g. Look, feel, abilities) <ol style="list-style-type: none"> 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 having a basic conversation? 5. The hedgehog is handmade, what are your thoughts on personalising robots; individuals designing or creating for personal preference of looks, feel and type of animal? 6. What do you think about how realistic or unrealistic the animal should be? How would you feel about a mythical animal? 7. How do you feel about life-simulation features? 8. Would you fancy having one of these animals yourself to keep, which one would you choose? (for roboticists – which one would you choose for an older person?)

Robots starting positions at each station (see Figure 6 for an example) were randomised, from left to right, to avoid introduction of bias. Researchers maintained a conscious effort to keep interaction unbiased, refraining from leading questions, and restricting their role to introducing animals and answering questions during free interactions. The procedure was maintained as much as possible between both settings. Roboticists were asked to think of the target audience of older people when responding to Key Questions.



Figure 6: Interaction Station 2

Materials

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

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

Data Analysis

Discussions at all stations were transcribed verbatim and analysed by two researchers (HB, KE). There were two sets of data for each setting, i) unprompted opinions based on comments and discussions during free interaction with the range of robots and toys, and ii)

focus group responses. Both sets of data were analysed separately with NVivo using content analysis to garner emerging themes. Content analysis was selected for inclusion of frequencies of theme occurrence (Vaismoradi et al., 2013), and involves systematic coding and categorising of text to garner trends, frequencies and relationships of words in discourse (Mayring et al., 2019). Researchers undertook a process of data immersion, coding, grouping codes, generating categories and reporting, as prescribed by Elo and Kyngäs (2008).

The results are reported in three sections:

- Section 1 provides the themes arising during content analysis of older peoples free interactions, giving initial insight into end-user requirements.
- Section 2 focuses on the themes from focus group discussions and features most commonly discussed by both groups in response to Key Questions (Table 5).
- Section 3 maps the relationship between older people's unprompted opinions and their focus group responses.

Results

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

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

Interactivity

The interactivity theme emerged on 185 occasions through codes: *interactivity, speech and talking, commanding the robot, fun, noises* and *interactivity lacking*, strongly suggesting

during live, unprompted interactions, older people demonstrated preference for interactive devices over non-interactive alternatives. The results also indicated eye contact, obeying commands and speech could be improvements on currently available devices.

Interactivity elicited positive comments from participants such as *"fascinating,"* (OP15) and provided a sense of achievement when a device appeared responsive; *"I got the cat to roll over!"* (OP16). Participants demonstrated most enjoyment when robots appeared reactive to the individual themselves, rather than producing random movements or sounds; *"fun isn't it!"* (OP6). In contrast, non-interactive devices provoked negative responses. The Perfect Petzzz dog was described as *"a bit of a disappointment,"* (OP6) as the dog *"doesn't do much"* (OP16) which may become *"boring"* (OP12) as *"you can't do more than pat its head"* (OP17). Perhaps surprisingly, participants also underappreciated the interactivity of Paro. The JfA animals were seen as highly interactive, despite more limited technological features, while Paro was described as *"on strike"* (OP7) because participants felt it *"just moves its head"* (OP3, OP1). Participants interacting with Paro sometimes displayed slight envy towards peers interacting with the JfA animals, *"you've done more with that cat than I got to do"* (OP11).

Despite enjoying interactivity of available robots, older people also expressed a desire for command response from robots during free interactions. The commands each animal received varied. Those directed at the JfA 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 JfA cat received similar requests including *"can you wag your tail?"* (OP3, OP1, OP8). Miro mainly received directional commands, *"turn around!"* (OP5-6, OP10-11, OP13, OP15, OP17-18) *"stop, turn, turn left, turn left"* (OP13) and Pleo received requests to play and eat; *"open wide, open wide, open up, that's it!"* (OP13).

Participants also repeatedly asked robots to *“look at me”* (OP5, OP7, OP16, OP15) suggesting facial tracking and eye contact could be a future interactivity improvement: Paro and the JfA animals received praise as *“special”* for *“looking right at”* the participant (OP2, OP4, OP13, OP17). Most frustration was noted commanding the non-interactive Perfect Petzzz dog, with 15 participants requesting or commanding the dog to *“wake up”* (OP1-6, OP9-13, OP16-18) or *“open your eyes”* (OP5-6, OP8-9, OP12, OP16). Participants reported limited appeal in an animal without responses, suggesting the non-interactive dog appeared *“dead”* (OP17).

Participants also demonstrated desire for robot speech, comparing devices to the resident budgie, and asking *“talk to me good boy”* (OP7) because it would *“be better than talking to myself”* (OP7). Another participant commented *“it’s the company [...] I talk to the furniture! [...] if you live alone you often don’t hear voices”* (OP13), and *“I like to talk to things [...] I think I just like to hear a voice”* (OP14). Another spoke to Pleo, saying *“I wish you could talk, yes I wish you could talk”* (OP16). Similarly, on 11 occasions, participants confused Miro’s electronic noises (not recognisable as specific animal vocalisations) with language, repeating, *“what are you saying?”* (OP5) *“you’re trying to talk aren’t you?”* (OP17) and *“I don’t know if it’s actual words or not”* (OP14). Upon understanding Miro’s noises were not *“actual words”* one participant described the robot as *“a dead loss”* (OP17).

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

Familiarity

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

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

In contrast, unfamiliar forms were perceived by older people as *"a toy"* (OP1) and more infantilising. During interactions with Miro and Pleo, one participant discussed preference for *"something, that to me, looks like something we've had, like dogs and cats and things, we've had dogs and cats you see"* (OP10). Participants showed clear preference for familiar forms, and realistic design, over unfamiliar when both were available; *"that is realistic [dog], we're not very likely to come into contact with one of them [seal]"* (OP5). Participants suggested seals were incongruent with their context, believing seals belong *"on the ice floats"* (OP4) or *"eaten with pepper sauce"* (OP4). The familiar animals were most often the devices praised for looking *"realistic"* (OP3), or behaving in a way that appeared *"very real"* (OP5).

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

Shell design

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

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

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

looked *“so real”* (OP1) suggesting the longer, shaggier coat felt more congruent with cat expectations.

Ownership

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

Naming was thought to relate to ownership, as naming a live animal occurs with possession, and signifies a developing relationship (38). Older people sometimes used names of previous pets, such as *“Milo”* (OP1) because *“they’ve got a cat called Milo”* (OP3). Other participants chose generic names, such as *“Fido”* (OP11) or *“Tigger”* (OP4) while some got creative with names like *“Shandy”* (OP7) because the dog *“is a mixture”* (OP7). Once older people had allocated a name, it endured throughout their interaction, *“are you wagging your tail for me Shandy?”* (OP7). Naming occurred mostly with the JfA cat and dog.

Further evidence for ownership came from a code of the same name. Ten older people commented on acquiring a robot during free interactions, such as *“do you know, I’d love this [cat], I’d love this in my apartment”* (OP2). Another suggested *“the service should have one [JfA dog]”* (OP6) with peers commenting in agreement; *“we’ll all go out and buy one now!”* (OP17). Of all occurrences, ownership was only shown towards the JfA 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 JfA dog, but requested a larger size as *“I don’t do little doggies”*

(OP16). The participant requested it “look like a golden retriever” because “it’s the only dog we’ve ever known” (OP16). It is possible evidence was limited during free interactions as participants were unaware of the possibility.

Section 2: Focus Group Results

This section presents the focus groups results as a numerical comparison between end-users and developers, to provide a clear understanding of any differences between the two groups. The features presented represent the most prevalent themes during content analysis of responses to Key Questions (Table 5). 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 6: The number of older people and roboticists providing positive, negative or non-responses for each feature and the resultant level of difference or agreement

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

Key: green = difference ≤ 4, orange = difference ≥ 13

Table 6 compares opinions of older people and roboticists towards design of companion robots specifically for older people. The largest divergences in opinions were noted for scores for realistic aesthetic, robots talking human language, personalisation of robots and familiar form. Older people and roboticists seem to agree on the need for interactivity and soft-fur in response to Key Questions 1 and 2 (Table 5). There also appears to be some agreement between the two groups on inclusion of life-simulation features and mythical design, although older people were generally more positive towards life-simulation and more negative towards mythical design. Some participants did not respond to every feature, resulting in lower numbers of responses for some features. Familiarity, life-simulation and mythical design received lower responses, possibly suggesting these features were less important, and thus participants felt less inclined to comment. However, this could also derive from the semi-structured nature of the focus groups, where realistic, familiar or mythical design were all discussed in relation to Key Question 10.

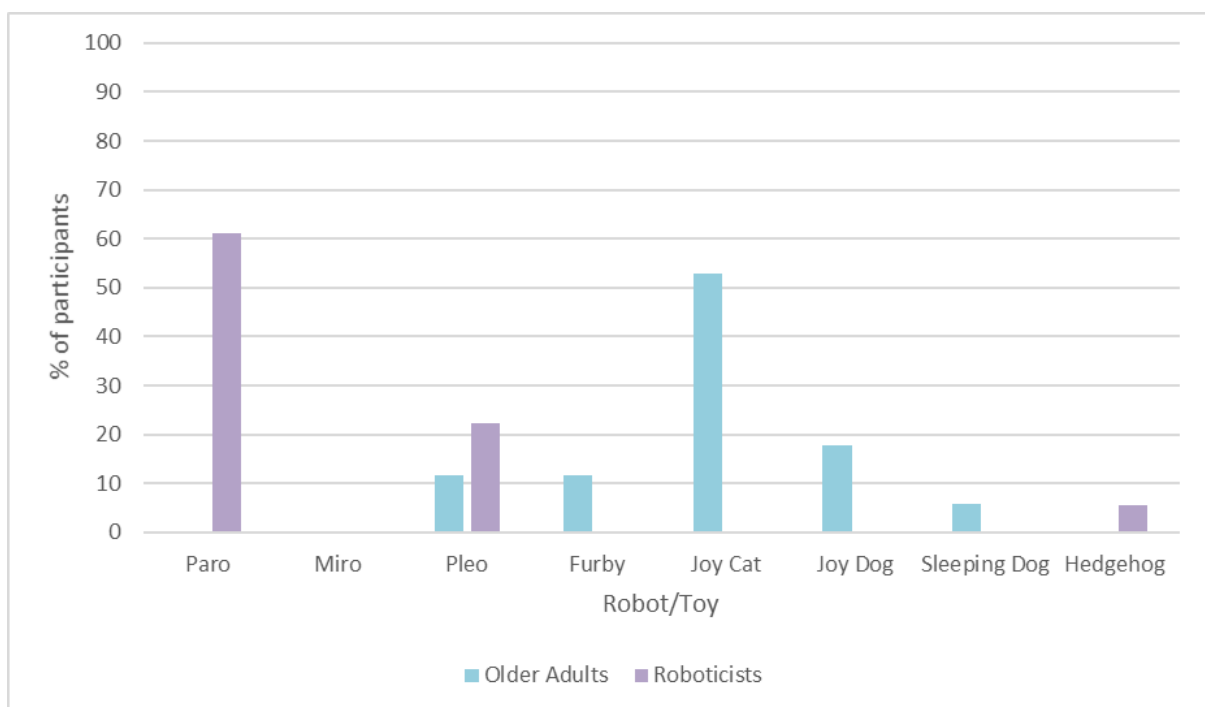


Figure 7: Choice of robot/toy for use with older people, shown by participant group

The preferred animal among older people in response to Key Question 8 was the JfA cat, with 9/17 (53%) participants selecting this animal (Figure 7), followed by the JfA dog. Paro, Miro and the homemade hedgehog were not selected by any older person. The preferred animal among roboticists was Paro (11/18), followed by Pleo the dinosaur, then the homemade hedgehog. The JfA dog and cat, Miro, the Perfect Petzzz dog and Furby were not selected by any roboticists, and some roboticists did not select any of the available animals.

Table 7: Examples of evidence from each group during focus group discussions

Theme	Example Evidence	
	Older People	Roboticists
Interactivity	<p>“If you’re sat there on your own, you want some reaction” (OP6)</p> <p>“That one [JfA 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 [...] 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>

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

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

“It’s quite a good idea, yeah I do, someone who’s got a particular animal” “We were talking about colours, I like that one, she’s always had black cats, It would be nice to have a choice of different colours” (OP13)

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

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

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

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

“It would make more sense” (R1)

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

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

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

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

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

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

“Maybe in five years time..” (OP16)

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

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

Life-simulation	<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>
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Table 7 provides examples of the different views of older adults and roboticists during focus group discussions, further examples can be found in Appendix C.

Section 3 – Relationship between Free Interaction and Focus Group Data

This section explores how the themes arising during unprompted, free interaction support the validity of the prompted focus group results (Figure 8): all older people who discussed interactivity (15/17, 88.24%) desired this feature for a robot pet. As seen in Section 1, this feature was highly valued by older people during free interactions, with many participants desiring additional interaction, such as obeying commands and talking. In the focus group theme of talking 12/17 (71%) older people felt positively towards robot speech.

Themes from older peoples unprompted free interactions

Themes from focus groups

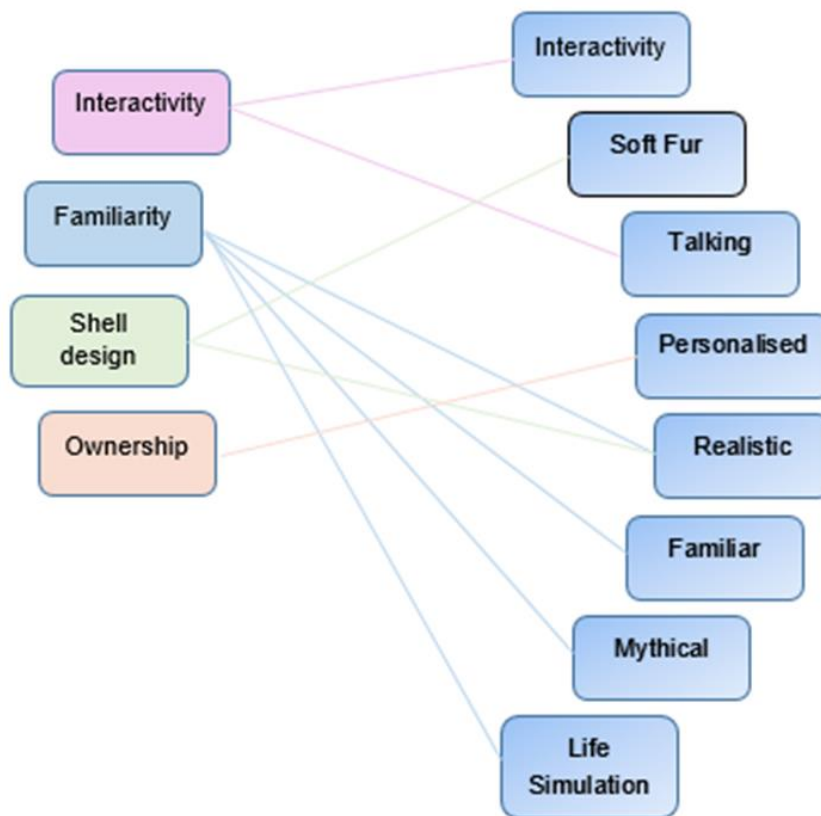


Figure 8: Mapping the relationship between older people’s unprompted opinions and focus group themes

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

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

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

Discussion

User-centred design is often cited as beneficial (Moyle et al., 2018; Chammas et al., 2015) but rarely used in companion robot development. The differing preferences of end-users and potential developers in our direct comparison demonstrated the importance of user-centred design when developing companion robots for older people. Our results justify additional effort for the reportedly difficult process of integrating user requirements into

design (Green et al., 2000), and may aid acceptability of user-centred design in practice (Chammas et al., 2015). Some of our roboticists felt user involvement in development could damage illusions of the robot, perhaps helping explain the minimal use of this process. However, rather than damaging illusions, adopting user-centred design may actually ensure devices receive adequate acceptability to promote use (Heerink et al., 2010). Future development of robots using user-centred approaches may result in more consistent positive outcomes than those previously reported for Paro (Robinson et al., 2015; Moyle et al., 2016; Thodberg et al., 2016; Robinson et al., 2013). Implications of improved design, acceptability and use would be significant given the potential benefits of companion robots for older people, those with dementia, and their family and care team (Jorason et al., 2015; Wada et al., 2005; Saito et al., 2003; Liang et al., 2017; Petersen et al., 2017; Robinson et al., 2015). Our results suggest strong acceptability and preference of the JfA cat and dog, and limited acceptability of Paro when these more familiar/realistic comparisons are available. This result is important given a lack of comparison studies of companion robots (Kachouie et al., 2014) and apparent selection bias towards Paro in research (Pu et al., 2019).

Further to highlighting the value of user-centred design, this study provided initial insights on end-user design requirements. Older people and roboticists both saw interactivity as important. Older people wanted interactivity for companionship, fun, and reduced loneliness through responsiveness. Some roboticists on the other hand raised concerns on over-stimulating older people. Our older adults displayed little interest towards non-interactive animals, whose lack of responsiveness appeared frustrating. This disinterest in unresponsive/inactive companions is congruent with the finding an 'active' Paro was more engaging than an 'inactive' Paro (Moyle et al., 2017a). While interactivity appears essential, our results demonstrated the advanced responsivity of Paro may be unnecessary. Despite

having fewer technological abilities, the JfA cat was perceived as most interactive, most likely because of its greater range of movements available, including animated head and legs, rolling-over, blinking and cleaning movements. Therefore, the range and variety of responses may be more important than the sophistication of sensors a robot possesses.

Our older people were interested in companion robots understanding and responding to simple commands. Use of commands is only briefly mentioned in previous literature (Lazar et al., 2016), and our findings appear contrary to a study (Klamer & Allouch, 2010) finding no evidence for the importance of enjoyment or playfulness factors among community dwelling older adults. Our group actively sought playfulness from robots, believing this would sustain enjoyment for longer. Responsiveness to simple commands such as “*paw*” could be a consideration for future robot design. Interestingly, there were fewer command expectations for the JfA cat than other robots, perhaps due to a reduced association between live cats and training versus live dogs. These expectations could be used to support use of an unfamiliar form such as Paro, whose design was aimed at reducing expectations (Shibata & Wada, 2011). However, older people still displayed command expectations for Pleo, Miro and Paro, (unfamiliar forms), disputing this theory. One could speculate the cat’s larger quantity of movements results in a reduced need to command actions.

Older people also positively evaluated the potential for human speech from a companion robot. These results contradict the suggestion that, congruent with the uncanny valley theory, human acceptability of sounds depends on the realism of the context (Jones et al., 2008). In one study (Komatsu & Yamada, 2011) participants related less to an AIBO dog beeping than a computer emitting an identical sound, perhaps due to contradiction in context between a dog and a beeping noise, thus suggesting animal sounds would be most acceptable for animal robots. Our results, however, indicated positive attitudes towards

speech capabilities for provision of company. Frennert and Östlund (2014) reported developers were influenced by stereotypical perceptions of older people as lonely and fragile, but failed to incorporate requirements of participating older people into design. Our group of older people thought loneliness could be eased through devices capable of simple conversation. This could be a user-driven improvement to currently available companion animals if our results are replicated in wider samples. It is possible, however, this feature will be evaluated differently in future research with a sample of cognitively impaired older people. Our participants were cognitively intact and therefore aware of the artificial nature of the robots or toys; older people with dementia may find the incongruence of human speech from an animal less acceptable.

Eye contact was a further improvement desired by older people, some of whom were disappointed when robots failed to look towards them. Gaze following may increase social relevance of the robot. This may be particularly true when eye movement is intentional rather than random (Abubshait & Wiese, 2017). While the pre-programmed movements of the JfA cat were positively evaluated, intentional gaze following may be an improvement for optimal social companionship. The importance of improving sociability for robot acceptance was noted before (de Graaf et al., 2017), and this addition of apparent social behaviour could improve acceptability.

Most older people preferred soft, cuddly fur for the outer shell. Our group of roboticists generally agreed, although both groups raised concerns regarding hygiene in comparison to a hard shell. This corroborates previous findings on care providers' preferences for robots aimed at their older service users (Heerink et al., 2013; Jung et al., 2017), although others have reported older people's preference for mechanical design on robots (Pino et al., 2015). These results may reflect the broader range of socially assistive robots used (machine-like,

mechanical, human-like and animal-like robots); however, results generally imply a robot should indeed be recognisable as robotic (Pino et al., 2015). One study (Robinson et al., 2013) also reported a family member demonstrating stigma towards his father interacting with soft-toys, suggested potential gender barriers with soft, cuddly robots. Our study found no notable difference between males and females, and suggests companion robots for this market should use soft fur in the design. Providing the optimum tactile characteristics are particularly important considering evidence suggests touch is one of the most important modalities of interaction for dementia patients, creating a natural method to engage with animaloid robots (Shibata & Tanie, 2000).

Considering the importance of tactile characteristics (Jung et al., 2017), a further feature for consideration in future development is life-simulation, another capability positively evaluated by older people, but lacking from current examples including Paro. Our research supports the previously reported (Jung et al., 2017) assumption of care-providers that a simulated heartbeat would be a valuable addition to Paro, but additionally demonstrates older people themselves also valued life-simulation features, including simulated heartbeat, simulated breathing and the feeling of purring. Older people even suggested warmth as an additional feature. This result appears congruent with older adults' desire for a realistic, life-like companion.

A realistic, familiar animal form was a definite aesthetic requirement for our group of older people. This was also reflected in their choice of JfA cat as their preferred device, as a familiar, realistic option, with Paro not selected by any older adult. Previous research focusing on opinions of care providers revealed criticism of Pleo for lack of familiarity (Heerink et al., 2013), while the intentionally unfamiliar Paro (Shibata & Wada, 2011) is the most often utilised companion robot in research (Pu et al., 2019). The end-users in our

research thought Paro, like Pleo, was too unfamiliar. The most familiar animals, the JfA cat and dog, were preferred for being more relatable and congruent with the contexts in which older people lived. The unfamiliar forms appeared incongruent and infantilising, perhaps explaining the tension Lazar et al. (2016) found towards their selection of unfamiliar animals.

This is relevant insofar as some companion robots, such as Paro, are intentionally designed using unfamiliar forms to avoid the robots failing to meet expectations (Shibata & Wada, 2011). Most of our roboticists followed this line of thinking and responded negatively to familiar animals, unsurprisingly selecting Paro as their preferred companion robot. It is further likely the roboticists appreciated the advanced technical capabilities of Paro, but our study suggests such sophistication may be unnecessary for older people. Research conducted 19 years ago also suggested older people disliked the feel and behavior of a robot cat compared to real cats (Shibata & Tanie, 2000); however, currently available robotic cats are likely more realistic than the Tama OMRON Corp cat used in that study.

The preference for realistic and familiar robots may result from relatability, with older people perhaps having personal experience of cats and dogs given the prevalence of ownership of these species (Murray et al., 2010). 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 JfA cat and dog more often than alternatives suggests familiarity may additionally help facilitate a sense of ownership. Thus, our results imply, rather than being problematic (Shibata & Wada, 2011), 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 (Hsieh & Want, 2003). Reminiscence therapy uses memories, feelings and thoughts from the past to facilitate pleasure (Elias et al., 2015). 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 (Pino et al., 2015; Heerink et al., 2013), but has not been explored directly with end-users. Our older people positively evaluated a more person-centred approach to robot aesthetics, praising the potential to interchange robot 'skins' to match personal preference. It is possible personalised robots would be more acceptable than a single design for all users. This could alleviate some disparity in response to Paro, as seen in previous RCT research (Moyle et al., 2019).

In contrast, our roboticists underestimated the value of personalisable aesthetics, and failed to predict older people's desire for human speech and life-simulation features. The transcript evidence suggests roboticists had an awareness of Mori's (2012) uncanny valley hypothesis. This is not surprising given their field of interest, and it is possible this, and related literature, had influenced roboticists' views on robot design to favour unrealistic and unfamiliar forms, and to undervalue life-simulation features that would undoubtedly increase the realistic impression of a robot.

Although our study was limited by recruiting older people from just one setting and roboticists from one University (although from varied educational and occupational

backgrounds) we found marked differences in their views that need to be accounted for in the development of companion robots. If creative methods of coproduction are used (Easton et al., 2019), both groups would need to think more about why they liked certain features and it is likely they would develop a new product that would be owned by this co-design group. Although there are no guarantees, a product so designed might have a higher chance of being liked by the wider population of older people.

Our study recruited older people from a retirement complex and the generalisability of their views to care home residents is limited. Our finding of the acceptability of such devices among a more independent sample is in contrast to previous research which implied more independent older people felt 'too able' to use robots (Pino et al., 2015). Thus, there may be a market among this more independent sample that has previously been underestimated.

Another limitation of our study was the short interaction time of ten minutes at each station, providing initial preferences. Research has suggested acceptance should be measured over longer periods of use, allowing for familiarisation and more informed attitudes towards the device, which may be more predictive of actual use (Wu et al., 2014). Future longitudinal research is therefore required exploring how these initial preferences develop over time, to assess any differences in loss of engagement, or wellbeing outcomes. Our interaction period was however longer than previous research where participants only interacted with each robot for one minute (Heerink et al., 2013).

Our study's smaller group sizes compared to previous research (Heerink et al., 2013) may have limited influence of social desirability bias or group dynamics. The small sample size, and small numbers of responses to some features during focus groups, is a further limitation. On the other hand, use of qualitative, free interaction transcriptions increases

confidence in our focus group results, even where response numbers were low, as preferences were often evident through unprompted interaction.

An important strength of the current study is the active participation of older people themselves. Some previous research exploring design features of companion robots for older people focused mainly on care provider opinions (Pino et al., 2015; Jung et al., 2017). 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 (Lazar et al., 2016), providing a varied array of features of interest and allowing older people to provide truly informed opinions.

Conclusion

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

currently included as standard on companion robots, such as eye-contact, life-simulation features, personalisation, obeying commands and the potential for interactive language.

Study 3 reflection

Study 3 provided initial insight into older people's preferences and requirements from a companion robot, and demonstrated the value of user-centred design in this context, considering the large variation in design perceptions shown between end-users and developers. Study 3 demonstrated some interesting features with potential, including eye contact, personalisation of robots, talking human language and life-simulation, further to soft fur and realistic and familiar embodiment.

Although Study 3 demonstrated the importance of user-centred design, the study had a small sample, and its likely care home residents have somewhat different perceptions to the older adults in supported living, meaning further research was then required to ascertain user driven design requirements from older adults in residential care. Study 3 thus led to Study 4, the methodology for which was discussed with the older adults in Study 3 as part of the CAR approach. Following data collection, all older adult participants in Study 3 were asked to comment on the methodology, and how well they felt it would translate to a care home setting. Collaborators noted use of one table rather than three (and moving robots rather than participants), would be an improvement for care home residents, who were likely frailer and less mobile, but otherwise were happy with the methodology and focus groups.

Study 4 therefore furthered Study 3, and responded to the identified literature gap noted by Kachouie et al. (2014), on the lack of comparison studies within the companion robot literature. Study 4 makes an important contribution in this regard. Concerning the CAR

approach, Study 4 focused on *Acting*, in being an important data collection opportunity to inform user-centred design of future companion robots. With regards to the user-centred design actions, Study 4 again contributes towards *specifying the user requirements*.

3.4 Study 4: Acceptability and design preferences of older adults in care homes towards eight forms of companion robots: A user-centred design approach to informing future robot development

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Table 8: Breakdown of participants to gender and stakeholder group

Table 9: Breakdown of participants from the five care homes

Figure 9: Robots used from left to right, Paro, Miro, Pleo rb, JfA dog, JfA cat, Furby, Perfect Petzzz dog, Hedgehog

Figure 10: Question 1, preferred device

Figure 11: Question 2, reason for preference

Figure 12: Question 4, preferred feel of a new device

Figure 13: Question 6, features to avoid in new robot

Figure 14: Question 7, opinions on a new device speaking human language

Figure 15: Question 10, which device would participants keep for residents use

Study 3 and 4 reflection

Study 3 and Study 4 aided in ascertaining a list of design features, requirements and embodiments that had received interest among stakeholders. The results of these studies have implications for future robot designs, in informing developers of possible features to include. These studies also highlight an issue with the current selection bias towards Paro in research, as the unfamiliar embodiment is undesirable to older people, and actually creates a worrying response (making individuals feel ‘nuts’ or ‘like fools’). From this information, we can suggest that developers can thus respond to the identified design requirements, although questions remained around appropriate robot size and weight, and hygiene was raised as a concern.

The discussions on hygiene were furthered in Study 5, which also aimed to respond to suggestions in the literature that Paro is too expensive for real-world use by exploring price and procurement with stakeholders directly, a further literature gap responded to.

With regards to the CAR approach, Study 5 fits within the *Reflect* phase, as care home staff and managers reflected on their observations of residents engaging with robots during Study 4, and subsequently discussed and debated potential real-world procurement of devices for their own settings. Study 5 was also key in the CAR aim to bridge the gap between research and practice. Despite abundant research on companion robots, there was limited evidence of their real-world use, and a lack of literature exploring the practicalities of such (Koh et al., 2020a). Considering the user-centred design actions, Study 5 returns to providing an *understanding of use context*, but also contributes towards *specifying organisational requirements*.

3.5 Study 5: Implementation model for companion robots in care homes: Initial insight into the understudied factor based on views of key stakeholders

Introduction

Worldwide, the health and social care (H&SC) sector is under increasing pressure (Moyle et al., 2017a), with greater demand for services (Broadbent et al., 2009), partially due to the aging population and increasing life expectancy (Abdi et al., 2018; Broadbent et al., 2009; Moyle et al., 2018) as human function deteriorates with age (Chatterji et al., 2015; Garçon et al., 2016). The challenge is further exacerbated by declining H&SC workforce numbers (Abdi et al., 2018). Researchers have thus become interested in implementing assistive robotics as a supporting strategy (Broadbent et al., 2009). Here, we are interested in companion robot pets, designed congruent with animal aesthetics and behaviours (Broekens et al., 2009; Moyle et al., 2013). Paro, the robot seal, is the most well-researched example (Pu et al., 2018). Such devices can create wellbeing benefits for older adults, people with dementia and stakeholders in their care, including; reduced agitation and depression (Jøranson et al., 2015) for residents, more adaptive responses to stress (Saito et al., 2003), reduced care provider burden (Saito et al., 2003), and significantly improved affect and communication between dementia patients and day care staff (Liang et al., 2017). Furthermore, Paro has been reported to reduce psychoactive and analgesic medication use (Petersen, 2017), and even decrease blood pressure (Robinson et al., 2015).

While there has been abundant research on acceptance of social robots, and impact of such devices (Moyle et al., 2016; Moyle et al., 2017a; Odetti, 2007; Pino et al., 2015), less research has focused on the companion robot market, or considered stakeholder perceptions on procurement of devices. Research exploring real-world procurement is essential to bridge the gap between companion robots being a well-researched and

potentially beneficial tool, and being a device with real-world impacts and implications to practice. This literature gap appeared true for various robot types (Belanche et al., 2020; Landscheidt et al., 2018), and would have implications for developers and businesses working in this field, particularly if results prompted use of a new business model. New business models can offer opportunities and possibilities for small and medium sized enterprises (SME) (Landscheidt et al., 2018). Currently, companion robot procurement occurs through a traditional product-centred sales concept, as with the general robot market (Landscheidt et al., 2018). However, it remains unclear if this model is the optimum approach for successful and wide-spread implementation considering the intended end-users are care home residents. Exploring stakeholder perceptions on procurement models for companion robots is of value considering the expected increase in reliance on technology in H&SC (Maguire, 2018).

Previous research has documented challenges with current companion robot procurement, for example, the cost of Paro at ~£5000 makes this device unattainable for adoption in most care homes (Moyle et al., 2016). Although Mervin et al. (2018) demonstrated Paro can provide a cost-effective intervention for agitation in older people, stakeholders we have spoken to reported that the initial outlay is too much, congruent with concerns of care staff in previous research (Moyle et al., 2016). As noted by Moyle et al. (2016) staff reported nursing homes lacked such funds, and thus were unable to introduce a Paro into practice. The prohibitive price and traditional product-centred sales model thus limits the number of care homes able to benefit from the robot (Moyle et al., 2017a), particularly impacting people of lower socioeconomic status, who would be denied the potentially therapeutic tool (Chiberska, 2018; Huschilt & Clune, 2012). Affordability of companion robots is additionally a key concern of family members as stakeholders in the care of older relatives care

(demonstrated in Study 8). Alternative platforms vary in price (e.g. NeCoRo originally ~£1250, AIBO ~ £2300, JfA cat ~ £100), however the literature is lacking any stakeholder driven understanding of appropriate costs or alternative business models, which would be highly influential in real-world purchase and adoption decisions. In general business modelling, there is increasing interest in the combination of physical product and ongoing service, a product/service system (PSS) (Landscheidt et al., 2018). It is possible such a model could be desired or required by aged care stakeholders, but research to this regard has been lacking across a number of areas of robotics (Belanche et al., 2020; Landscheidt et al., 2018). For businesses to succeed, particularly PSS models, they need to understand what is required to meet their specific customers' demands (Barquet et al., 2011), with model design depending on the components and services required for successful implementation (Landscheidt et al., 2018).

An understanding of stakeholder perceptions on procurement price and models for real-world robot adoption could be highly beneficial for robot businesses, allowing manufacturers to increase the market size (Landscheidt et al., 2018). Specifically, we are unaware of any existing literature exploring methods of real-world adoption with relevant stakeholders in older adults care. We therefore aim to provide some initial understanding from aged care stakeholders in this exploratory study. Any insight which may help improve real-world implementation of companion robots could benefit older people and the care sector due to the reported benefits (Jøranson et al., 2015; Petersen, 2017; Wu et al., 2016).

Method

Participants

In total, 29 care home staff, and 10 resident relatives from five different care homes participated in Study 4, 29 of these participants chose to debate implementation models.

This exercise forms Study 5. Seven of the participants were family members, and 22 were staff members, of which, five were care home managers and the rest were care staff, activities coordinators or deputy managers.

Procedure

Care home managers, staff and resident relatives observed residents interacting with a range of devices (Figure 16), then completed interviews to discuss their perceptions. The interview also included discussion on design and robot features (Study 4) but here we focus on the discussion surrounding implementation of companion robots into care homes. The observation of resident interactions provided first-hand experience to participants on adopting robots into their setting, including initial reactions of residents, group dynamics, challenges and benefits, to provide more informed reflections on their views towards implementation. The audio-recorded interviews were semi-structured, with conversation points including:

- Stakeholder perceived appropriate price for a companion robot,
- preference for purchase or rental models,
- and challenges or considerations they observed.

Materials

Stakeholders observed the residents within their respective homes interacting with a range of eight companion robots or alternatives (Figure 16). Recording equipment was additionally used for data capture.



Figure 16: Devices residents interacted with, from left: Paro, Miro, Pleo, JfA pup, JfA cat, Furby, Perfect Petzzz dog, handmade knitted hedgehog.

Data Analysis

The interviews were transcribed and analysed using content analysis, which involves systematic coding and categorising of text (Mayring, 2000), as prescribed by Elo and Kyngäs (2008).

Results

The discussions produced five key themes; lease model preference, permanent availability, rental benefits (services required), multiple devices and affordability. The themes are explored below. Participant UID's are presented following quotes, the five care homes are coded Homes_1 – 5, S represents staff, F represents family, followed by the participant number.

Lease Model Preference

Our stakeholders demonstrated clear preference for a PSS type, leasing model for the real-world procurement of companion robots into care homes. Ten of our stakeholders commented on the benefits of a continuous lease model, with others nodding in agreement; *“I would want to rent”* (Home_5_S4), *“a sort of lease arrangement”* (Home_4_S1), *“rent [...], I think that would be best”* (Home_2_S1). In contrast, only four stakeholders demonstrated any interest in the purchase model, mainly due to concerns on devices availability; *“I'd say buying, because people who really like them [...] would appreciate it all the time”* (Home_1_S1), *“they'll feel a bit more attached [...] knowing it's theirs, rather than [...] they've got to give it back”* (Home_2_S3). The rental method was preferred due to stakeholder reflections on the services required to keep the robots in practice.

Rental Benefits (services required)

The services desired through a potential PSS system became clear, particularly, stakeholders demonstrated concern around devices becoming “*broken*” (Home_5_S4). Investing in an expensive platform for contexts where breakages and damage is a concern certainly appears to be a barrier against purchase investments; “*if a care home brought it and it broke, then it would stay broke!*” (Home_2_S1). In contrast, leasing appeared to provide a solution to this barrier, “*because if you rent it and it breaks you get repairs*” (Home_2_S1), or the company “*could replace it*” (Home_5_S4). In relation, stakeholders identified the desire for “*some kind of insurance*” (Home_4_S2), with the potential for damage in this context a real concern; “*if they came back a different colour with a leg missing would you complain*” (Home_4_S3). Stakeholders also shared concerns around “*hygiene*” (Home_4_S1) and infection control, “*cleaning is another important factor, imagine a cup of tea, that would be very necessary*” (Home_5_F1). A solution suggested was a recommended “*cleaning regime*” (Home_4_S2). It was therefore desirable for a company to provide a service around “*maintenance*” (Home_5_F1), “*maintenance and breakages, we’d like that*” (Home_4_S2).

Permanent Availability

Our stakeholders also highlighted any lease arrangement would need to be continuous. Requirement for permanent availability was highlighted by nine stakeholders, “*renting per week or per month*” (Home_5_S4), to ensure permanent availability of devices, as concern was demonstrated towards devices been being taken away “*one week and then it was gone*” (Home_5_S7), which “*could be distressing*” (Home_1_F2) and create “*panic*” (Home_5_S8) for residents. The stakeholders were particularly aware of this potential distress having observed positive interactions of their residents with the devices; “*people like [resident], she, you know, she’s getting quite attached in there*” (Home_1_S1). The

importance of permanent availability was further highlighted through stakeholders continued concerns on breakages. One stakeholder suggested *“they should certainly [...] be available all the time, even on a rental, if one needed to go for repair, a substitute could be provided, a courtesy one, in case residents became upset”* (Home_1_F2), *“seeing the good they do, you couldn’t take it away”* (Home_1_F2).

Multiple devices

Requirement for multiple devices was noted by 13 of our stakeholders, as *“you couldn’t have one”* (Home_1_F3) device to share, which could result in *“jealousies”* (Home_5_S2). This appeared particularly relevant for homes caring for people with dementia *“especially with the different mood swings”* (Home_2_S2). While 13 stakeholders agreed on *“more than one, because they’d start fighting over it”* (Home_1_S1), some stakeholders felt there should be one for each resident who would benefit. The limits of only one device for wellbeing benefits were also noted, *“because you could have two or three people that are getting a bit agitated at the same time, you don’t want one, because actually what do you do, who do you give it to?”* (Home_3_S1). Generally, participants wanted a *“mix”* (Home_1_S1) of *“lots of”* (Home_1_S2) robot *“cats and dogs”* (Home_4_F3).

Affordability

With regards to an upfront purchase cost, if a business was to adopt a product-centred sales approach, 20 stakeholders commented on appropriate price, with suggestions ranging from *“£50”* (Home_3_S1) to *“£200-£300, being realistic”* (Home_4_F1). Although the PSS model was preferable, stakeholder perceptions on suitable investment price for a one off purchase (average £165.55) demonstrates the issue with the current model in use. This was highlighted by a stakeholder, as *“actually the rental scheme would be very good, some homes [...] couldn’t afford to buy a Paro, or they couldn’t afford the upfront layout of*

hundreds or thousands of pounds” (Home_3_S1), particularly in larger homes, “if you have a 100 bed care home, how do you divide one Paro and one cat, [...] a rental scheme would be good” (Home_3_S1). The price of platforms such as Paro (~£5000) are clearly beyond reach of real-world stakeholders in older adult care. Stakeholders reported purchasing anything “a lot more than a hundred” (Home_2_F1) “you would think twice about” (Home_5_S5). Stakeholders felt one-off purchases would be more appropriate by family members, for specific individual residents who may particularly benefit from their own device, “some resident families would happily buy them” (Home_3_S1), “split the cost between four granddaughters, £25 each” (Home_1_F3). It could therefore be an appropriate model to pair a PSS lease model with a purchase option; “rental scheme would be good, you could base it on whatever you thought was viable, [...] I know some residents would also buy their own so it would be good to have an option” (Home_3_S1).

These results are summarised in Figure 17 based on combination of the above themes.

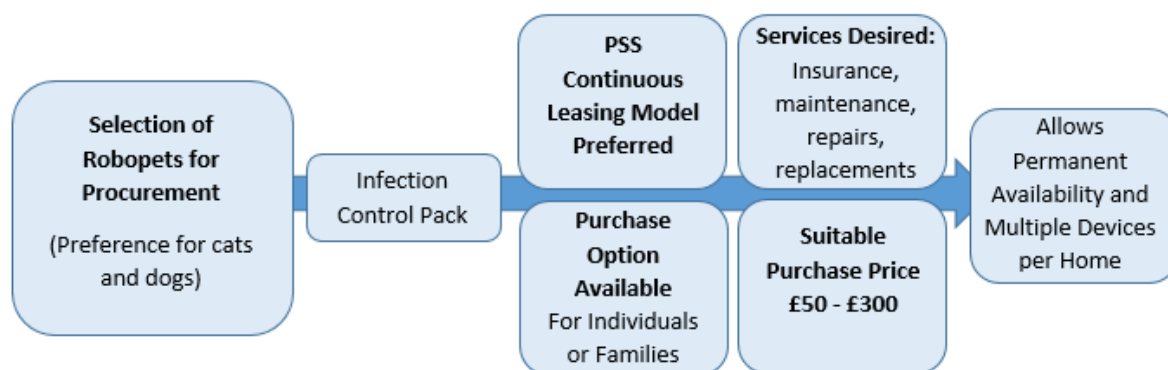


Figure 17: Stakeholder preference for companion robot procurement

Discussion

Currently, companion robot procurement for care homes relies on a traditional product-centred sales approach, which may have limited widespread real-world adoption of devices such as Paro, which has been reported as too expensive for care homes to purchase (Moyle et al., 2016). This is supported here, where stakeholders reported caution in spending decisions over £100. Our results have indicated potential for use of an alternative model, involving leasing of devices, eliminating the larger, one-time cost, and allowing for provision of services longitudinally. Future adoption of this model could create greater ability for care homes to implement devices, without needing to rely on charitable donations, fundraising and resident relatives to purchase multiple devices, as we have observed currently. Desire and requirement for this new model among our stakeholders could be a positive outcome for potential businesses, creating scope to divert from traditional sales based processes currently in place, to a PSS model (Landscheidt et al., 2018), whereby an initial product is provided, further to an on-going service (Landscheidt et al., 2018), to jointly fulfil customers' needs (Reim et al., 2015). In this context, the product provided would be use of robot pets, and the service provided would be the ongoing maintenance of the usability of those products. Interest in PSS systems has been increasing across a variety of domains, generally, a PSS approach can create economic benefits for companies (Reim et al., 2015), however potential businesses have been lacking knowledge and insight to allow for implementation (Reim et al., 2015). The results of this study therefore have implications for businesses, particularly SME's (Landscheidt et al., 2018) who may develop this sector. Movement to a PSS model of companion robot adoption would subsequently have implications for the care sector, potentially increasing the market size (Landscheidt et al., 2018) and therefore resulting in more widespread use of the therapeutic tools.

As noted by Landscheidt et al. (2018) leasing contracts are suitable for customers with limited investment possibilities, as with care homes (Moyle et al., 2016), as the payment is periodic. The initial outlay for platforms such a Paro, or indeed many multiple cheaper devices was noted by our stakeholders as prohibitive to device implementation. In contrast, a PSS model could allow care homes access to greater quantities of robots than could be afforded with a product-centred sales focussed model. As seen in our results, care homes have requirement for multiple devices, due to issues in sharing, jealousies, and large numbers of residents, making a leasing model even more appropriate in this context.

Previous work has noted three main categories for PSS; result-oriented, product-oriented and use-oriented (Reim et al., 2015; Tukker, 2004). Result-oriented models focus on providing outcomes rather than products/services, and are thus less appropriate in this context (Reim et al., 2015; Tukker, 2004). Product-oriented models sell a product, and additionally commit to services related to the product (Reim et al., 2015; Tukker, 2004). In contrast, use-oriented models do not involve selling the product (passing ownership of the robot to the customer), but rather make the product available for use under lease (Reim et al., 2015; Tukker, 2004). The company thus maintains responsibility for the products usability. This seems like the desired approach from our results. The continued usability of devices appeared to be a key concern. Our stakeholders demonstrated some concern around breakages and damage in their use context, particularly in settings caring for those with dementia, making purchase options even less appealing. Our stakeholders appeared to find comfort in a leasing model that could provide insurance, repairs and replacements. Fear of investing a large one-off payment in an expensive platform (such as Paro) likely limits real-world purchases, as the purchase would be wasteful should the product become

damaged, as appears likely from our results. This barrier to one off investments has been reported previously for industrial robotics (Landscheidt et al., 2018).

As noted previously, successful PSS relies on understanding of what the customer would value from the company, the requirements and desires need identifying before a company can produce and distribute these values (Barquet et al., 2011). Our results have highlighted the services of value in this context to be insurance, repairs, maintenance, permanent availability, multiple devices and infection control. Cleanliness is a valid concern considering the desire for devices to be shared among residents, and infection control concerns for robot pets have been discussed previously (Martyn, 2018). Future businesses should therefore account for this barrier through provision of an infection control pack. This could include a cleaning method, schedule and products. Based on the feedback of stakeholders, we have explored cleanliness of companion robots in Study 6.

Further to the benefits of PSS to the stakeholders themselves, this approach could be advantageous to future businesses, the provision of ongoing services extends the companies purpose, therefore beneficial financially (Reim et al., 2015). However, a use-oriented approach carries increased risk for the company compared to product-oriented, with more responsibility placed on the company to guarantee availability of usable products/services for a set time (Reim et al., 2015). Conversely, this confidence in provision could increase trust and likelihood of care homes acquiring services, increasing the market size (Landscheidt et al., 2018).

The price of the PSS scheme would of course depend on the services offered, which was noted by our stakeholders, who felt unable to estimate a suitable leasing cost without further details of the services. One stakeholder did however report lease price should be comparable with weekly activities (e.g. weekly singers costing less than £50). This could be

an area of future enquiry based on discussions with both SME's and care stakeholders to establish the appropriate level of service and cost. This study has provided initial exploratory research in this area, as related literature was entirely lacking, however much further work is now required.

The market for businesses based on this model could be substantial. The UK has an aging population (Abdi et al., 2018), and increasing care needs (Kingston et al., 2018). Based on our research to date, potential consumers could also include people residing in supported living facilities (Study 3). For this reason, alongside the main use-oriented PSS approach, the product-oriented (Reim et al., 2015) purchase option would be additionally advantageous, allowing flexibility for various settings, and of course access to a larger market. Future research could establish generalisation of this model to alternative cultural settings, considering challenges posed by the aging population are experienced worldwide (Kingston et al., 2018).

The strengths of this study include the novel exploration of perceptions of real-world stakeholders into companion robot procurement. Input from relevant stakeholders is fundamental for real-world robot use (Pino et al., 2014), with relatives and carers key in ensuring successful deployment (Sharkey, 2014), justifying research to understand their perceptions on this process. Business model research for other sectors of robotics has been theoretical, based on conceptualisation, with the authors acknowledging the lack of data as a model basis (Landscheidt et al., 2018). Furthermore, successful PSS depends on an understanding of the values and services required (Barquet et al., 2011; Landscheidt et al., 2018), our study has provided initial insight from potential future consumers themselves. A further strength is that stakeholders had observed their residents or relatives interacting with a range of companion robots prior to the interview. Although this observation was

limited (1 -3 hours), it allowed stakeholders more informed opinions, such as observing and reflecting on potential issues of real-world use (jealousies, attachments, damages). The importance of real-world interactions with robots for informed opinions has been noted previously (Jung et al., 2017).

Limitations of this work include the relatively small sample, with 25 of our stakeholders choosing to discuss implementation models. A further limitation is this study provides only initial insight into a previously understudied area, the data gathered does not provide sufficient basis for firm conclusions. This study does however provide the basis for further work in this area, ideas for which are discussed in Appendix F.

Conclusion

Based on the input of our older adult care stakeholders, results suggest some interest in a use-oriented PSS system, with optional product-oriented approach where appropriate for the real-world implementation of robot pets. Stakeholders discussed preference for robot leasing, with ongoing services including; insurance, maintenance, repairs and replacement, further to infection control assistance. The leasing method provided a solution to noted barriers to robot implementation through the current purchase model; fear of investing a large payment on a device that may become broken, inability to afford expensive platforms and cost of buying multiple devices. While this initial insight is interesting, the main implication of this work is the clear requirement for further enquiry in this area.

Study 5 reflection

Within the CAR cycles, Study 5 gave us the opportunity to *Reflect* with collaborators following the initial studies into robot requirement, acceptability and design, and begin

establishing the context of use. Although an exploratory study with limitations in conclusions to be drawn, Study 5 provided some insight into care home settings as a market, demonstrating limited investment potential for such devices. Study 5 also highlighted hygiene and breakages as key concerns. The apparent probability of breakages would of course limit likelihood of care homes investing in very expensive robots in any case, as does the desire for more than one device, which is an interesting result.

3.6 CAR Cycle 1 Reflection

During Cycle 1 of this collaborative action research, studies involved the input of collaborators to establish the requirement and acceptability of SAR among policy and decision makers, explore the value of a user-centred design approach, and subsequently attain the necessary feedback of end-users and key stakeholders on suitable robot design and implementation considerations. Reflecting on all studies included in Cycle 1 provided much insight into *user and organisational requirements* and *context of use* to inform user-centred design of future robot pet developments. Study 1 confirmed there is a requirement for social support within H&SC, particularly for older and lonely individuals, and also suggested H&SC stakeholders may be open to technology, and specifically SAR, assisting in this regard. Study 2 furthered Study 1, with an exploration directly into acceptability, with positive results. The implications of Study 2, demonstrating H&SC stakeholders are open to the use of SAR in their settings, is future robot implementations are likely to be supported by decision makers and staff responsible for facilitating interactions, who may have posed a barrier had they demonstrated poor acceptability.

Study 3 highlighted the value of user-centred design for companion robots, demonstrating significant differences between designers and end-users in their perceptions towards a suitable device for older people. In response, Study 4 provided key stakeholder perceptions

on robot design, through a comprehensive comparison of available devices. Indeed, Study 4 supported the results of Study 3, suggesting that the most well researched robot, Paro, is poorly matched to user requirements, further to appearing significantly unaffordable based on the results of Study 5.

Based on the combined results in Cycle 1, a number of design recommendations were provided to Robotriks, the company collaborating on producing a new companion robot based on user-centred feedback. The design recommendations based on Cycle 1 were; soft fur, familiar animal, realistic aesthetics, changeable skins, customisability, improved feeling of robot insides, gaze direction, command response, interactivity, vocalisations and life simulation.

Despite the insight gained during Cycle 1, a number of further research questions arose during the studies and discussions with collaborators, a strength of action research (Nichols, 1999). In the *Planning* of the next cycle, I therefore aimed to respond to the arising research questions.

Studies 3 and 4 provided a number of robot features, behaviours and design factors of interest for inclusion to stakeholders. However, considering a key barrier in the real-world procurement of Paro is the price, and the evidence in Study 5 to suggest limited investment potential for implementing care homes, future robot developments must ensure devices remain affordable. For this reason, the results of Studies 3 and 4 informed a 'feature ranking' survey in Cycle 2, Study 6, which focused on prioritising design features, allowing developers to simultaneously select the most important features for robot acceptability and usefulness while maintaining affordability by neglecting less important features. In particular, Cycle 1 did not provide enough insight into the type of interactivity required and the desirability of talking or life simulation features. Studies 3 and 4 also highlighted the

importance of eye design and gaze direction, with older people naturally engaging with robots by looking at their eyes and faces, meaning further work into optimum eye design would be of value. During Cycle 1, collaborators additionally raised queries on appropriate size and weight for devices, with many participants commenting that Paro in particular was too big and heavy. This research question appeared unexplored and was again responded to in Study 6.

During Cycle 1, as mentioned, it became apparent robot cost was a key factor likely to influence real-world implementation. The significant difference between care staff perceived affordability and the actual cost of Paro demonstrated requirement for further insight on robot price. Affordability appears likely to be a crucial component in allowing the researched benefits of companion robots to be realised in real-world practice.

Understanding of affordability was therefore furthered in Cycle 2, with Study 6. The possibility of a rental price was not furthered, as without further exploratory work into this concept, the idea remains too abstract. The possibility of leasing arrangements for companion robots, or indeed other forms of SAR in social care, remains an interesting area for future enquiry as we move towards greater reliance on technology within H&SC.

Cycle 1 also demonstrated hygiene was a repeated concern for collaborators. This concern would likely impact stakeholder perceptions on real-world implementation and thus required research in response. Cycle 2 therefore included an infection control study (Study 7a) to assess the efficacy of a cleaning procedure that would allow safe use of such devices. A further consideration arising during Cycle 1 was robot ethics. This concern was presented mainly by care residents and particularly family members, and may have presented a barrier to real-world robot use. In response, ethical concerns were explored in Cycle 2 (Study 8).

Cycle 1 additionally revealed robustness is a key stakeholder requirement, evident in the results of Studies 2 and 5. Fear of breakages appears to be a key concern for care staff and H&SC stakeholders. This consideration was responded to in Cycle 3, requiring longitudinal, real-world exploration under ecologically valid contexts.

In summary, Cycle 2 aimed to respond to research questions arising in Cycle 1 on; robot design, priority features, hygiene and ethical concerns. Cycle 2 also aimed to summarise a suitable 'base design,' by reflecting on collated results and their relevance to informing robot morphology.

Chapter 4: CAR Cycle 2 – Responding to new research questions

Cycle 2 began with a quantitative survey. Due to the mixed-methods approach, Cycle 1 had allowed for mainly qualitative insight into desirable robot features, but limited means of prioritising design requirements numerically. Study 6 in particular is a good example of the benefit of a pragmatic mixed-method approach, which allowed a quantitative understanding of feature priorities without losing the ‘voice’ of stakeholders, through informing survey design based on their earlier qualitative input.

Thus, for Study 6, the project returned to an *Acting and Observing* stage of CAR, in actively seeking further data and clarification from stakeholders, based on the requirement for feature prioritisation and unanswered research questions from Cycle 1. Regarding the user-centred approach, Study 6 again returned to *specifying the user requirements*, but in furthering the query on appropriate price, Study 6 also aids in *specifying organisation requirements*.

4.1 Study 6: Prioritising design features for future companion robots aimed at older adults: Survey ranking results from relevant stakeholders

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Figure 18: Demonstrating considerable variation in design of some of the available robot pets used in previous research. The devices shown on the right are included in this study.

Figure 19: Companion robots and toys available for interaction before questionnaire completion (from left, Paro, Miro, Pleo, JfA dog, JfA cat, Furby, Perfect Petzzz dog, Hedgehog).

Table 10: Five design categories showing 42 features of interest included on questionnaires

Table 11: Participant demographics

Table 12: Showing i) the features ranked in order of importance, based on the number of times they were scored higher than the features presented alongside them

Figure 20: Percentage of responders selecting each animal as ii) preferred device for target audience, iii) most appealing eyes, iv) most appropriate size and v) animal with most appropriate volume and frequency of vocalisations

Figure 21: Showing vi) visual representation of free text feedback behind choice of preferred animal (word size relative to frequency).

Figure 22: Showing vii) visual representation of free text feedback behind choice of most appealing eyes (word size relative to frequency).

Study 6 reflection

During Cycle 1, Studies 3 and 4 had demonstrated the importance of interactivity from devices, however, no insight had been gained into what form of interactivity was more suitable, to inform future developments on selection of sensors. Study 6 responded to this, contributing towards a further literature gap, in suggesting robots responding to touch and sound as the preferred interactivity type. These functions match those of the JfA devices, which have consistently been the preferred pets throughout the studies in this thesis. This provides strong support to the suitability of these sensors and this level of sophistication in response, with additional sensors and intelligence an unnecessary expense. This allows for the suggestion that the sophisticated technology included in Paro (somewhat responsible

for the unaffordable price), is not necessary for a companion robot for this client group. It is likely other forms of SAR could benefit from more advanced technology, certainly physically assistive or voice-controlled devices, however for the purpose of companion robot pets, simple movements and vocalisations in response to touch and sound appear to provide a suitable social entity. Indeed, Study 6 again demonstrated the cost of Paro far surpasses a feasible price for this audience. While there have been some mentions of Paro's cost in previous work, no empirical research had questioned affordability to date (other than Study 5). Study 6 thus responded to this literature gap in providing a feasible price point of around £225, not dissimilar to the results of Study 5.

This study also responded to a literature gap on appropriate size, with stakeholders in Study 4 concerned over Paro's size and weight. The results of Study 4 were supported here, where stakeholders selected the JfA cat (considerably smaller and lighter), as most appropriate in size, and also ranked its 'huggable size' as a key design feature, highlighting the importance of this factor. It is quite possible the size and weight of Paro, further to the unfamiliar embodiment, created some of the variance in response in previous research. The physical size and weight of the device may have been quite uncomfortable for frail older people, perhaps impairing consistency of research outcomes. In support of one feature of Paro's design however, the seal was perceived as having the most appealing eyes. The importance of eye design was noted in Cycle 1, Studies 3 and 4, and Study 6 suggests the large, cute eyes of Paro, providing perceived attention and eye contact, are desirable. Future robot eye design could thus seek to replicate the large dark eyes, and perhaps consider the eyelashes for additional appeal.

While many of the outstanding design queries were responded to in Study 6, a number of key factors remained unexplored. One such factor was infection control. Hygiene concerns

were originally raised by collaborators in Study 4, and reflection on real-world use in Study 5 again supported the importance of adequate cleaning procedures. Infection control for companion robots had gathered very limited research prior to Study 7a below, which subsequently generated fair local and international media interest. Study 7a returned to the user-centred activity of *understanding use context*, by contributing towards the knowledge base on practical considerations of robot implementation. Regarding the CAR approach to this doctoral project, Study 7a simultaneously contributed towards *Planning* (in allowing creation of a cleaning procedure for future research and implementation in Cycle 3), and *Acting* (in actively collecting data and insight in response to collaborator concerns).

4.2 Study 7a: Microbial contamination and efficacy of disinfection procedures of companion robots in care homes

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. <https://doi.org/10.1371/journal.pone.0237069>

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Introduction

Life expectancy is increasing worldwide (Abdi et al., 2018), contributing towards an increasing demand on health and social care resources (Moyle et al., 2018), because human function deteriorates with age (Garçon et al., 2016; Chatterji et al., 2015). There is an identified need for research on maintaining wellbeing of older people (Steptoe et al., 2015), to assist declining numbers of professional care workers (Abdi et al., 2018). Improving wellbeing is essential for those in long term nursing facilities, who are vulnerable to feelings

of isolation and loneliness (Siniscarco et al., 2017), and those with dementia, a condition associated with changes referred to as behavioural and psychological symptoms of dementia (BPSD), and includes agitation, anxiety, depression, delusions and hallucinations (Cerejeira et al., 2012). BPSD can reduce wellbeing, but also increase care provider burden and distress (Cerejeira et al., 2012; Sheehan, 2012), hospitalisation and healthcare costs (Cerejeira et al., 2012) and is associated with institutionalisation and medication use, including antipsychotics, which have serious side effects (Sheehan, 2012), including cardiovascular issues (Stoner, 2018), and mortality (Maust, 2015). Companion robots may provide a non-pharmacological psychosocial intervention to assist with these healthcare challenges.

A systematic review showed there was a wealth of research available on the use of social robots, or companion robots in care and long term nursing homes (Kachouie et al., 2014), with various robots and interactive toys available (Heerink et al., 2013; Picking & Pike, 2017). Much of the previous research focused on Paro the robot seal (Pu et al., 2018). The benefits of interaction with Paro for older adults, including those with dementia, are reduced depression and agitation (Jøranson et al., 2015), more adaptive stress response (Saito et al., 2003), reduced loneliness (Robinson et al., 2013), and reduced nursing staff stress (Saito et al., 2003; Wada et al., 2004). Paro may also reduce use of psychoactive and analgesic medications (Petersen et al., 2017), and even lower blood pressure (Robinson et al., 2015). Nursing staff previously discussed perceptions of Paro, noting the usefulness for older people and potential social benefits, with the device aiding interpersonal relationships (Moyle et al., 2016). It should be noted, the aim of companion robots is to augment human care, rather than replace. Similar is true of robots used in other care contexts (for example

children with autism) (Cao et al., 2019; Esteban et al., 2017), and support has been reported for the social mediation effect of such devices (Robinson et al., 2013; Wood et al., 2015).

However, little has been published on practical maintenance considerations of companion robot use. A review of benefits of and barriers to Paro implementation in care settings noted infection concerns as a key barrier (Hung et al., 2019). The Health Protection Agency (2013) provides guidance for community infection control nurses, health protection nurses, and care home staff including the decontamination of equipment, but little is known about how to do this for new technologies such as companion robots. We demonstrated Paro and other robot animals and toys to hundreds of people as part of the eHealth Productivity and Innovation in Cornwall and the Isles of Scilly (EPIC) project (2017) in 2017-18 in Cornwall, including many nurses and care home staff, who frequently raised concerns of hygiene and infection control. We also found in other work (Study 3) that relevant stakeholders expressed concerns regarding cleaning. The Department of Health and Social Care (2008) suggests good infection control is imperative to ensure service users receive safe care. A previous large-scale randomised controlled trial of Paro in long-term care facilities described the employed hygiene protocol (Moyle et al., 2017a), including cleaning Paro after each use with disinfectant spray and wipes, and cleaning the storage box weekly. This reflects the cleaning procedure suggested by the Paro website (2014). However, research was lacking on the efficacy of such procedures, or any potential risk companion robots pose for care home residents in terms of microbial transmission.

Background

We are aware of only two studies on infection control and Paro (Klein et al., 2017), only one of which reported a cleaning procedure based on use of the robot on a UK National Health Service (NHS) dementia ward for 9 months (Dodds et al., 2018). Dodds et al. (2018) included

a broad cleaning protocol discussing risk reduction measures and processes before, during and after use of Paro. Results suggested cleaning was successful based on Adenosine Triphosphate (ATP) luminometer readings of below 50 relative light units (RLU). The authors, however, acknowledged the limitations of the assessment method (Martyn et al., 2018), as although it provided an estimation of surface cleanliness it is impossible to convert luminometric results to number of microorganisms (Sygula-Cholewińska et al., 2014).

Sygula-Cholewińska et al. (2014) suggested many studies indicated intracellular ATP levels vary so much between microbial taxa that tests of ATP should not be viewed as indicative of the presence of microbial pathogens. They suggested the method should not be commonly applied due to limitations such as low sensitivity of commercial luminometers for microbe detection, poor result reproducibility, and environmental factors influencing measurement outcomes (Sygula-Cholewińska et al., 2014). A literature review by Health Protection Scotland (Infection Control Team, 2017) found most studies showed no correlation between ATP and microbial contamination. They concluded there was insufficient evidence to support using ATP as a marker of microbiological cleanliness.

The protocol described by Dodds et al. (2018), therefore, has limited quantitative microbiological support, as noted by Rowson and colleagues (Martyn et al., 2018). Furthermore, the research was limited only to Paro, reported to have anti-bacterial fur (Sharkey, 2014), thus restricting generalisability of results to a wider selection of companion robots without anti-microbial coverings. There was also no identification of microbes conducted, and samples were taken periodically over 9 months, rather than before and after cleaning (Dodds et al., 2018). Thus, no comparison was provided to demonstrate the impact of the cleaning on either microbial load or removal of specific microbes. There was, therefore, still a strong requirement for research using more valid and standardised

methods (Martyn et al., 2018), as well as a range of companion robot alternatives without anti-bacterial properties of Paro, to begin establishing a tested cleaning procedure for companion robots used by older adults.

Previous research investigating general cleaning efficacy includes work by Santos-Junior et al. (Santos-Junior et al., 2018), who sampled high-touch surfaces in a nursing ward before and after cleaning. They used ATP bioluminescence assay, aerobic colony counts (ACC), *staphylococcus aureus* colony count, and resistance to methicillin (Santos-Junior et al., 2018). They collected 80 samples over four weeks, 40 before cleaning and 40 samples 10 minutes after cleaning to allow disinfectants to dry. The disinfectant used was NIPPO-BAC PLUS. They collected samples with contact plates containing tryptone soya agar with neutralizers. Results were analysed following incubation, and suggested only two of the five sites tested demonstrated significant decrease in RLU. ACC results showed that on two sites, microbial load was higher after cleaning and disinfection. They concluded the cleaning and disinfection process showed little effectiveness.

Kenters et al. (2017) also tested cleaning efficacy, exploring effectiveness of various disinfectants, using a known positive method of contaminating tiles with a test solution of *clostridium difficile* strains. The authors compared wipes and sprays of various ingredients using colony count and ATP. Their results suggested that wipes performed better than sprays with the same active ingredient. Wipes including hydrogen peroxide (1.5%) demonstrated the highest bactericidal activity.

Woodland et al., (2010), assessed colony counts on healthcare cubical curtains before and after cleaning. They used swabs to sample from high-touch areas of 20 curtains. Samples were incubated then colony-counts were conducted and micro-organisms were identified using gram stain and colony morphology. Colony counts increased slightly immediately after

laundering before declining by 56% after one week, and the two most frequently present microorganisms were *coagulase negative staphylococcus* and *micrococcus species*. They suggested current laundry procedures may not be completely effective. A limitation, however, of this study was reliance on swabbing, which can create greater variation in sampling than more standardised methods such as contact plates (Shin et al., 2013).

Similar research on infection control for companion robots appears lacking, other than Dodds et al. (2018). Indeed, a literature review of hygiene for robotic animals in hospitals identified related research focused only on children's toys and dolls (Scholten et al., 2016). The authors concluded little is known about the hygienic application of robotic animals in the clinical setting (Scholten et al., 2016). Previous research investigating microbiological hazards on children's toys and play equipment included Martínez-Bastidas et al. (2014), who found interaction with play-park equipment influenced microbial presence on both children's hands and toys. *E.coli* was predominant, but *staphylococcus aureus*, *klebsiella pneumonia*, *serratia*, *giardia lamblia* and *hepatitis A* were also found. The importance of these results is emphasised by other studies that suggested a chain of transmission of infection not only from person to person, but from fomites (objects) to people (Embil et al., 2009; Reynolds et al., 2005). Randle and Fleming (2006) supported this concern, finding toys specifically can spread infection between children in healthcare settings.

Rowson and colleagues (Martyn et al., 2018) discussed infection control concerns with Paro noting soft-toy type shells are notoriously difficult to decontaminate, with no clear guidelines present on best practice. They also acknowledged the need for quantitative microbiological evidence on adequacy of any decontamination procedures, particularly when considering robot use with vulnerable older adults and those with dementia (Martyn

et al., 2018).

Older adults may be particularly vulnerable to health consequences when exposed to pathogens due to a decline in immune function with aging (Montecino-Rodrigues et al., 2013). Older people also have reduced levels of gastric acid, and consequently experience increased risk of developing infectious gastroenteritis (Montoya & Mody, 2011).

Furthermore, older adults residing in care homes are at particular risk, due to concentration of high-risk individuals in the environment, and the susceptibility of this environment to spreading pathogens (Jordan & Hawker, 2006). Infections in nursing home samples are associated with higher rates of morbidity and mortality, hospitalisation, and healthcare expense (Montoya & Mody, 2011). It is therefore important to establish if companion robots can transmit potentially harmful microorganisms between users and to assess efficacy of cleaning methods to allow safe use of companion robots in such settings. This paper therefore begins to contribute to the necessity noted by Scholten et al. (2016), for research furthering knowledge on robot animals and infection control.

Although Paro appears to be the most well researched companion animal robot (Pu et al., 2018), other interactive toys and robots are commercially available, such as the dinosaur Pleo, Miro, or the JfA cat and dog. Some of these cheaper devices have been used in previous research with older adults (Heerink et al., 2013; Picking & Pike, 2017). We therefore included a range of commercially available toys and robots with potential for use with older adults. As Paro has been designed with anti-bacterial fur that can be washed with anti-bacterial products (Sharkey, 2014), our study provides a comparison with the surfaces of possible alternative robots. Our study thus has implications for: (i) the use of current companion robots in health and social care settings, (ii) the materials to be used in future

robot design, (iii) cleaning procedures for robots and toys in care homes and similar contexts, either for real-world or research purposes.

Method

Setting

This investigation formed part of a collaborative action research project exploring use of companion robots and alternatives in care homes for older adults and people with dementia. Non-probabilistic convenience sampling was used to select two care homes as research sites. Both homes provide residential care for individuals with and without dementia. Four residents in each home volunteered to take part. In the first home, four females participated with a mean age of 86 (SD 14.84). In the second home, three females and one male participated, with a mean age of 90.75 (SD 4.09). The study also involved collaborating with a microbiology laboratory, which follows UKNEQAS (2019) and LABQUALTY (2020) for external quality assurance of bacterial identification, and is also UKAS accredited (2020).

Ethical approval for this study was discussed and waived by the Faculty of Science and Engineering committee at the University of Plymouth, as data collection involved no human participants, older adults volunteered to assist in handling companion robots, as they are familiar with them for non-research purposes. A highly ethical approach was taken, with written consent gained from collaborators who were fully informed on research aims and potential implications. The Microbiology Investigation Criteria for Reporting Objectively (MICRO) checklist was used to guide the writing of this manuscript (Appendix G), although not all points were deemed relevant to this study design (Turner et al., 2019).

Design

Our study had two parts:

In stage one we investigated the microbial load on eight devices (Figure 23) following use, to establish contamination and infection risk. Tests were repeated after cleaning by the researcher, to assess efficacy of the procedure.

In stage two, we repeated this using only two animals (JfA dog and cat) with care staff themselves conducting the cleaning. The cat and dog had been present in the home for eight weeks, undergoing cleaning after each use by the care staff. Our procedure and materials were otherwise identical to stage one.

Both stages involved collection of environmental specimens during December 2018, in Cornwall, UK.

Materials

Robots

A range of robots and alternatives were used (Figure 23).



Figure 23: Eight robot and toy animals used in stage one

From left: Paro, Miro, Pleo rb, JfA dog, JfA cat, Furby Connect, Perfect Petzzz dog, Handmade Hedgehog.

Selection was based on current involvement in the larger project, and through providing a range of shell types and materials currently used on socially assistive robots (Table 13).

Table 13: Shell types of the robot animals and alternatives

Animal	Shell Type	Fur Length (approx.)
Paro (2014)	Anti-bacterial, anti-static soft fur (exact composition protected under intellectual property, but includes silver particles for anti-bacterial properties)	1cm
Miro (Consequential Robotics Ltd., 2017)	Hard, smooth plastic	N/A
Pleorb Dinosaur (Innvo Labs Corporation, 2012)	Soft textured plastic (SEBS thermoplastic elastomer)	N/A
Joy Dog (Ageless Innovation LLC, 2018)	Soft-toy fur (polyester, acrylic mix)	1cm
Joy Cat (Ageless Innovation LLC, 2018)	Soft-toy fur (polyester, acrylic mix)	2.5cm
Furby (Hasbro, 2019)	Soft-toy fur (polyester and acrylic mix) and hard smooth plastic	0.8cm
Perfect Petzzz Breathing Dog (2013)	Soft-toy fur (100% polyester)	0.6cm
Knitted Hedgehog (Black Sheep Wools, 2014)	Soft toy fur (polyester and lurex mix)	2cm

Cleaning Products

We used the following cleaning products for disinfection of the devices: (i) Sirafan Speed Disinfection Spray for Surfaces by Ecolab (2008), and (ii) Super-Sani Germicidal Wipes by PDI (2018). Both companies currently supply disinfectants to health care providers. The use of both a spray and wipes was suggested by Moyle et al. (2017b) and the Paro user manual (2014).

The PDI Super Sani-Cloths were selected as they are recommended for use in health care and medical settings to control cross contamination hazard, and also in the Paro cleaning

instructions (Paro Robots, 2014). The wipes also allow for wiping of hard surfaces on devices, such as noses or eyes, and to allow the anti-bacterial product to be worked thoroughly into fur-type shells. Furthermore, research suggesting superiority of wipes over sprays despite similar composition (Kenters et al., 2017). The PDI company suggests these wipes are bactericidal, tuberculocidal and virudicidal, with broad coverage of microorganisms, including multi-drug resistant organisms (PDI, 2018). The active ingredients include Isopropyl Alcohol, n-Alkyl dimethyl ethylbenzyl ammonium and chlorides. Although we have not tested for viruses here, this product also appears on the USA Environment Protection Agency List N (2020) of disinfectants meeting criterion for use against SARS-CoV-2.

The Sirafan Speed Spray was suggested for trialling by contacts at Ecolab, due to the speed of disinfection and lack of rinse necessity, as rinsing is unfeasible for devices without removable skins. The disinfectant is suggested to be effective against bacterial, viral and fungal infections (Ecolab, 2008). The active ingredients include Isopropyl Alcohol and 1-Propanol.

Products were selected for being more powerful than everyday disinfectants, due to the importance of intensifying disinfection on high-touch surfaces that could allow transmission of pathogens to service users (Santos-Junior et al., 2018). Although both products are designed for hard surfaces, there is a lack of disinfectant products available specific to soft surfaces, and therefore currently available products may provide adequate substitutes. PDI and Ecolab currently supply to health and social care facilities, so the chosen products are easily accessible.

Agar Plates

We used agar filled contact plates, supplied by Cherwell Laboratories. Irradiated tryptone soya agar was used, with four neutralisers to inactivate residual disinfectants. Plates were

triple vent contact plates with a surface area of 25cm². This type of agar is a general purpose nutrient agar currently used in environmental sampling, and is recommended for recovering a variety of microorganisms. Tryptone soya agar was used in previous research (Santos-Junior et al., 2018).

Procedure

The research was conducted in two care homes, reflecting the intended ‘real-world’ use of companion robots (Kachouie et al., 2014). Devices were taken to two care homes providing residential care for older adults with and without dementia. Devices were cleaned using the described procedure (Figure 24) on site to minimise any influence of microbes collected during transportation.

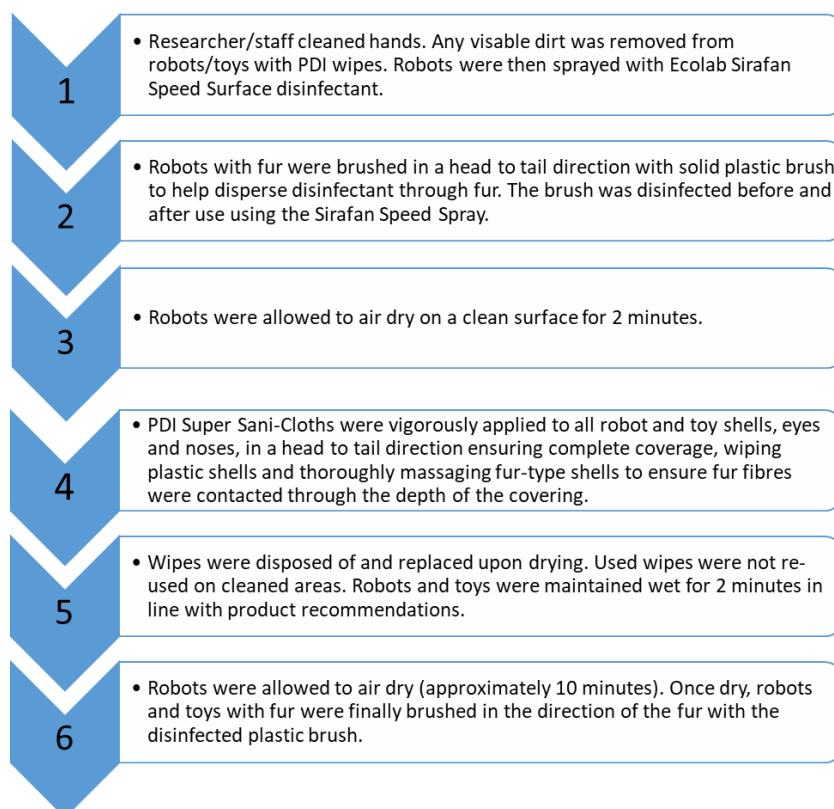


Figure 24: *Cleaning procedure for use with socially assistive robots in care homes or other health and social care contexts*

The process of cleaning each robot or toy. The procedure took approximately six minutes, with additional drying time. This was applied to both soft-furry and hard-plastic shell types. Storage boxes and associated components such as chargers were also cleaned weekly using the same method.

Once cleaned, four care home residents interacted with the robots, in a group session reflective of real-world use and research practice (Kachouie et al., 2014; Pu et al., 2018). The four participants were invited to interact with each robot for five minutes with each robot receiving 20 minutes of interaction.

The researcher then sampled from the robots using contact agar plates to gain a measure of microbial load after use. Contact plates were applied to the sections of the robots most commonly touched based on review analysis of previous video recordings of 45 different care home residents interacting with each of the eight animals. This sampling of high-touch areas reflects previous methodology (Santos-Junior et al., 2018; Woodland et al., 2010). The plate was in contact with the robot for 10 seconds, as in previous research (Shin et al., 2013).

The robots were cleaned again using the suggested hygiene procedure (Fig 2), then sampling was repeated to examine the efficacy of the cleaning method. This before and after cleaning sampling is suggested to be an established method of evaluating cleaning and disinfection practices (Martyn et al., 2018; Galvin et al., 2012).

All sampling from the robots was conducted by the same researcher to standardise sample collection. Sixteen samples were collected in stage one, with each of the eight animals being sampled from once before cleaning and once after. Four samples were collected in stage two, with two animals being sampled before and after cleaning. Previous research by Woodland et al. (2010), used swabs for testing microbial contamination of cubicle curtains

in a health care setting, however the contact plate method allowed greater standardisation, and was used in previous research (Santos-Junior et al., 2018). Sampling via swabbing requires two processes; sampling from the object itself and inoculation of the plate, while the contact plate method allows for inoculating of any bacteria directly from the object to the agar (Shin et al., 2013).

Analysis

Samples were transported straight to the collaborating microbiology laboratory and incubated at 30 - 35°C for 5 days to grow any environmental organisms or enteric/pathogenic bacteria sampled from the animals. Colony counts were conducted at 48 and 120 hours, and CFU/cm² calculated, providing an indicator of how 'unclean' robots become during standard care home use, and to assess the efficacy of the cleaning procedure, and initial comparisons of shell type. A threshold of ≤ 2.5 CFU/cm² was considered acceptable, based on previous research (Infection Control Team, 2017; Santos-Junior et al., 2018; Galvin et al., 2012). In stage one, identification was conducted on colonies remaining after cleaning using gram stain, colony morphology and coagulase agglutination as in previous research (Woodland et al., 2010). This was to ascertain what microbes had remained following cleaning. In stage two, identification was conducted on micro-organisms present before cleaning, using the same methods. This allowed insight into microbes potentially transmitted on companion animals, and analysis of what microbes were removed during cleaning.

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

https://osf.io/4qud9/?view_only=183ae25f030a4e0b905a50286f99ca8c

Results

Stage One

Most of the devices gathered enough microbes during 20 minutes of standard use to have a microbial load above the acceptable threshold of 2.5 CFU/cm² (Table 14).

Table 14: CFU/cm² on each robot before cleaning and after cleaning at 48 and 120 hours incubated

Animal	Before Cleaning		After Cleaning	
	48	120	48	120
Paro	3.20	3.20	0	0
Miro	0.04	1.08	0	0.64
Pleo	3.84	4.48	0.04	0.04
JfA Dog	8.96	9.60	0	0
JfA Cat	1.28	1.92	0	0
Furby	10.88	10.88	0.04	0.04
Perfect Petzzz Dog	17.28	19.20	0	0
Hedgehog	2.56	3.20	0.08	0.08

The Perfect Petzzz dog demonstrated particularly unacceptable levels, followed by the Furby and JfA dog. Only two of the animals remained within acceptable levels following use, the JfA cat and Miro. The post-cleaning CFU/cm², however, demonstrates regardless of material type, or previous microbial load, the described cleaning procedure effectively brought the CFU/cm² on each animal down to well below acceptable levels, thus strongly supporting cleaning efficacy for bacterial contamination. Further to post-cleaning results being well

within recommended limits, the remaining colonies following cleaning were identified as *aerobic spore-bearers* which are ubiquitous in the environment and pose relatively little risk.

Stage Two

The cleaning procedure was effective when carried out by care home staff (rather than the researcher). Using the benchmark of ≤ 2.5 CFU/cm², it is clear microbial load on the animals was high following a group session, but that cleaning by a care staff member, following the standard procedure (Figure 24) removed microbes (Table 15).

Table 15: CFU/cm² before cleaning, and after cleaning by a care staff member, at 48 hours and 120 hours incubation

Animal	Before Cleaning		After Cleaning	
	48hr	120hr	48hr	120hr
JfA cat	24.32	29.44	0	0
JfA dog	5.76	10.24	0	0

Identification conducted on the samples taken before cleaning suggested the presence of *diphtheroids*, *ASB*, *micrococcus species*, *coagulase negative staphylococcus* and *staphylococcus aureus*. Some of these bacteria can present a risk to human health (Chandran et al., 2016; Taylor et al., 2017). No gram-negative bacteria were present suggesting faecal contamination at time of sampling was unlikely. No colonies were present following cleaning.

Discussion

The reported benefits of social robots have significant implications for health and social care, strongly supporting the use of such devices with older adults and individuals with dementia (Picking & Pike, 2017; Jøranson et al., 2015; Saito et al., 2003; Robinson et al., 2013; Wada et al., 2004; Petersen et al. 2017). Full implementation of companion robots

however requires adequate protocols in place for safe and effective use. The concern of interest for our study was infection control, particularly for bacterial contamination. To the best of our knowledge, our study is the first of its kind in confirming, through initial empirical evidence, the strong requirement for adequate infection control procedures when using companion robots or toys in health and social care contexts. Previous research has suggested acceptable levels of aerobic colony counts are ≤ 2.5 CFU/cm² (Santos-Junior et al., 2018). Our results demonstrate a single group session in a care home setting produced a microbial load higher than the accepted level on the majority of devices. These microbial loads identified the importance of adequate infection control, particularly with vulnerable people such as older adults (Montecino-Rodriguez et al., 2013), living in care homes (Jordan et al., 2006). This strengthens the need for validated cleaning techniques for use on socially assistive robots in health and social care settings, as noted by Rowson and colleagues (Martyn et al., 2018).

The cleaning procedure we employed was informed both by previous research (Moyle et al., 2017b) and product recommendations (Paro robots, 2014), and our study provides initial empirical support for the efficacy of this cleaning procedure. The reduction in colonies to well below the recommended threshold following cleaning in both stage one and stage two suggests the cleaning procedure and products described are effective and feasible, and that cleanliness results are replicable by care staff. The procedure appeared similarly effective for both fur-type and hard-shell robots. The procedure described in our study therefore has implications for research and practice, providing a possible solution for implementation or research with companion robots and toys, where infection control is a concern, such as care homes. This research has also suggested that when employing a suitable cleaning

procedure, more economical robots can be cleaned to the same infection control standard as Paro, who has an anti-bacterial covering (Sharkey, 2014).

The contact plate samples in the current study were taken from the areas of animals touched most frequently, based on video review of interactions during the wider project. Santos-Junior et al. (2018) suggested previously that high-touch surfaces constitute most risk for transmission of microorganisms, therefore the risk of microbial contamination would have been greater had adequate cleaning not been undertaken. The identification of *staphylococcus aureus* also demonstrates the importance of adequate cleaning. While it is present in normal human flora of many healthy individuals, it can cause superficial and sometimes serious infections when allowed to enter the bloodstream or internal tissues (Taylor & Unakal, 2017), a significant burden of morbidity and mortality for older adults (Big & Malani, 2010).

Preventing the transmission of *staphylococcus aureus* is clinically relevant for infection control purposes because of the potential for transmission of methicillin-resistant *staphylococcus aureus* (MRSA) within the healthcare setting. Microbes such as *staphylococcus aureus*, including MRSA, can be transmitted by direct contact or through fomites (Lotfinejad et al., 2020). Objects such as robots and toys are fomites with potential to form vehicles of microbial transmission (Embil et al., 2009; Randle 2006), and therefore should be treated with adequate infection control procedures. Brodie et al., (2002) previously discussed risks of live animals in health and social care, including an MRSA outbreak potentially contributed towards by a cat. The authors suggested improved hygiene as the principle measure in reducing disease transmission. Our results suggest the cleaning procedure of the current study removed *staphylococcus aureus* due to the complete absence of colonies following cleaning. The remaining colonies in phase 1 were identified as

Aerobic Spore Bearers and therefore again, further to being well below the recommended threshold, present very little risk.

Given the high colony counts seen before cleaning, we suggest if companion robots are used in group sessions, members of the group should have hands cleaned both before and after robot use, to limit any microbial transmission. The importance of hand washing has, of course, also been emphasised to control the spread of viruses, particularly the SARS-COVID-19 virus (Lotfinejad et al., 2020). Despite the limitations of the previous research by Dodds et al. (2018), a number of important points were identified in their paper, including avoiding use of Paro with individuals with infections, or open wounds. We would suggest this advice also applies to the wider use of SAR in care homes and other health and social care contexts. The high colony counts seen in this study have further implications for other materials used in care homes likely to form vehicles of transmission, particularly with regard to group sessions where objects may be shared amongst residents.

One interesting and slightly anomalous result was Miro grew very few colonies even when 'unclean.' It may be Miro remained cleaner due to the solid plastic case, although we cannot draw firm conclusions with the limited number of samples we collected from plastic shells. Rowson and colleagues (Martyn et al., 2018) noted the difficulties in decontaminating soft-toys, and perhaps hard-shells are more suitable for infection control purposes. Alternatively Miro may simply have been exposed to fewer microbes due to limited physical interaction with this device: while the care home residents were free to touch, hold, cuddle and interact with each robot as they wished, we observed Miro was physically touched less than the alternatives (who received kisses and cuddles in addition to petting). This variation in interaction may also explain the differences seen in microbial load before cleaning between the different animals. We cannot easily generalise from individual devices to the materials

from which they are made as the infection load will depend on both material and interaction behaviour.

The devices, once cleaned with the stated products, are not expected to cause skin irritation or pose health risks, if allowed to dry thoroughly before use. However, care should be taken to read full product information (Ecolab, 2008; PDI, 2018), and inform residents and carers of the products used to check for any allergies or skin sensitivities. The cleaning products detailed can be flammable, and thus care should be taken with the items themselves, although the product evaporates and thus contact with and flammability of the disinfected animals should cause no additional issues. Cleaning of devices should be undertaken by staff, following precautions, and away from any care home residents, or health and social care service user, to minimise risk of direct exposure to disinfectant substances. Products should also be stored securely and COSHH (Control of Substances Hazardous to Health) assessments undertaken (Health and Safety Executive, 2018).

The range of devices included is a strength of our study, as the objects provided a range of shell types, from hard plastic to soft and furry. The previous research was conducted only with Paro (Dodds et al., 2018), which has anti-bacterial fur properties (Sharkey, 2014). The results of our study therefore have wider implications and better generalisation, although further research is required, with larger samples over longer periods in more natural settings, for firm conclusions on effectiveness (as opposed to efficacy) and comparison between shell types. The inclusion of hard-shelled robots such as Miro would suggest this cleaning procedure may also be applicable for a wider group of robots with potential for use in health and social care, such as humanoids like Pepper (Piezzo & Suzuki, 2016) or telepresence devices such as Giraff (Coradeschi et al., 2014), although checks should be performed for any cautions provided by individual product companies.

Another strength of our study was the use of contact plates. Woodland et al. (2010) relied on swabbing, which creates greater variation and allows less standardisation than contact plates (Shin et al., 2013). Furthermore, we used aerobic colony counts. ATP luminometer measures had been used previously (Dodds et al., 2018), which are reported to have considerable limitations (Sygula- Cholewińska et al., 2014), while the use of aerobic colony counts before and after cleaning is an established measure of cleaning efficacy (Martyn et al., 2018; Galvin et al., 2012).

Finally, our study has some ecological validity, that is, the research was conducted in care homes, providing residential care for older adults, which reflects well the current intended use for such devices (Kachouie et al., 2014; Pu et al., 2018). The older adults interacted with the animal devices in group sessions, again reflecting current use of the devices in real-world and research contexts (Kachouie et al., 2014; Pu et al., 2018). The animals were cleaned on site, both by the researcher in stage one, and by a care staff member in stage two, furthering the generalisability of results to real-world situations.

A limitation of this study was the relatively small number of samples, with 20 samples collected and analysed in total, and only four samples acquired from plastic shell-types. While our study gives users of such companion robots confidence in their use further research could be conducted to statistically analyse any differences between shell types in the harbouring of microbes. This could inform shell selection for future robot design. We recommend further research in this area utilising larger numbers of samples, and repeated testing to allow statistical comparison. A larger study would also allow assessment of how effectively this cleaning procedure could be translated to a larger scale with a longer time frame, a limitation to this study. However, regardless of shell type, it appears from initial

investigation that employment of an adequate cleaning procedure can bring microbial load well below acceptable limits for all shell-types considered in the current study. An implication of this finding is that currently available robots and toys without anti-bacterial coverings may provide alternatives to Paro without posing additional contamination hazards. Future research may also look to establish efficacy of alternate cleaning products, particularly for any availability of disinfectant specific to soft-surfaces.

Nursing staff have education and training on infection control of care equipment (NHS Education for Scotland, 2019). Our study provides evidence based guidance on how to control infection on this new addition, companion robots, to the care home environment. As noted by Rowson and colleagues (Martyn et al., 2018), surfaces in hospitals can allow transmission of nosocomial pathogens. We encourage further research, using the cleaning procedure detailed in the current study and maintaining a range of social robot shell-types, providing known positive trials with specific nosocomial pathogens, to further enhance confidence in the procedures efficacy and applicability to wider health care contexts, such as hospitals.

Further Work

As identified, there is little other work exploring infection control with companion robots, and more work is certainly needed, particularly due to the limited number of samples collected in this study and requirement for further in situ testing with care staff. This preliminary study would suggest little difference between more affordable devices such as the JfA devices and Paro, with the anti-microbial covering (Sharkey, 2014), in any case, our additional work demonstrated limited appeal for Paro and Miro, as both lack characteristics appealing to older adults (Study 3), meaning they are unlikely to be implemented and used as much. In contrast, we know more affordable JfA cats and dogs are being implemented

widely (Study 10; Lancashire Telegraph, 2020). Of priority therefore, in response to this widespread implementation, further testing should examine transmission of viruses further to bacteria. Given the high numbers of deaths in care homes as a result of the SARS-CoV-2 virus (Aprahamian & Cesari, 2020), further studies of both bacterial and viral infection control on robot companions are urgently needed.

In summary, our study provides a basis for further research in this area, and is highly relevant, due to considerable interest in use and implementation of companion robots in contexts such as care homes (Kachouie et al., 2014; Pu et al., 2018; Jøranson et al., 2015; Moyle et al., 2017a), and due to the significance of any issues in infection control for this setting. Older adults are particularly vulnerable (Montecino-Rodriguez et al., 2013), as are individuals in care homes (Jordan & Hawker, 2006). The implications of infection can be catastrophic, including mortality (Montoya & Mody, 2011). Rowson and colleagues (Martyn et al., 2018) previously reported the need for evidence supporting adequacy of decontamination techniques for Paro and similar robotic animals, using established methods such as ACC before and after cleaning (Martyn et al., 2018; US Environmental Protection Agency, 2020). Our study provides the initial step for such research.

Conclusion

Companion robots hold significant potential for improving aspects of health and wellbeing for older adults. Numerous benefits have been reported, however research has been lacking on the important factor of infection control. We have demonstrated through colony counts and microbe identification that robots and toys can pose a bacterial infection control risk in health and social care contexts such as care homes. Our simple cleaning procedure has efficacy and gives some confidence that companion devices with a range of soft and hard shell types can be used relatively safely and that cheaper devices are no more risky than

Paro. However, further research is needed both addressing viral infections and the effectiveness of our procedures in situ in the longer term.

Study 7a furthered

Although Study 7a established bacterial risk of robot pets, the outbreak of the SARS-CoV-2 pandemic highlighted an additional risk present. As Covid-19 cases increased in the UK, the research team reflected on the use of robot pets, considering that we were aware of their increasingly widespread use in care homes, and tendency for sharing devices between residents. The below reflection responded to concerns, although no new data was collected, Study 7b involved checking our cleaning procedure against published guidance and provides novel input and advice during the unprecedented times. Study 7b was published on ResearchGate for the purpose of immediate availability, with benefit to the care community and academics prioritised over author benefits of peer review.

4.3 Study 7b: Potential transmission of SARS-CoV-2 via robot pets in care homes

(ResearchGate CC BY 4.0).

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Xiao and Torok (2020) rightly put limiting person-to-person transmission as the first measure to control COVID-19. Older adults have been particularly susceptible to SARS-CoV-2, with dramatic case fatality rates reported, and care homes presenting challenges for preventing its spread (Aprahamian & Cesari, 2020; Wang et al., 2020). Although there is published advice about SARS-CoV-2 persistence on various surfaces (Kampf et al., 2020; van

Doremalen et al., 2020), we have not yet seen publications regarding persistence on soft, artificial fur-type surfaces, like those used for robot pets.

Robot pets (e.g. Paro the seal and JfA cat and dog) may benefit care home residents, improving wellbeing and reducing loneliness, agitation and depression (Abbott et al., 2019). Such devices could therefore reduce loneliness and depression among older adults resulting from social distancing (Wang et al., 2020). Their use is becoming widespread (Study 10) and care home staff have informed us their robot pets are indeed demonstrating particular usefulness at present, assisting with loneliness and depression in the absence of usual visitors or scheduled activities. However, while robot pets could assist in this regard, they are often a shared resource, passed between residents and staff. The plausibility of SARS-CoV-2 transmission on fomites therefore raises implications for such devices.

We previously carried out empirical work demonstrating robot pets could transmit bacteria between care home residents, and tested the efficacy of a cleaning procedure to stop it (Study 7a). We included eight different devices with varying surfaces (plastics, polyester, acrylic, and lurex). To understand microbial load following standard use in care homes, we sampled from the robots following 20 minutes of group interaction with four care home residents. Colony counts and CFU/cm² calculations suggested that during this short interaction robots acquired unacceptable levels of bacterial contamination. Although our study focussed on bacteria and not viruses, it nevertheless indirectly raises the possibility of a significant source of viral transmission in long-term care facilities.

In the second stage of our work, we tested our cleaning procedure on contaminated devices (Study 7a). This procedure used two disinfectant products; PDI Super-Sani Germicidal Cloths (PDI 2020) and Ecolab Sirafan Speed spray (Ecolab, 2008). We removed visible dirt with PDI wipes, before robots were sprayed with the Ecolab spray, and brushed in a head-to-tail

direction with a solid plastic brush to disperse disinfectant. Devices were allowed to air dry before PDI wipes were vigorously applied to all areas, in a head-to-tail direction, to ensure complete coverage and fur fibre contact through the depth of the covering. Devices were maintained wet for 2 minutes, with wipes replaced upon drying. The results strongly supported cleaning efficacy, with CFU/cm² falling well within the acceptable threshold on all devices.

Although we did not test for viruses, in particular SARS-CoV-2, we have reviewed the cleaning products we used against the USA Environment Protection Agency (2020) List N of Disinfectants for Use Against SARS-CoV-2. PDI Super-Sani Germicidal Cloths have an EPA number and are included on List N, confirming that the product is registered as an agent meeting EPA criterion for use against SARS-CoV-2.

However, we could not find an EPA number for the Ecolab Sirafan Speed spray. Ecolab Sirafan Speed spray has a chemical composition of 35% 2-propanol and 25% 1-propanol. Kampf et al. (2020) reported that a biocidal agent with a “combination of 45% 2-propanol with 30% 1-propanol [...], readily inactivated [SARS-CoV] coronavirus infectivity by approximately 4 log₁₀ or more” in 30 seconds in suspension tests. This was similar to the effect of Ethanol at 80% or Sodium Hypochlorite (bleach) at 0.21%. Given that the Ecolab Sirafan Speed spray’s composition is only 35% 2-propanol and 25% 1-propanol it may therefore not be effective against SARS-CoV-2, although we cannot confirm this without more research.

Due to potential limitations of the Ecolab spray in combatting this virus, it is possible the order of application should change from our original procedure, to prioritise use of the PDI wipes first and avoid brushing any SARS-CoV-2 contamination further through the soft

materials before adequate disinfectant is applied. Maintaining use of the Ecolab spray secondarily would still be beneficial for bacterial control.

Robot pets may be particularly useful during this pandemic and consequential isolation, but safety must be prioritised, and shared use of such devices appears unsafe at present. We are aware and concerned that robot pets are still in use in care homes, and often kissed and cuddled. We are also unaware of SARS-CoV-2 advice being provided by the main robot pet producers. We therefore report an urgent need for empirical investigation of SARS-CoV-2 transmission on robot pets and immediate action within care homes to respond to this identified risk, particularly to remove devices from shared use.

Study 7a and 7b reflection

The results of Study 7a were used to inform collaborators for Cycle 3, Study 10 and 11, which involve real-world implementation of robots into care settings, in providing a recommended cleaning procedure. As such, this demonstrates how the CAR approach has allowed research to feed into practice. Collaborators raised hygiene concerns in Cycle 1, during the *Act* and *Reflect* phases of Study 4 and 5, which were responded to with research in Cycle 2, with Study 7a, and the learning taken back to collaborators in Cycle 3, for the next *Act* phase of Study 10 and 11. Study 7b was not produced until later in the doctoral project, although was used to inform collaborators during Study 11.

Of note, we were also contacted by the Joy for All company, who adapted their cleaning procedure, conducted additional laboratory tests and emphasised individual use of their products entirely in response to Study 7a and 7b, demonstrating far reaching impact.

Study 8 returned to a *Reflecting* phase, in allowing further enquiry into ethical concerns, a consideration raised by collaborators in Cycle 1, Study 4. Regarding the user-centred actions, Study 8 contributes towards *understanding use context*, in establishing an understanding of ethical issues of robot pet use as a potential barrier to real-world implementation.

The issue of infantilisation appeared to be the only concern raised in Study 4, although for older adults this concern was restricted mainly to unfamiliar robots that looked more like toys than living pets due to their incongruence with the setting. Some family members also raised slight concern, comparing robots for older people to providing children's puzzles. Infantilising is indeed one of the concerns raised by some ethicists on the use of robot pets, as is deception. The desire for robots to be even more realistic and life-like (Study 3 and 4) could indeed increase likelihood of deception occurring with older adults. For this reason, the perceptions of younger people were explored, as family members of older adults, to assess their views on ethical considerations around robot pets. Family members in particular were thought to be the stakeholder group with most potential to form a barrier to real-world use, due to the slight concerns raised in Study 4, but also due to family member disapproval in previous research (Birks et al., 2016; Robinson et al., 2013).

4.4 Study 8: Ethical perceptions towards real-world use of companion robots with older people and people with dementia: Survey opinions among younger adults

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<https://doi.org/10.1186/s12877-020-01641-5>)

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Background

Robotics may provide a technological aid in meeting the increasing demand on health and social care (Broadbent et al., 2009) caused in part by increasing life expectancy (Broadbent et al., 2009; Abdi et al., 2018; Moyle et al., 2018), as human function deteriorates with age (Garçon et al., 2016; Chatterji et al., 2015). Companion robots such as robot pets designed congruent with animal aesthetics and behaviours, have particular potential in aged care (Broekens et al., 2009; Moyle et al., 2013). The most well researched example is Paro, the robot seal (Pu et al., 2018). Research has suggested numerous benefits of interacting with Paro, including reduced agitation and depression in dementia (Jøranson et al., 2015; Wada et al., 2005), a more adaptive stress response (Saito et al., 2003), reduced care provider burden (Saito et al., 2003), and significantly improved affect and communication between dementia patients and day care staff (Liang et al., 2017). Furthermore, Paro may reduce psychoactive and analgesic medication use (Petersen et al., 2017), and even decrease blood pressure (Robinson et al., 2015). Alternatives to Paro include, amongst others, Miro, Pleo, and the JfA devices, some of which have been used in previous research (Heerink et al., 2013). Although research with alternatives is limited (due to an apparent selection bias for Paro and a limited availability of comparison studies (Pu et al., 2018; Kachouie et al., 2014)), we previously found evidence that more affordable, less sophisticated devices may offer acceptable alternatives (Study 3), with potential for reproducing the cited benefits of Paro (Sharkey, 2014).

That said, these reported benefits need to be considered in the context of ethical concerns of robot implementation with older people (Sharkey, 2014). In the following, we review some of the relevant literature for the most commonly discussed concerns, including infantilisation, deception, reduced human contact and intrusions on privacy (Sharkey, 2014; Chiberska, 2018; Sparrow, 2002). Sparrow and Sparrow (2006) assessed the reported

capacity of robots to meet older people's needs, particularly considering social and ethical implications. The authors claim to provide "a much-needed dose of reality" [p:143], suggesting robots are unable to meet social and emotional needs in almost all aspects of care. They raise the issue of potential for harm, with technological restrictions and potential dangers (eg. trip hazards), removing hopes of robots aiding with personal care, mobility or daily tasks. Potential for harm raises the additional issue of accountability should harm result from robot implementation (Sharkey & Sharkey, 2010). However, the most ethically controversial proposed role for robots appears to be of companions for older people, the concept of which is sometimes reported as "positively bizarre" [p:308] (Wachsmuth, 2018), unethical, and "akin to deception" [p:148] (Sparrow, 2006).

Regarding deception, some authors feel companion robot benefits rely on delusions as to the real nature of the interaction, described by Sparrow (2002) as "sentimentality of a morally deplorable sort" [p:306], with this deceit making robot use misguided and unethical. Sparrow (2002) argued robot behaviour is merely imitation: robots do not possess human frailties, and thus cannot 'understand' human experience and mortality, rendering them incapable of appropriate, genuine, emotional response (Sparrow & Sparrow, 2006). Thus, the extent to which a person feels cared for depends on delusions of robot capabilities. In contrast, Wachsmuth (2018) discussed necessity of 'true' care for older people, suggesting the illusion of responses to feelings and suffering of the care recipient would suffice, despite a robot's qualitative experience (without neurophysiological basis for consciousness) not being a 'true' caregiver. Sparrow and Sparrow (2006) would likely disagree, reporting "the desire to place [robots] in such roles is itself morally reprehensible" [p:154] as robots in roles requiring care, compassion and affection expresses a "gross lack of respect for older persons" [p:156].

Sparrow (2002) further suggested if an older person treats a robot pet as living, thus engaging in the delusion, we have done them a disservice. This appears likely to occur: Robinson et al. (2016) noted participants interacted with Paro as a live pet, with some perceiving Paro as having agency despite awareness the device was robotic. The issue of deceit, in particular concerning the distinction between robot and live pet becomes even more problematic with the presence of dementia (Sharkey & Sharkey, 2012). Deception is therefore a common ethical concern specific to companion robots that can also be problematic for acceptability among older people's relatives. Sharkey (2014) suggested, despite a vulnerable older person enjoying robot pets, and perhaps not distinguishing between living and not, relatives may feel they were suffering humiliation and loss of dignity through deception (although it is also possible this tension would ease upon witnessing potential quality of life benefits (Gustafsson et al., 2015)).

A further ethical issue commonly discussed is reduced human contact. The substantial economic pressures within aged care may result in substitution of human staff with robotic alternatives, which is problematic as human social contact provides significant wellbeing benefits, autonomy and communication opportunities (Sparrow & Sparrow, 2006).

However, given the regrettably low standard of care provided on occasion by human carers, possibly as a result of high demands including a large workload and low pay (Sparrow & Sparrow, 2006), there is well-documented increasing concern that older people can suffer abuse and mistreatment (Sharkey, 2014). Dignified treatment by human carers is therefore not a given. In contrast, robots are unable to get angry, abuse an older person or become tired and stressed. Therefore, a small reduction in human contact may be an acceptable compromise for improved quality of care and interaction if robotics could ease strain on human care providers. Support comes from research suggesting reduced carer stress with

Paro implementation (Saito et al., 2003; Shibata, 2012). Furthermore, robots may mediate social interaction (Robinson et al., 2016), providing a conversation topic between staff, family and older people, and more opportunities to engage socially (Sharkey, 2014). Sharkey (2014) suggests however, despite solving negatives of human behaviour, robots also lack the true positives; compassion, empathy and understanding. Sparrow and Sparrow (2006) argue, due to the crucial role of emotional labour and meaningful conversations for wellbeing, any reduction in human contact would be indefensible.

A further ethical concern is infantilising, an issue also raised for doll therapy, seen by some as congruent with the idea of second childhood, being dispiriting and deficit-based (Sharkey & Sharkey, 2012; Cayton, 2006). Infantilisation may damage acceptability for family members, as supported by Robinson et al. (2013) who reported a care resident's son conveyed their father was not the type to cuddle a soft toy. Another concern is equality of access, as the current cost of companion robots may be prohibitive for people of lower socioeconomic status, who would be denied the potentially therapeutic tool (Chiberska, 2018; Huschilt & Clune, 2012).

Whilst the literature is rich with commentary on potential ethical issues, we have been researching real-world robot pet implementation with older people in care homes, and to date, seen limited evidence of ethical concerns amongst older people themselves. Although some residents in Study 4 felt unfamiliar pets were infantilising, the majority of older people throughout our work have demonstrated good acceptability. We have noted however, occasions where family members have reported such concerns. Family members are key stakeholders in the care of older relatives, and views of relevant stakeholders are fundamental for real-world use (Pino et al., 2015). Presenting the views of relevant stakeholders is the core contribution we seek to make with this paper. Successful real-world

use of companion robots depends on skilled and careful deployment by relatives and carers (Sharkey, 2014), thus negative ethical perceptions would likely impair implementation, forming a barrier to adoption (Goher et al., 2017).

Some previous research has assessed perceptions of older people themselves, including Wu et al. (2014), whose results suggested ethical/societal issues presented a potential barrier to robot use, namely privacy and reduced social contact. Pino et al. (2015) also conducted a survey and focus group with 25 older people and informal carers, who discussed stigmatisation, privacy issues, dignity, infantilising, replacing human carers, and cost being prohibitively high. Although the exploratory study provided initial insight, with only seven informal carers surveyed, more research is required specific to family member perceptions. A larger sample would additionally allow a comparison between the highlighted concerns to identify the most significant potential barriers. Furthermore, the study involved demonstration of only one robot (RobuLAB 10), with PowerPoint demonstrations of other available SAR, limiting participant ability to assess robot capabilities (Jung et al., 2017). In contrast, we surveyed opinions based on real-world interaction with companion robots, providing informed perceptions with increased validity.

Views of health and social care professionals have also been reported. For example, questionnaire results from 2365 trainee care professionals suggested participants felt companion robots were more beneficial than monitoring or assistive robots, and provided low ratings for maleficence (van Kemenade et al., 2019). Nonetheless, research directly surveying ethical perceptions among older people's family members appears limited. Although much literature debates ethics philosophically, providing a strong overview of potential issues (Stahl & Coeckelbergh, 2016), fewer studies specifically assess stakeholder perceptions. Stahl and Coeckelbergh (2016) argued, further to philosophical speculation, we

need dialogue and experimentation closer to the context of use. The authors suggest academic reflection on ethics is divorced from the context of practice, with literature mainly addressing what the robot ethics community “think are important ethical issues” [p:154] whilst stakeholder voices remain unheard.

Here, we therefore explore perceptions and prevalence of ethical concerns among younger adults as family members of potential end-users of companion robots, and compare importance of various ethical concerns for this significant stakeholder category, thus contributing to robot ethics understanding for real-world implementation and potential barriers to successful use. This study addresses a timely topic, with real-world and research use of social robot pets increasing, and their use in dementia care being explored, both in the UK and elsewhere (Broekens et al.,2009; Moyle et al., 2013; Pu et al., 2019; Jøranson et al., 2015; Wada et al., 2005; Saito et al., 2003; Liang et al., 2017; Petersen et al., 2017; Robinson et al., 2015; Heerink et al., 2013; Kachouie et al. 2014).

Methods

Design

This study is a cross-sectional survey with self-completed (with assistance where needed) questionnaires following on from interaction with four companion robots. Previous research relied only on videos and pictures for participants to form opinions (Pino et al., 2015; Jung et al., 2017). Ethical approval was received from the Science and Engineering ethics committee at the University of Plymouth.

Procedure and robots

We hosted an interaction station at a Science Gallery exhibition in November 2018. The overall exhibition comprised 10-15 exhibits exploring the impact of technology on

connection (either negative or positive). Visitors to the exhibition were therefore likely to have an interest in issues such as relationships and ethical considerations of technology use in this context. Our station (a room in the Gallery) provided discussions on intimacy for older people, and the potential role of companion robots, and thus served as a good opportunity to survey ethical concerns within context. Participants had the opportunity to interact with four examples of robots and toys for use with older people (Figure 25).



Figure 25: From left, Paro, JfA dog, JfA cat, Pleo.

Participants interacted with devices on the table, or picked up and held devices if they chose. Following interactions, attendees were invited to take part, provided written informed consent, then completed a survey.

Survey

Based on the literature, we designed a self-completed questionnaire on both sides of one sheet of paper (Figure 26). The front page asked for participant demographics, which robots they liked and if they might buy one, leading to an open question asking if they had any concerns around the use of robot animals for older people or people with dementia. The back page asked questions based on concerns raised in the literature (reduced human contact, carer’s convenience, privacy, affordability, deception, infantilisation, potential injury) and seeking responses using 7-point Likert-type scales questioning the importance of each ethical concern. Each item was scored from 1 (not at all a concern) to 7 (very much a concern).

Please tick this box to confirm you have read the participant information sheet and are happy to take part in this research

1) Age:

2) Do you have older adults (65+) in your family?

3) Do you have a relative with dementia?
If Yes do they live at home, or a care home, or other?

4) Which of the robots was your favourite, and why?

5) Is there anything you do not like about any of the robots?

6) Would you purchase one of these robots for your older relative? Which one?

7) How do you feel about the use of robot animals with older adults or people with dementia generally? Thinking perhaps of an older relative in your family?

8) Do you have any concerns around the use of robot animals for older adults or people with dementia?

Please turn over

9) The concerns below have been mentioned in previous literature. Please indicate how much of a concern you believe each item is, with 1 being not at all a concern and 7 being very much a concern.

Not a concern Very much a concern

Do you think using a robot pet would mean a reduction in human contact?
1 2 3 4 5 6 7

Do you think a robot may be used for the carers' convenience?
1 2 3 4 5 6 7

Do you think robot pets could be intrusive or detrimental to privacy?
1 2 3 4 5 6 7

Do you think benefits would be limited for older adults with lower socioeconomic status not being able to afford a robot?
1 2 3 4 5 6 7

How much of a concern do you believe deception is – robots perceived as living beings?
1 2 3 4 5 6 7

How much of a concern do you believe infantilising is – robot 'toys' for older adults?
1 2 3 4 5 6 7

Do you think there is potential for injury or harm?
1 2 3 4 5 6 7

Figure 26: The questionnaire

Results

Sixty-seven people interacted with the robots and then agreed to complete a questionnaire. They had an average age of 28 years (Range 18-65, SD 10.99). Most (53/67 (79%)) reported having older adult relatives, and 11/67 (16%) had a relative with diagnosed dementia.

Section A of the survey first gained understanding of participant device preferences, likes and dislikes, available in Appendix H. It is worth noting, only one dislike referred to a potential ethical concern (reducing human contact).

Table 16: Responses to purchasing a device for an older relative (Q3)

Response	N (%)	Additional
Yes	39 (58)	Paro Pleo Cat Dog 10 4 14 10
No	21 (31)	Example Reasons “Too expensive” “They can decide themselves” “I don’t think they’d like it” “Not into animals” “Not yet” “They have real animals”
None/Unsure	7 (10)	

Most participants would purchase a device for an older relative (Table 16). Many participants suggested more than one device, and the most popular option was the JfA cat. It is also worth noting, of the 10 participants who reported they would purchase a Paro, four wrote an additional comment such as “if cheaper or more affordable.” Price was also a common reason for participants reporting they would not buy their relative a device, or a deciding factor on selecting a device other than Paro. This would indicate financial cost is a key deciding factor, with no ethical concerns reported as the reason for not purchasing a device.

Table 17: Responses to open question on general feelings towards companion robots for older people (Q4)

Response	N (%)	Example Evidence
Positive	44 (66)	“it would be very therapeutic for them” “I think it would be very successful in providing comfort to my relative with dementia, particularly the dog, for nostalgic purposes”

Mixed	10 (15)	“I struggle with the concept of replacing care with robotics but in neurodegenerative diseases such as AZ dementia it can be harder on family members sometimes and if it stimulates/soothes them then maybe” “A good idea, the problem would be making the robot responsive enough without it being too expensive”
Negative	5 (7)	“I would have thought it was a bit ridiculous” “I would be slightly worried of infantilising the person, the person may get upset or see it as a trick”
None	8 (12)	

Table 17 demonstrates the majority of participants felt positively when surveyed on general feelings towards companion robots for older people. Within the participants with a mixed response, negative feelings are often justified based on potential benefits. A very small minority provided a completely negative response. Further example evidence can be found in Appendix H.

Table 18: Responses to open question on ethical concerns of companion robot use with older people (%) (Q5)

Response	N (%)	Examples	
Concern	20 (30)	Concern	N
		Batteries	2 “Emotional distress if the batteries ran out”
		Malfunction	1 “What happens if they malfunction?”
		Human Contact	7 “Might encourage people to be distant from the elderly”
		Robustness	1 “Toughness, can they withstand a fall?”
		Deception	4 “They could become confused as to whether the robot was real or not”
		Privacy	1 “Should not be connected to net (privacy)”
		Danger	2 “Tripping/falling”
		Dignity	2 “They may try to feed or walk them, potential embarrassment”
		Infantilisation	1 “May feel patronised, belittled with a fluffy toy”
No Concern	40 (60)	“No” “None” “No, it seems very safe”	
Unsure	2 (3)	“I don’t know” “Not sure”	

No Response	5 (7)
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Most (40/67) reported having no ethical concerns (Table 18). A further five left the box empty, perhaps also indicating a lack of concerns to report, or alternatively reflecting a lack of understanding. This would suggest prevalence of instinctual ethical concerns is low. The concerns raised by 20 of the 67 participants are summarised in table 18, demonstrating deception and reduced human contact were the most prevalent concerns noted by participants upon unprompted questioning of ethical issues. While prevalence was low, the examples do provide some support for the ethical issues reported in previous literature. However, the concerns around battery life, malfunctioning and robustness relate better to the performance of the robot, rather than ethical concerns. Some further examples are available in Appendix H.

Table 19: Potential ethical issues scored on Likert-scales based on level of concern (1= not at all a concern – 7=very much a concern).

Potential Issue	Median	Mode	Mean	SD
Socioeconomic Status – Equality of Access	5	6	4.72	1.75
Robots for Carer Convenience	4	5	3.98	1.58
Infantilising	4	4	3.45	1.70
Deception	4	4	3.44	1.61
Reduced Human Contact	3	2	3.06	1.68
Injury or Harm	1	2	2.38	1.67
Privacy	2	1	2.17	1.54

Table 19 demonstrates participants felt the most concerning factor related to equality of access to devices through socioeconomic factors. This concern received the highest mean score, but also the highest median and mode, meaning this issue was most commonly scored as of more concern. The second most concerning issue appears to be robots being

used for carer convenience. The least concern was seen for reduced human contact, privacy issues, and potential for injury or harm, all receiving means, modes and medians below the midpoint of 3.5. Infantilising and deception mean scores sit just below the midpoint, whilst the median and mode are just above, demonstrating some concern.

Finally, we acknowledge a possible concern with our participant sample. That is, despite the obvious participant interest in robotics as they attended this exhibition, we recognise 14 out of the 64 participants did not report having an older relative. We therefore analysed (crosstabs and Fisher exact tests) our data from our three key reported outcomes for statistical difference between participants without an older relative, with an older relative and with a relative with dementia. We found no difference between the three groups for the three outcomes we assessed; decision to buy/not buy (table 16) (.320, $n=60$, $p=.925$), general perceptions (table 17) (1.390, $n=59$, $p=.618$), and ethical concerns (table 18) (5.897, $n=62$, $p=.051$). This would suggest the default views of potential future stakeholders is congruent with actual stakeholders.

Discussion

Ethical concerns of stakeholders differ from those raised in the literature

We have demonstrated ethical concerns highlighted during philosophical debate of companion robot use (Sharkey, 2014; Chiberska, 2018; Sparrow, 2002, Sparrow & Sparrow, 2006; Sharkey & Sharkey, 2010; Sharkey & Sharkey, 2012) may differ from those voiced by real-world target groups. The majority of our participants would purchase a companion robot for an elderly relative, suggesting any ethical concerns were not prohibitive to intention to buy. As such, although an awareness of potential issues is evident, they do not appear to weigh strongly enough to act as barriers to successful real-world implementation.

In particular, no specific ethical concerns were reported as a reason for not purchasing a device.

The difference we have noted between robot ethics literature and real-world stakeholders is an interesting result: speculative concerns raised in the literature (Stahl & Coeckelbergh, 2016) appear mismatched with the priorities of family members within a real-world context. It is of course possible the lack of significance placed on debated issues by a key stakeholder group may in fact point to a need to increase awareness of these concerns. As such, we have identified a need for further reflections, in the ethics literature, on the implications of a real-world stakeholder group not sharing the same concerns as those raised by the robot ethics community. Whilst stakeholders have demonstrated ethical concerns in previous, mainly qualitative research with small samples (Pino et al., 2015; Wu et al., 2016), re-evaluation may be required in light of these more empirical findings.

Economic cost is an important factor

Interestingly, economic cost of companion robots presented itself as a continual theme throughout our results, for example as a common reason for not wishing to purchase a device for an older relative further to lack of interest in animals, or limited requirement for such a device. Further support for the central role of the cost barrier comes from participant comments on Paro. Although ten participants suggested they would purchase Paro for a relative, four added the condition “if cheaper.” Financial output is clearly a key deciding factor, and whilst others (Mervin et al., 2018) have demonstrated the cost-effectiveness of Paro as a psychosocial wellbeing activity for older people, the initial expenditure appears prohibitive for family members, a stakeholder group likely to be responsible for purchasing such devices for older relatives. The issue of cost was repeated throughout responses to various questions in our study, including a participant suggesting the challenge faced in

companion robot development is “making the robot responsive enough without it being too expensive.” The idea of “responsive enough” is therefore a topic for further exploration (Study 3 and 10). The younger demographic of the sample could also help explain this result, as cost may be less important among a sample of stakeholders already paying for elder care.

A minority are concerned about reduced human contact and deception

When surveyed with an open question on ethical concerns, most participants reported no concerns. The concerns highlighted by 20/67 (30%) participants however, were congruent with the previous literature. The issues highlighted most often were reduction in human contact, and deception. Companion robots may mediate social contact (Robinson et al., 2016), and reduce care provider burden (Saito et al., 2003; Shibata, 2012), potentially improving quality of care, therefore further research may be required to directly assess impact on social contact of real-world companion robot implementation, based on both quantity and quality of subsequent human interaction. In the meantime, as suggested by Chiberska (2018), we must ensure this technology is applied appropriately. Furthermore, the potential benefits (Jøranson et al., 2015; Wada et al., 2005; Saito et al., 2003; Liang et al., 2017; Petersen et al., 2017; Robinson et al., 2015) make it harder to justify avoiding companion robot use based on ethical concerns (Sharkey, 2014; Chiberska, 2018; Sparrow, 2002, Sparrow & Sparrow, 2006; Sharkey & Sharkey, 2010; Sharkey & Sharkey, 2012) that do not appear to be a particular concern among family members as real-world stakeholders. It has for example been suggested (Gustafsson et al., 2015) family members may justify concerns such as deceit upon witnessing benefits of interaction for their relative. This is supported in our results: participants presented conflicted opinions, beginning with an ethical concern and often justifying the issue so long as interactions were beneficial in stimulating or soothing relatives, or eased challenges faced by family members.

The issue of deception is more difficult to mitigate. Whilst real-world companion robot implementers can be mindful of complementing human contact, rather than substituting entirely, ensuring a lack of deception is more difficult when working with individuals with dementia (Sharkey & Sharkey, 2012). Older people with dementia may indeed perceive robots as social agents and engage with them as such (Study 10 and 11; Sparrow, 2002), which is reported within the literature as unethical and problematic (Sparrow, 2002). However, with only 4/67 (6%) participants reporting this concern, prevalence is low. This contrasts the specific suggestion relatives may themselves feel their family member was suffering humiliation and a loss of dignity through deception (Sharkey, 2014). Thus, it does appear philosophical debate on ethical concerns differs from the priorities of a real-world stakeholder group. As previously noted (Stahl & Coeckelbergh, 2016), there is a requirement in the literature to complement the speculative debate with dialogue within the context of use, providing a voice to stakeholders. Our study would suggest family member concerns on deception are unlikely to form a major barrier to real-world use.

Of further interest from the open question on ethical concerns, was that three of the concerns raised related to performance of the device rather than moral ethical concerns. This would suggest these participants did not hold moral concerns around the use of companion robots with older relatives; rather, they wanted to ensure their reliable and successful use.

Perceived importance of ethical concerns when prompted

The Likert-scales also produced interesting results. As we used a 7-point scale, a midpoint would be 3.5. When looking at the means received by each issue, only two were scored above the midpoint of 3.5, and thus suggesting some level of concern: use of robots for carer convenience and inequality of access through socioeconomic status. This provides

further support for the impact of high economic cost on the real-world uptake of companion robots, and furthers the argument that the ethical concerns commonly debated (Sharkey, 2014; Chiberska, 2018; Sparrow, 2002, Sparrow & Sparrow, 2006; Sharkey & Sharkey, 2010; Sharkey & Sharkey, 2012) hold little impact and relevance to family members, as key stakeholders in their older relatives care. Although reduced human contact, privacy issues, infantilisation, deception and potential for injury are commonly debated in robot ethics literatures (Sharkey, 2014; Chiberska, 2018; Sparrow, 2002, Sparrow & Sparrow, 2006; Sharkey & Sharkey, 2010; Sharkey & Sharkey, 2012), all received means below the midpoint of 3.5, suggesting little prevalence of concern among younger adult family members. Infantilising and deception did receive modes of 4, suggesting some concern, but were still scored of lower concern than carer convenience and equality of access.

Negative views demonstrate suitability of companion robot is not universal

The small number of participants in our survey with negative views towards the robots would suggest these devices are not suitable for everyone, and that there will be incidences of negative response, as seen in previous research (Study 4, 10 and 11; Robinson et al., 2013). Similar incidences were seen in our survey, such as a participant reporting the idea of companion robots “was a bit ridiculous,” importantly, however, negative views accounted for only 5/67 (7%) responses to the open question on general feelings towards companion robots for older people.

Limitations and strengths

This research has provided important insight into the ethical perceptions of the stakeholder group of younger adult family members, a group shown in previous research to hold

impactful opinions towards the real-world use of companion robots (Robinson et al., 2013), and who have been identified as a key stakeholder group to be consulted on ethics (Sharkey, 2014; Chiberska, 2018; Pino et al., 2015). However, a limitation of this study is that there remains a requirement for further dialogue with additional stakeholder groups (older people themselves, care providers, robot designers), to further previous work with small samples and mainly qualitative focus (Pino et al., 2015; Wu et al., 2014) and build a clearer picture of prevalence of ethical concerns within the context of real-world use, as we have. Pino et al. (2015) noted informal carers were less sensitive to privacy concerns than older people with cognitive impairments, who were concerned surveillance applications could damage their privacy. Carers were more positive towards the risk-prevention applications. It is therefore possible the family members in our research felt more positively about certain ethical aspects than older people would themselves, identifying the importance of further and continuing ethical research with the wider stakeholder groups. Establishing prevalence of ethical concerns is particularly important in the context of 'real-world' use, as highly prevalent issues are likely to form barriers to adoption and would signal the requirement for further considerations.

A limitation of our sample is possible distance between our participants and their older relatives, due to the potential participants were not currently directly involved in care of older relatives. It is possible results would differ among a sample of informal carers as stakeholders. Historically, however, family members such as emerging adults, adolescents and younger children have been neglected from inclusion as stakeholders in older relatives care (Sharkey, 2014; Chiberska, 2018; Sparrow, 2002; Sparrow & Sparrow, 2006; Sharkey & Sharkey, 2010; Wachsmuth, 2018; Robinson et al., 2016), despite care involving a whole family system, not only a spouse or older adult child (Beach, 1997). The lack of similar

studies available currently would suggest this neglect is still occurring, highlighting the value of our work and relevance of our participants. Furthermore, younger adults may experience additional impact through the burden experienced by their parents, who may be caring for a grandparent (Beach, 1997). Expanding our understanding of 'stakeholder' could have additional positive implications and acknowledging younger adults as secondary, or perhaps more distant stakeholders could provoke more research into the experiences of this group, and their potential in supporting with the ever-increasing burden of disability associated with the aging population.

We also acknowledge the relatively small sample, but, as noted by others (Stahl & Coeckelbergh, 2016), the traditional approach to ethics literature for healthcare robots has mainly involved philosophical reflection, creating a strong requirement for studies that report participant dialogue on ethical concerns acknowledged as limited within the literature. Therefore, our findings are of strong relevance to the social robot and gerontological community in providing interesting data and insight into a previously understudied area. This study also provides the basis for further research, and prompts further ethics studies reporting stakeholder perceptions. An important implication of our work is that it creates further questioning in this area, and should provoke more exploration into a potential misalignment between stakeholders and ethicists, further to investigations into reasoning. Whilst our study does not address the mismatch in full, it does begin the process of endeavour in this area. Future research may also look to develop methodologically, perhaps with video scenarios of specific instances of ethical concerns. Future research might also consider the ethical perceptions of alternative forms of SAR, such as Pepper (Piezzo & Suzuki, 2016), currently too expensive for widespread use. We chose to focus on robot pets as these devices are currently starting to be deployed across a

greater number of situations in real-world implementation, as they are more affordable and accessible.

Conclusion

We have found interesting differences between the robot ethics community and real-world stakeholders regarding priority concerns for ethical use of companion robots with older adults, which can inform further dialogue in the ethics community. We have further identified a need for ethical literature reflecting on the implications that stakeholders appear not to share the concerns commonly debated in literature. Issues such as infantilisation and deceit appear less relevant to stakeholders of such devices than equality of access due to prohibitively high costs of currently available companion robots. The finding that cost is a primary influential factor is an important outcome of this study, rarely discussed in previous literature, providing an important consideration for robot developers and implementers targeting aged care end-users. A further implication for those working in aged-care is that implementation of such devices is unlikely to encounter many ethical barriers among relatives, despite previously reported concerns.

Declarations

Ethics approval and consent to participate

Ethical approval was received from the Faculty of Science and Engineering ethics committee at the University of Plymouth and participants provided written informed consent.

Availability of data and materials

Additional data used and/or analysed during the current study are available in Appendix H.

Study 8 reflection

Study 8 aided in contributing towards the *understanding of use context* and demonstrated limited prevalence of ethical concerns among family members. The pragmatic, mixed-methods approach to this project allowed us to explore prevalence of ethical concerns numerically further to qualitatively, for an understanding of likely impact. Of course, family members are not the only stakeholders involved in real-world companion robot use, but they do appear to be the group most often cited as possessing ethical concerns. The results of Study 8 demonstrate that despite some awareness of moral dilemmas, these were unlikely to be prohibitive to real-world purchase decisions. This is informative for future implementations, as a mechanism to dispel fears of family disapproval. Additionally useful is the confirmation that economic cost of such platforms is an important factor, Study 8 demonstrated the cost of Paro is not only prohibitive for care homes but also for resident relatives. With both stakeholder groups unable to consider a Paro purchase, this explains the limited real-world adoption of the device. In conversations with collaborating care staff as this project progressed, stakeholders felt it was likely Paro customers to date must have mainly consisted of academic institutions, for research purposes. Combined with prior studies, the results of Study 8 helped inform selection of most suitable devices for real-world *user-assessments* in Study 10 and 11.

Reflection with care home collaborators on the results of Study 8 also led to interesting perceptions on other forms of deceit. Collaborators reported having life-like dolls and role play shops, further to themes within their care homes, to represent the 1930's or a steam train carriage. Such measures were not considered immoral, but were enjoyed by residents, often allowing for reminiscence, a powerful tool for older people. In line with the family members in Study 8, care collaborators felt any ethical concerns are far outweighed by the

potential benefits of robot pets. Without implementations such as doll therapy, robot pets, role-play shops, many residents face an alternative of apathy and lack of meaningful activity, which have no benefits for wellbeing. In fact, lack of meaningful activity is associated with poorer quality of life and physical and mental health (Smith et al., 2018).

With this in mind, SAR has great potential for this audience, not only through the sub-type of robot pets. To this regard, Study 9 had a more general focus on SAR design, as in Study 1 and 2, but is useful for developers of robot pets as much as other forms of SAR.

4.5 Study 9: Morphology of socially assistive robots for health and social care: A reflection on 24 months of research with anthropomorphic, zoomorphic and mechanomorphic devices

(Accepted RO-MAN 2021)

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Study 9 is available in full in Appendix I, but is summarised here, as it did not include any original data. Study 9 instead provided reflective work based on Studies 2, 3, 4 and 8. Each of these four studies had different samples, audiences and aims, but the purpose of Study 9 was to collect and consolidate combined learning from all four studies in generating a recommended 'base design' for morphology of robots aimed at H&SC, as current literature creates difficulty in drawing general conclusions. Post-reflective work of this kind is important, as the combination of data and results from varied studies allows for provision of some concrete design suggestions. As with Studies 1 and 2, the aim of Study 9 was to ensure 'higher-level' acceptability to support procurement and facilitation of robots by decision makers and implementers. While Study 1 and 2 established current higher-level acceptability, Study 9 looked at how robot morphology could best ensure acceptability in future. Study 9 concluded that biomorphic designs

(anthropomorphic/zoomorphic/biomorphic) seemed advantageous over mechanomorphic embodiments in providing social presence. The results also suggested further benefits of zoomorphic design, in avoiding negative fear response and task expectations.

Study 9 Reflection

Study 9 provided an opportunity for the research team to engage in the *Reflect* phase of CAR, and make summative conclusions based on four different studies, and the input of different collaborators across the studies. Indeed, Study 9 suggests zoomorphic embodiment could be most suitable for this sector at present. While the work in Study 9 was not based on new data, the re-analysis for insight into morphology was novel. The aim of Study 9 was not to provide specific enquiry with end-users (provided elsewhere), but to inform general 'base designs' for SAR based on collation of the views of many collaborators, as in Study 1 and 2, to support future developments in attaining 'higher-level' acceptability for this sector.

4.6 CAR Cycle 2 Reflection

Cycle 2 responded to many of the research questions that arose in Cycle 1, together creating a comprehensive understanding of robot pet design, further to an improved understanding of factors affecting implementation, such as cost, hygiene and ethical concerns as potential real-world barriers. Additionally, Cycle 2 also furthered the broad understanding of SAR base design, to aid in promoting acceptability for key policy and decision makers.

The results of Cycle 2 strengthened the design recommendations provided to the collaborating robotics company producing a user-centred prototype, Robotriks, through additional support for the requirement of soft, cuddly, familiar and realistic embodiments, the desired interactivity types (in response to touch and sound), the importance of large,

cute eyes and perceived eye contact and again the potential inclusion of life-simulation features. As such, the results from Cycle 1 and 2 both contributed towards the *Producing a Prototype* activity in user-centred design (Daly-Jones et al., 2000).

Based on *Reflection* of all studies to date included in Cycle 1 and 2, the project then returned to *Planning* studies for the *user based assessment* action of user-centred design, now *context of use* and *user requirements* had been well established in Cycles 1 and 2.

Although the results of studies to date had been fed to Robotriks to inform development of the new prototype, (discussed further in Chapter 7), studies in Cycle 1 and 2 also indicated that there were currently available robots that appeared well matched to *user and organisational requirements* and the *context of use*.

During studies 3 and 4 it became evident that the JfA cat and dog were the most acceptable currently available companion robots included, being preferred by care home residents (Study 4) further to more independent older adults (Study 3). These devices most adequately met older adult design requirements; being soft, furry, familiar and relatively realistic. Based on Study 5, these devices also best matched care staff perceptions of appropriate cost, suggesting they were most likely to be adopted for any real-world use.

During Study 6 it also became evident that JfA devices likely best represented an appropriate size and weight for an older adult's robot pet. Furthermore, the JfA cat and dog fared just as well as Paro and other devices in Study 7a, being safe for use in care homes providing adequate infection control procedures were followed. However, the prior studies included in this thesis had relied on immediate perceptions rather than longer term use, and questions remained on novelty effect (as raised in Study 4) and robustness (as raised in Study 2). Literature was also limited on any impacts or benefits of affordable companion

robots, as those reported for Paro. For this reason, in Cycle 3 of the CAR, this thesis reports on longitudinal data of JfA cats and dogs implemented with older people.

Chapter 5: CAR Cycle 3 – User-based assessments

Chapter 5 provides two *user-based assessments* with the JfA robot cat and dog, the devices perceived as most suitable for the target audience and use context, therefore possessing greatest potential for real-world implementations. While Study 11 was a research trial planned with collaborators based on reflection of prior findings, Study 10 was opportunistic data collection, but evidences CAR bridging the gap between research and practice. During the project, HB and the EPIC team gave various talks and presentations on robot animals and the ongoing research at care focused and EPIC networking events. The interest generated in collaborative robot pet work underway in some care homes appeared to result in additional sites implementing devices. HB and the EPIC team were approached by two separate organisations who had chosen to purchase JfA devices for their supported living sites and were happy to be involved in research. The opportunity was taken to collect longitudinal data with very good ecological validity, based on the data collection coming from genuine robot implementations. Regarding the user-centred design activities, Study 10 thus provided the first *user-based assessment* of the devices selected as most appropriate (matching user and context requirements) currently available companion robots.

Study 10 was published in the proceedings of HRI 2020 as a late-breaking report with 2-page limit, therefore the below section provides a fuller version of the work than that available within the publication. A video summary is available here:

<https://www.youtube.com/watch?v=A3iUqdEcQpw>

5.1 Study 10: Longitudinal diary data: Six months real-world implementation of affordable companion robots for older people in supported living

(Published proceedings of HRI 2020) (published version available from

<https://doi.org/10.1145/3371382.3378256>)

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<https://doi.org/10.1145/3371382.3378256>

Introduction

Robots have potential as a technological aid in meeting increasing health and social care demand (Broadbent et al., 2009), caused in part by increasing life expectancy (Broadbent et al., 2009; Abdi et al., 2018; Moyle et al., 2018), as human functional capacity can deteriorate with age (Garçon et al., 2016; Chatterji et al. 2015). This issue is further exacerbated with decreasing numbers of health and social care workers (Abdi et al., 2018). One form of robot with particular potential for use with older people is companion robots, that is, robot pets designed congruent with animal aesthetics and behaviours (Broekens et al., 2009; Moyle et al., 2013). Paro, the robot seal, is the most well researched example (Pu et al., 2018). Studies have suggested numerous benefits of interacting with Paro, including reduced agitation and depression in adults with dementia (Jøranson et al., 2015; Wada et al., 2005), more adaptive stress response (Saito et al., 2003), reduced care provider burden (Saito et al., 2003), and significantly improved affect and communication between people with dementia and day care staff (Liang et al., 2017). Furthermore, Paro may reduce psychoactive and analgesic medication use (Petersen et al., 2017), and even decrease blood pressure (Robinson et al., 2015).

One issue with currently available literature is the limited availability of longitudinal ‘real-world’ studies. Long-term studies appear underrepresented in Human Robot Interaction (HRI) research generally, interestingly, an analysis of HRI conference papers over three years noted only 5/96 studies included more than one robot interaction session, highlighting requirement for long-term investigations specifically within this field, due to potential impact of novelty (Baxter et al., 2016). Longitudinal data is of course additionally relevant considering the general desire to see HRI systems implemented in the real-world (Baxter et al., 2016). This limited availability of longer-term investigations is also prevalent for companion robots specifically. Much previous research with Paro is over shorter time frames, for example 6 weeks (Liang et al., 2017; Thodberg et al., 2016), 10 weeks (Moyle et al., 2017a) and 12 weeks (Jøranson et al., 2015; Petersen et al., 2017). Wada et al. (2005) provide an exception, with Paro implemented in a care facility with older people over 12 months, however researchers controlled the intervention and dose (1 hour on a prepared desk, two days a week), and thus did not observe ‘real-world’ use. Further studies were part of well controlled trials (Pu et al., 2018), which although scientifically robust, provides little insight on ‘real-world’ non-research implementation. A review of research on socially assistive robots for older people concluded insufficient attention had been paid to the novelty effect, with studies not being long enough to eliminate either interest in or stress of the new and novel technology (Kachouie et al., 2014). It has also been suggested (Sparrow & Sparrow, 2006) that there is a sizable gap between companion robots being an entertaining and amusing novelty, and being an entity to form a friendship or social relationship with. The authors were cynical on how long devices remain entertaining, and how involving the relationships between the devices and users are in practice. In particular, they noted the potential for devices to lie abandoned, with bored users having exhausted their possibilities (Sparrow & Sparrow, 2006). Addressing these concerns around longer-term use is our core

contribution: specifically, we assess such 'real-world' use over a longer period, and with high ecological validity due to the low-impact methodology employed.

The previously mentioned study (Sparrow & Sparrow, 2006) further suggests there is likely a discrepancy between testing and real-world use of robots, particularly regarding robustness, reliability, cost, and additionally, ability to sustain interest. Longitudinal robustness and engagement with Paro has been reported; Wada et al. (2005) noted following a year of use, Paro had demonstrated durability and not been broken, also reporting no loss of interest in Paro over the 12 months. A challenge faced when implementing Paro is the cost. Although Mervin et al. (2018) demonstrated the device was a cost effective agitation intervention for older people over a 10-week study, the real-world stakeholders we have spoken to (care home managers, staff, older people, family members), report that the price of around £5000 is prohibitive to purchase, congruent with concerns of care staff in previous research (Moyle et al., 2016). As noted by Moyle et al. (2016) staff reported nursing homes would not have such funds, and thus would never be able to introduce a Paro into practice, highlighting the importance of research with more affordable potential alternatives.

Alternative devices are currently available at more affordable costs, including Pleo the dinosaur and the JfA cat and dog, which have been used in previous (albeit short-term, exploratory) research with older people (Heerink et al., 2013; Picking & Pike, 2017). Further work has even suggested more affordable devices such as the JfA animals may be preferred and more acceptable to older people than the commonly used Paro (Study 3). However, due to the apparent selection bias towards Paro in research (Pu et al., 2018; Kachouie et al., 2014), longitudinal, real-world studies with these more affordable, less interactive and sophisticated devices are lacking, but essential to ascertain ability to sustain interest and be robust enough within real-world use, to justify substitution of the more technologically advanced Paro.

We therefore collected data with high ecological validity, on the real-world implementation of affordable companion robots, to provide insights on developing relationships, novelty, robustness and longer term real-world use.

Methods

Design

We followed two supported living facilities that acquired affordable companion robots as an alternative to Paro for the first six months starting from the day of acquisition. In particular, we collected diary data for this time span. Due to prohibitively high cost of Paro, the sites both independently chose to purchase JfA devices (between £80-£110). This allowed the capture of 'real-world' use, in contrast to previous research where researchers provided intervention doses and use instructions. The implementation of the devices received no influence from the research team, creating highly ecologically valid data.

Ethical approval was received from the relevant University ethics committee. Our research participants were the care staff/site managers, who consented to share information they collected.

Materials

Robots: Older people on both sites had the opportunity to interact with JfA companion animals (Figure 27).



Figure 27: JfA dog, JfA cat.

Diaries: Both sites were provided with physical diaries in which to record their observations. Diaries were stored with the robots, with a sign to encourage data recording following use. The use of diaries to collect qualitative data has been used previously (Birks et al., 2016), and are particularly useful for usage scenarios, allowing assessment of user engagement and experience within a natural setting (Lischetke, 2014). The diaries were also complemented by a short interview with the manager of Site A upon collection of the diaries.

Participants and Settings

The two sites involved care for older adults and people with dementia or learning difficulties in supported living facilities. Sites are comprised of individual flats, apartments or residences with a communal area and care staff and management on site for additional support. The sites provide supporting housing for older people (over 60), with a need for accommodation with extra support, primarily due to dementia, but also frailty and learning difficulties.

Site A and B both implemented communal area group sessions with the devices. Site A cares for 64 (51 female, 13 male) individuals. Group sessions were available with the animals daily, with group sizes ranging from 14-40. Site A had purchased a JfA cat and dog, and later purchased an additional JfA cat. Site B cares for 30 (18 female, 12 male) individuals with additional day-care customers attending. Site B had purchased a JfA cat and group sizes ranged from 11-60 (including day-care customers additional to residents), with groups meeting and having interaction opportunities on two occasions each week.

Procedure

Animals were available within communal areas, and interaction was encouraged by staff. We did not suggest or specify an intervention dose, rather, we simply observed how real-world use developed.

Data Collection

The two sites maintained diaries over six months, using event-based sampling (Lischetzke 2014), whereby participants initiated data-collection through a pre-defined event, in this case, a reflection on robot interactions. Direct observations were conducted by two members of staff at each site, who reported on interaction between clients and devices through diary entries. At site A, staff observed interaction daily (week-days), and at Site B, staff observed interactions once or twice weekly. Following the six months, diaries were collected and a short interview was also conducted with the manager at Site A. Staff were asked to record reflections following interactions. In total, 35 diary entries were recorded, along with the additional interview data. Some weeks during the study lacked diary entries, this may reflect annual leave of collaborating staff, or reflect limitations of the chosen methodology.

Data Analysis

Diary data was collated with the interview data, and analysed using thematic analysis, common threads were identified across all available data, through familiarisation, initial code forming, collating codes into themes, before checking, defining and reporting (Braun and Clark, 2006).

Results

Emerging themes were; positive outcomes; acceptability, wellbeing use, change in use, negative responses and practicalities (Table 20).

Table 20: Themes with example evidence. Further evidence in Appendix J

Theme	Initial Codes	Interpretation	Evidence recorded by staff	*(R) indicates resident quote recorded by staff
Positive Outcomes	Entertainment, pleasure, reminiscence, communication, emotions	Reflects positive effects attributed to interaction. Suggests real-world impact on emotions and communication	"They make people laugh" "They bring back lovely memories and emotions" "Having the dog encouraged three people to talk about pets they had previously" "Enjoyed by many" "She would talk to and stroke [the cat] and become a lot more verbal"	
Acceptability	Acceptance, requesting animals, ownership, facilitator bonding	Devices demonstrated good real-world acceptability by staff and clients	"[Names] requested the animals, they want to hold them" "Sat for hours petting the cat" "Insistent she wanted one" "An estimated 80% of clients loved the cat" "Formed a strong bond and attachment" "I [staff] was surprised how protective I felt towards the cat"	
Wellbeing Use	Easing anxiety, distraction, alleviating moods	Apparent wellbeing outcomes attributed to interaction	"A good distraction" "Anxiety eased" "We have used the cats to de-escalate an emotional situation" "It really seemed to calm her down" "She was crying, shouting, swearing [sic]. Immediately her body language changed, she was relaxed, smiling, within seconds, she was laughing" "Deescalated the whole situation and worked really, really well" "Very therapeutic"	
Change in Use	Change in use	No novelty effect, early months detail structured 1-2 hour sessions, then change to robots continually present and in-use	"1-2 group session" "2 hours" "Present all day" "Very much part of the service" "Part of the home" "As normal pets would be" "Have just become part of the norm" "Sitting on laps as normal pets world"	
Negative Responses	Negative response, unnecessary distraction, gender difference, jealousy	Some negative responses, minority of records, two cases of extreme negative responses were from males	"Creepy"(R) "He himself [resident] would wring its neck and tear its head off" "That horrible thing"(R) "Smash it up"(R) "It would just be a time waster"(R) "I would be fussing it all day, so wouldn't get any housework done"(R) "Very reluctant to allow others to take the cat" "Everyone wants them at the same time"	
Practicalities	Cost, robustness, cleanliness	Price too high for some older people themselves, devices appeared robust	"Disappointed in the price" "The cats are looking a little bit loved, but the dog is still looking perky" "They are doing well, but I could imagine they get dirty quite quickly"	

Positive Outcomes

This theme represents the positive outcomes of interaction with the devices recorded in the diaries, and emerged through the initial codes of entertainment, pleasure, reminiscence, communication and emotions.

Entertainment was a key 'reason for use' listed in both Site A and B diaries. Staff at both sites reported that *"everyone was happy to interact"* and devices *"certainly put smiles on*

everyone's faces." There are multiple incidences recorded where the devices *"make people smile."* Site A suggested *"responses are always positivity and smiles."* Staff report *"when you take the animals in, immediately you get a response, they're excited and they're looking forward to it and it's fun."* It appears from the diaries that devices were particularly well enjoyed by individuals with dementia and learning difficulties, although older people with physical challenges were also pleased to interact, they did not appreciate them to as great an extent. Despite being *"enjoyed by many"* the strongest attachments were formed by those with cognitive impairment. Those less interested in the animals were reportedly still happy to see them, recognising and appreciating the happiness they gave others. It appears the cat was *"enjoyed the most,"* so much so that Site A purchased an additional cat during the six months, due to the success of implementation. Grooming the cat appeared to hold particular appeal, with older people *"nurturing"* it with *"lots of brushing."*

The diaries demonstrated those forming strong attachments often presented an emotional response. The diaries reported feelings including participants being *"quite emotional,"* interacting with the cat with *"such tenderness,"* with responses being *"really very moving."* The diaries further reported a group session with older people with learning difficulties. The group demonstrated very good acceptability of the cat, with the primary concern being that each group member received equal petting time. The diaries repeatedly evidenced good awareness of sharing and fair turn taking. The diaries report devices had a *"calming but uplifting effect on the group,"* being *"soothing"* and *"relaxing."* A further positive outcome was reminiscence. Our collaborators reported the devices brought *"back lovely memories and emotions"* of clients previous pets, including *"having the dog encouraged three people to talk about pets they had previously."* A further related outcome was a perceived increase in communication of older people, with diaries suggesting clients were more verbal when the

cat was present. Records demonstrated one particular older person who would *“talk to [...] and stroke [the cat]”* and *“become a lot more verbal when [she] has the cat.”*

It is clear therefore, that real-world implementation of the JfA products induced a number of positive effects attributed by staff to the presence of the devices, showing a real-world impact on emotions and communication.

Acceptability

This theme represents evidence throughout the diaries that devices were well accepted by clients and staff at each site, and emerged through the initial codes of acceptance, requesting animals, ownership and facilitator bonding. The diaries recorded that upon the fourth group session with the animals at Site B, clients were *“excited to see the cat and have their turn to hold it”* suggesting interaction with the cat fairly quickly became a desired activity. Furthermore, at Site A, the fourth diary entry, one week after implementation, noted animals were actually requested by clients, rather than interaction being initiated by staff bringing out the devices, as *“they want to hold them.”* Group members referred to *“loving”* the cat, some older people had short interactions of 10-25 minutes, before passing the device on to a peer, others spent the *“whole morning”* or *“hours”* with a device on their lap. The diaries suggest participants spoke to the cat *“exactly the same way that people speak to living animals or babies”* demonstrating acceptability of the device as a social agent. This interaction congruent of that with a live animal was repeated throughout the records, with devices being *“stroked as they would a cat and dog.”*

Most clients found the devices acceptable. Our collaborator at Site B reflected and reported in one diary entry that an estimated 80% of participants in the sessions *“loved the cat.”* The dairies reported participant comments towards the devices, including; *“cute,” “excellent,”*

“adorable,” suggesting they thought it was *“real”* and could not help but pet it. Collaborators believed the main reason for the 20% of participants who disliked a device was that it was *“creepy.”* The dairies recorded participant comments including *“it’s quite scary [...] I’m used to my real cat.”* The dairies also demonstrated, that although well received generally, *“maybe half a dozen”* older people on both sites developed a very strong *“bond”* and *“attachment”* to the animals. Staff reported these individuals would *“talk to [the animal] as it was her own.”* During times animals were to be stored (over-night), they had to be shut in an office *“to stop them wandering, because some people are quite attached to them”* and were reluctant to part with them.

Further to good demonstrated acceptability among older people, dairies also supported acceptability of devices among our collaborating staff who were facilitating the sessions. One data collector reported her careful maintenance of the cat, and apparent conflict over storing the cat in the box, our collaborator *“reasoned with”* herself, as *“this is a piece of equipment so it doesn’t need to be out of the box.”* The collaborator was also reluctant to pass the device on to colleagues, wishing to make sure the cat was *“looked after,”* providing care and use instructions, and feeling *“a huge measure of relief”* upon the cat’s return. The dairies also record cases of staff naming the cat, and anthropomorphising about names that suited or *“fit”* the cat. There is further evidence of anthropomorphism through staff reporting feeling *“disrespectful”* when referring to the cat as *“it”* in the dairies, and admits becoming *“attached”* and *“protective.”* The JfA devices thus show good acceptability within real-world implementation for both clients (older people) and staff.

Wellbeing Use

This theme represented dairy evidence that real-world use of the JfA products appeared to have wellbeing outcomes for older people, and emerged through initial codes; easing anxiety,

distraction and alleviating moods. Anxiety was another key reason for use recorded in the diaries, second to entertainment. The cat was reported to ease anxiety, being a distraction from the cause of distress. The diaries reflect on a particular individual who becomes agitated and anxious about what time her visitors may be coming. Staff reported that interacting with the cat provided *“a good distraction”* allowing the client to *“forget time,”* and helping her *“anxiety ease.”* For another older person, the diaries recorded the cat can *“take her mind off anxiety.”* A collaborator reported *“we have used the cats to de-escalate an emotional situation.”* Diary entries evidence a crisis situation, where a client reported *“a cry for help,”* *“out of pure desperation,”* the staff recorded that the lady was *“very emotional, very scared, very timid, shaking and nervous.”* Upon recognising the individuals need the staff *“took the cat out [...] she really took to the cat, she spent quite some time with the cat on her lap [...] it really seemed to calm her down.”* Staff suggested that *“although it is fun, it has a really calming effect as well.”* A further incident was reported of *“a customer who frequently becomes agitated and verbally abusive to staff, through frustration as part of her illness.”* The diaries evidence occasions where she would be *“crying, shouting, swearing, phoning the police,”* staff responded by offering her the cat, *“immediately her whole body language changed, she was relaxed, smiling, literally within seconds, she was laughing.”* The resident found humour in the cat licking its paw, and *“totally calmed down”* after *“sitting with the cat for ages and ages.”* The cat therefore *“deescalated the whole situation and worked really, really well.”* The licking paw movement of the cat appeared particularly well received, being *“unexpected”* and thus making people laugh. It appears possible from diary data that some of the mood benefits may result from the perceived care requirement of the animals. Records suggest clients would ensure to *“be very lovely”* towards the devices, being *“very gentle”* and *“talking to them,”* perhaps halting agitated or violent behaviours, and providing *“comfort and joy.”*

Change in Use

Interestingly, the diaries also reflected a change in use of the robots, this theme emerged only from a code of the same name, but appeared to be an interesting, novel result of this real-world observation of implementation. This evidence for a change in use over time contributes towards answering the key question of this study. When assessing the duration and frequency of interactions over the six months, they actually increase with time. The sessions progress from well structured, 1-2 hour group activities in July, to having the devices *“present all day,” “very much part of the centre,” “part of the home,” “as normal pets would be”* by October, continuing until the end of the study. It appears therefore, that at least over six months, the animals did not lose their appeal, suggesting initial acceptance is not a novelty effect, rather, acceptance actually continues to grow. This is a positive result suggesting full acceptance and implementation of these accessible companion robots in real-world older person care. By November, the diaries suggest the animals *“have just become part of the norm,” “sitting on laps as normal pets would.”* A further development in use within this real-world observation, is that further to structured group sessions, or general daily use, the animals were also used as ‘as required’ interventions. Much research focuses on using robots in structured sessions, but this observation of real-world implementation demonstrates an interesting further potential use.

Negative Responses

The diaries do report some incidences of negative response, although these are certainly within the minority, it is important to consider these outcomes. This theme emerged through the initial codes of negative response, unnecessary distraction, gender differences and jealousy. As noted above, our collaborators believed an estimated 20% of older people did not like the devices as much as other users, namely due to perceiving them as *“creepy,”* there

were however two specific incidences of strong negative reactions. One diary entry recorded a gentleman being initially interested in the cat, before becoming agitated and suggesting his live cat would *“rip it up”* and that he would in fact encourage it to do so, even that *“he himself would wring its neck and tear its head off.”* A further negative response recorded was another gentleman referring to the cat as *“that horrible thing,”* and *“creepy”* suggesting he would *“smash it up,” “break it and put it in the bin like all cats should be.”* Our collaborator referred to concern around the active discussion of harm towards the cat, questioning the motives behind the comments. These are the only two incidences of extreme negative responses over the six months from both sites, however they do suggest such devices are unlikely to have completely universal appeal. Interestingly, both incidences were with men, and although many men enjoyed the animals, it was also noted by staff that the strongest attachments were formed by women, as *“female customers tend to prefer them more.”*

Further to the extreme negative responses, there were incidences within the diaries where older people appeared to enjoy the device, but worried it would reduce their productivity, distracting them from chores or other activities. Diaries reported *“while people were curious about the cat and wanted to look at it and pet it for a short while, it seemed more like a slightly unwelcome distraction from their conversations.”* Further evidence for distraction came from a group session where an older woman reported she *“would love one,”* however, she felt *“it would just be a time waster”* and another who suggested *“I would be fussing it all day, so wouldn’t get any housework done.”* Diary entries also evidence some small issues with jealousy. Staff reported some individuals became *“instantly attached”* being *“very reluctant to allow others to take the cat.”* Although Site A suggest *“when we bring them out initially, everyone wants them at the same time, but the customers are quite good at sharing.”* It appears throughout the records, that although some older people displayed reluctance to

part with a device or jealousy towards another user, there was minimal negative consequence, with much more evidence in support of fair sharing.

Practicalities

A final theme was that of practicalities, although evidence was not prolific. This theme emerged from the codes of cost and robustness. For older people themselves, the price of the JfA devices seemed too high for them to be able to purchase an animal personally, with many older people at Site B querying purchasing a cat for themselves, but reporting the cost was too much, leaving them *“disappointed.”* It is worth noting however, that the cost does not seem prohibitive for the site managers, particularly on Site A, where three devices were purchased by the end of the study. Regarding robustness, it was noted that no major issues occurred, neither technical nor physical, it was reported that *“the cats are looking a little bit loved, but the dog is still looking perky.”* There were no issues with breakages reported. It seems therefore, that over six months and on two sites, the JfA devices were robust enough to withstand prolonged daily use without issue.

Discussion

This study provided important real-world data on the use of affordable companion robots with older people over a six month time frame. This study did not measure wellbeing outcomes quantitatively through validated measures, as previous research has for Paro (Jøranson et al., 2015; Wada et al., 2005; Saito et al., 2003; Liang et al., 2017; Petersen et al., 2017; Robinson et al., 2015), however, Moyle et al. (2017b) noted previously that some benefits can be missed by selected psychometric measures, recommending including comments of staff and family members. The staff reports in our study support the potential for JfA companion animals to provide wellbeing benefits under real-world use circumstances, particularly for reducing anxiety, agitation and alleviating moods, noted through the theme

of wellbeing use. These outcomes have been reported previously for Paro (Jøranson et al., 2015; Wada et al., 2005), but there is limited research on more affordable devices such as the JfA products. This demonstrates the potential for more affordable devices to provide a possible alternative for the more expensive Paro, where a companion robot is desired but Paro's price is perceived as prohibitive. Although further research is now required to assess the wellbeing outcomes with these devices quantitatively (Study 11), this study has provided important insight into the wellbeing potential of such devices under real-world conditions.

As noted, some of the previous research on wellbeing outcomes for companion robots is from well-controlled research trials (Pu et al., 2018), and thus provides limited generalisability of outcomes from 'within-research' contexts to real-world use, debated as the difference between efficacy and effectiveness (Kim, 2013). Efficacy can be seen as the assessment of a healthcare intervention under 'ideal' circumstances, whereas effectiveness is the assessment of the intervention under usual circumstances of healthcare (Kim, 2013; Haynes, 1999). The selected and controlled conditions of planned research provides explanatory data, rather than pragmatic research under real-life conditions. Our opportunistic study would therefore go some way towards suggesting potential effectiveness of JfA products in achieving benefits for anxiety and agitation among older adults with dementia and learning difficulties, under real-world conditions, without any researcher input, and over a prolonged period. Whilst this finding now needs further exploration, longitudinal insights such as this study do strengthen the argument that wellbeing changes may result from the intervention, rather than unmeasured individual characteristics (Telzer and Fuligni, 2009).

A review previously acknowledged insufficient attention paid to the novelty effect within social robot research with older people (Kachouie et al., 2014). As Sparrow and Sparrow

(2006) suggested, it remained possible that companion robots provide an amusing and entertaining novelty, short term. It was furthermore suggested devices may lie abandoned upon novelty dissipating. Our study has gone some way in answering this query for the JfA devices specifically, which did not appear to be novel entertainment objects, but actually demonstrated increasing acceptability and use over the six month study. The devices also demonstrated robustness despite prolonged daily use with multiple older people, and thus in these respects provide comparable long term engagement and robustness with the more expensive Paro (Wada et al., 2005).

This study would also support good acceptability of the JfA devices, whilst acceptability of socially assistive robots (including Paro) for older people has been reported previously (Pino et al., 2015), there was limited acceptability research specific to these more affordable devices. Piking and Pike (2017) previously provided five individuals with JfA cats, reporting after two months that two were rejected and returned, while three participants demonstrated acceptance. Their study was however a very small-scale preliminary study, which our study has furthered. The themes of positive outcomes and acceptability in our study would suggest good acceptability of these devices in real-world contexts with older people.

The evidence for negative responses within our study is interesting, and congruent with previous research (Moyle et al., 2017a,b) also documenting variation in response and incidences of negativity. This would suggest such devices are not suitable for everyone. It is of some interest that the two individuals displaying extreme negative responses were both men, similarly, our collaborators reported greatest acceptance and attachment among women. Previous research with Paro found similar gender differences, with women evaluating Paro higher in terms of feeling comfortable and wishing to interact with it

(Shibata et al., 2009). It may be that although such devices are appreciated and beneficial across genders, some gender difference does exist in the likelihood to form very strong attachments to robot pets. Further work is needed to explore this.

Previous debate on the ethics of companion robot use has suggested it is unethical that older people, particularly those with dementia (Sharkey & Sharkey, 2012), may perceive companion robots as live animals and social agents, and interact with them as so, reported previously as doing them a disservice (Sparrow, 2002). Our study suggests this certainly happened, with much evidence of older people perceiving and engaging with devices as social agents. Our study additionally suggests however that our staff collaborators, who are cognitively intact younger adults, also bonded with the devices and perceived them as social agents, caring for them and being reluctant to pass them to colleagues. This suggests bonding with a robot pet is not limited to people with cognitive impairment, and is perhaps less an issue of deception, and possibly a natural response to devices intentionally designed to replicate social agents.

A limitation of our study is that diaries were maintained at only two specific sites, limiting generalizability to other locations, including care homes, however, clients involved in this study were still relevant end-users (older people, primarily with dementia). This study does however demonstrate scope for wider use of such devices (supported living, learning difficulties). This study is also limited by many diary entries missing the initials of clients involved in that session. It is possible recording clients initials was not feasible for larger groups, or for use throughout the whole day, however this does mean we are not certain if comments made refer to the same individual during different episodes or many different people. A further limitation is the lack of validated measures used, however, this instead allowed an opportunistic real-world observation of genuine implementation, providing an important, ecologically valid, insight on the process and developing use of such devices.

Such methodologies allow capturing of momentary experience in close-to-real-time (Lischetzke, 2014). An implication of this study is the potential for more wide-spread adoption of such devices, and support provided for more affordable, less sophisticated robots and devices to be developed and researched for this purpose. There has been a clear selection bias towards Paro in companion robot research (Pu et al., 2018; Kachouie et al., 2014), problematic due to limited real-world uptake, likely in part due to prohibitively high cost (Moyle et al., 2016). Although this study can be furthered, results suggest initial potential for interactive ‘toys’ as accessible alternatives.

Conclusion

We have provided an important, longitudinal insight into the real-world implementation of affordable companion robots in older adult care. This study has demonstrated that the JfA cat and dog do not suffer from novelty effect, with use increasing over the six months. Furthermore, the devices appeared robust and demonstrated good acceptability among the majority of older people. This study also demonstrated potential for these more affordable companion robots to provide wellbeing benefits, including reduced agitation and anxiety and improved communication.

Study 10 reflection

Study 10 provided the opportunity to begin *user based assessments* with the devices best matching *user and organisational requirements* and *context of use*. The JfA devices were entertaining and older people did not lose interest over the longer time period. In fact, adoption appeared to improve longitudinally. This is a positive result for the field of companion robot research. Study 10 gave some suggestions that robots were more suitable

to individuals with cognitive impairments, although Study 3 suggested appeal among more independent older people. Suitability of robot pets was thus furthered in Study 11.

Study 10 additionally provided further insight into how real-world implementation may work. The devices were purchased by the care companies themselves, and older adults within Study 10 suggested JfA devices (seen as affordable to staff and family in Study 4, 5 and 6) were too expensive to purchase themselves. It is therefore likely that real-world implementation would depend on purchases from stakeholders in older adult care facilities, rather than older adults themselves. This further highlights the importance of 'higher-level' acceptability and positive attitudes towards SAR among stakeholders in the care of older people (Study 1, 2 and 9), who are clearly crucial in facilitating robot use.

Study 4 previously provided some evidence towards benefits of robots, particularly JfA devices, in prompting communication and reducing agitation (e.g. the case study with Hilary). However, Study 4 was cross-sectional and allowed for limited claims on the beneficial impact of such devices, longer-term. The results of Study 10 support the beneficial potential of JfA devices however, and justify further research into wellbeing potential, as explored in Study 11.

As seen in previous work, much literature exists on various uses and impacts of Paro, but studies with alternative devices are limited. Studies 1 and 2 have demonstrated requirement and acceptability of SAR for the H&SC sector and Studies 3 and 4 have demonstrated acceptability of robot pets for older adults specifically. Studies 3, 4, 5, 6, 7a and 8 were all used in the decision to select the JfA devices as the most appropriate currently available robots for *user based assessments* in Cycle 3. Likewise, the reflection in

Study 9 also demonstrated that familiar robot pets are a suitable and acceptable form of SAR for real-world implementation into H&SC at present. Study 10 provided an initial insight into the real-world implementation of affordable robot pets for older adults and demonstrated robustness and lack of novelty, but lacked any validated measures or outcomes, and additionally was conducted in a supported living facility, thus having limited generalisability to care homes. As the final study in this work, Study 11 aimed to provide an exploration of use and impact of affordable robot pets, again contributing towards the *user based assessment* action of user-centred design. Regarding the CAR approach, Study 11 was a key collaborative effort. Four of the care homes that had participated in Study 4 (and become collaborators for reflection throughout) were also participants of Study 11, and as such were involved in the *Planning* of the trial. Further to long-term collaborators, I additionally worked with the local dementia liaison and clinical psychology teams. Once the research team had decided upon the structure of the trial, and collaborators had informed the intended outcomes to measure, the dementia liaison team ensured appropriateness of the method for residents with dementia. Study 11 was the first study of this thesis directly involving care home residents with moderate to severe dementia (and thus lacking capacity), therefore collaboration with the dementia liaison team provided additional insight and expertise in the *Planning* of the research.

For additional confidence in selecting methods for Study 11, a pilot study was conducted to trial a number of scales and measures, to co-design feasible outcome measures for Study 11 with collaborators.

Study 11 pilot study

The pilot for Study 11 was conducted in one care home, to establish feasibility of outcome scales, with ethical approval from the Faculty of Science and Engineering Committee at the

University of Plymouth. A JfA cat and dog were placed in a collaborating care home for eight weeks, and collaborators engaged in completing and commenting on measures of loneliness, neuropsychiatric symptoms, challenging behaviour, depression, anxiety, agitation, care provider stress and medication use. The pilot did not provide sufficient data or sample size to report outcomes, but provided collaborators with an example of proposed measures, in order to co-design outcomes for Study 11. Based on previous research suggesting pets can produce varying benefits per each individual, restricting outcome measurement to just one primary outcome (e.g. agitation) was thought inappropriate. On the other hand, a battery of scales was also inappropriate due to participation burden. Collaborators and the research team thus decided on the neuropsychiatric inventory (nursing home version) as the primary outcome, with communication, challenging behaviour and occupational disturbance (as a measure of carer burden) as secondary outcomes. A fuller summary of scale selection is available in Appendix K. The CAR approach thus aided in the *Planning* of Study 11. The *Act and Observe* stages of the *user-based assessment* are described below.

5.2 Study 11: The implementation and impact of affordable companion robots in eight care homes in Cornwall England before and during the COVID-19 pandemic: an eight-month, stratified cluster randomised controlled trial.

(Paper drafted)

Authors: Bradwell, H.L., Edwards, K.J., Winnington, R., Thill, S. & Jones, R.B.

Introduction

The health and social care (H&SC) sector worldwide is under increasing pressure (Moyle et al., 2017a), with increasing life expectancy (Abdi et al., 2018; Broadbent et al., 2009; Moyle

et al., 2017a), and reductions in workforce numbers (Abdi et al., 2018) creating more demand for services (Broadbent et al., 2009). Assistive robotics as a supporting strategy for H&SC has generated particular research interest (Broadbent et al., 2009). Amongst these, robot “pets,” also referred to as companion robots or robopets, are a class of robots specifically designed to be congruent with animal aesthetics and behaviours (Broekens et al., 2009; Moyle et al., 2013).

Companion robots may offer a psychosocial method of improving wellbeing for older adults and people with dementia. The most well researched companion robot is Paro, the seal (Jung et al., 2017). The use of Paro for individuals in care homes, or with dementia, is very well studied (Kachouie et al., 2014), generally suggesting therapeutic benefit (Bemelmans et al., 2015a). The literature suggests benefits of interaction include: reduced agitation (Jøranson et al., 2015), reduced depression (Misselhorn & Stapleton, 2013), more adaptive stress response (Saito et al., 2003), reduced loneliness (Robinson et al., 2013), and reduced care-provider burden (Saito et al., 2003; Wada et al., 2004). Previous research by Petersen et al. (2017) demonstrated Paro could reduce psychoactive and analgesic medication use. Jøranson et al. (2015) also reported a Paro intervention group used significantly less psychotropic medication compared to the control group. This outcome is particularly relevant due to the detrimental impact of pharmacological treatments on older adults (Sheehan, 2012; Sullivan, 2014). However, Paro is expensive at ~ £5000 per robot, and this limits the number of people able to benefit from interactions (Moyle et al., 2017a). For this reason, we have conducted various studies to compare Paro with seven more affordable robots and toys based on factors including design preference, requirements and practical considerations with key stakeholders (older adults including care home residents, care home staff, resident family members and wider H&SC professionals). These studies have

used a collaborative action research approach (CAR) involving stakeholders as collaborators in all stages of the research process, including design, data collection and reflection (Nichols, 1997). The inter-disciplinary studies to date have been a pragmatic mix of focus groups, surveys, observational diaries and interviews.

Results thus far have consistently suggested a strong preference for the JfA cat and dog (Study 3, 4 and 6), based on factors such as familiarity, life-like aesthetics, relatability, and interactivity. Further work has additionally shown the JfA devices are likely the most suitable size and weight for older adults, and have the most appropriate volume and frequency of vocalisation (Study 6), and appear affordable enough for real-world implementation (Study 5), further to appearing safe regarding microbial contamination with suitable cleaning (Study 7a). Additionally, there was little evidence to suggest ethical concerns would pose a barrier to implementing robot pets with older people (Study 8). We therefore selected the JfA cat and dog as the most appropriate currently available companion robots. In Study 10, results demonstrated it to be unlikely JfA devices suffer from a novelty effect, and the results suggested good robustness of devices. The results also suggested some possible wellbeing outcomes, including reduced agitation and improved communication, although these outcomes were not measured directly. Previous work was also not conducted in care homes and lacked participation of residents with limited mental capacity due to dementia. Study 11 aimed to rectify these literature gaps, providing a robust exploration of JfA robot implementation in eight care homes, with validated outcome measures and qualitative perspectives on the use and impact of these devices for older people and individuals with dementia living in care homes.

Previous work with JfA devices

There appears to be limited research available assessing affordable alternatives for outcomes similar to those achieved with Paro. Studies 4 and 10 together with others' work have suggested possible positive impacts on communication, including conversations being facilitated (Pike et al., 2020; Hudson et al., 2020), and providing companionship (Picking et al., 2018; Marsilio et al., 2018), although as with other platforms, results also indicate some incidences of negative response such as jealousy and over-attachment (Study 10), or dislike and rejection (Pike et al., 2020). Picking and Pike (2017), used the JfA cat to assess positive effects for community-dwelling individuals with dementia and their carers. They asked carers about their experience of having the cats, and how they had been used. Their early results suggested a progressive companionship was developing, and carers reported positive change. However, Picking and Pike (2017) focused on individuals living in the community. Their sample, therefore, likely differs from the target audience within care homes of study 11. Siniscarco et al. (2017) suggested older adults in residential care were more likely to experience feelings of isolation and loneliness than those in the community. The Picking and Pike (2017) study was also relatively small, with only five cats distributed to five individuals with dementia and their carers, two cats were rejected leaving only three participants in the study. Their study also lacked any validated, quantitative outcome measures.

Previous work by Tkatch et al. (2020), did employ outcome measures, and demonstrated significant improvements in loneliness, mental wellbeing, purpose, resilience and optimism after one month of interacting with JfA pets. However, their study again focused on generally healthy, community dwelling older adults, and additionally lacked a control group.

Wexler et al. (2018) conducted more rigorous work, with a RCT with a JfA cat and dog, for older adults who became hospitalised. 160 older adults took part, 80 who received animals for the duration of their hospitalisation and 80 in the control group who received 15 minute

visits from a nursing student. Results suggested the intervention group experienced less delirium, loneliness and fewer falls. There was no significant effect found for cognition or depression. The study provided support for the potential of more affordable robots to be as beneficial as Paro (Pu et al., 2018b). However, the study was conducted within a hospital, and thus again provides a very different context to care homes. Participants within the Wexler et al. (2018) research also received a robot each, and thus had full availability of that device, whilst one robot per resident is unfeasible in care homes, even at the more affordable price. The study also did not measure agitation, anxiety, challenging behaviour or neuropsychiatric symptoms. The authors did aim to measure use of restraints, but limited incidence did not allow for statistical analysis. It is unclear at present why participants had been hospitalised and if any had dementia, or if the participants usually resided in the community or care facilities. The duration of hospitalisation is also unclear.

Hudson et al., (2020), also conducted a study using JfA devices, to explore the effect on alleviating loneliness. Twenty participants received a robotic pet and completed semi-structured interviews which demonstrated good acceptability, comfort and companionship. The participants were again community-dwelling older adults, and the study lacked outcome measures, although evidence of participants showing their pet to others suggests devices may mediate social contact.

Marsilio et al. (2018), conducted perhaps the most relevant study, providing a JfA cat to 11 care home residents for 6 weeks, and measuring agitation (CMAI), oxygen saturation, heartrate and medication use at baseline and after the study. Qualitative weekly reflections were also maintained. They observed a decrease in agitation and increase in oxygen saturation. This study did however have a small sample, and was conducted over a short time frame. Furthermore, the use of pre and post measures without a control group is a

limitation of the work. Additionally, devices likely hold benefits broader than agitation, and their potential needs further exploration, particularly with a larger sample and over a longer time period, to exclude any novelty effect. Marsilio et al. (2018), provide no detail on device implementation, such as quantity, intervention dose, intervention schedule or method of use (e.g. facilitated/un-facilitated interactions, individual/group sessions).

Further to assessing outcomes with such devices, research is also required for practical factors, important for real-world implementations beyond research use. Study 7a demonstrated the JfA devices could be maintained to the same standard as Paro for infection control, but robustness remained unexplored. Wada et al. (2005) noted that following a year of use within a care home, Paro had demonstrated durability and not been broken. Study 10 also demonstrated robustness of JfA devices in two sites over 6 months, but the supported living sites may have presented less risk of breakages than care homes. Wada et al. (2005) also commented on no loss of interest in Paro over the 12 months, and research is required furthering Study 10 to confirm lack of novelty with less interactive and sophisticated devices.

Study 11 therefore builds upon limited literature on outcomes of more affordable companion robots, particularly for care home residents, who are the most common target audience for intervention with companion robots such as Paro (Kachouie et al., 2014; Pu et al., 2018). Recent work has indeed acknowledged a scarcity of knowledge on the use of SAR generally in real-world care situations (Schüssler et al., 2020).

Study 11 aimed to:

- Explore if affordable robot pets lead to improved wellbeing and are robust and engaging over 8 months in care homes and nursing homes.

- Identify under what circumstances, for which care home residents, and with what impact the robot pets are used.

Methods

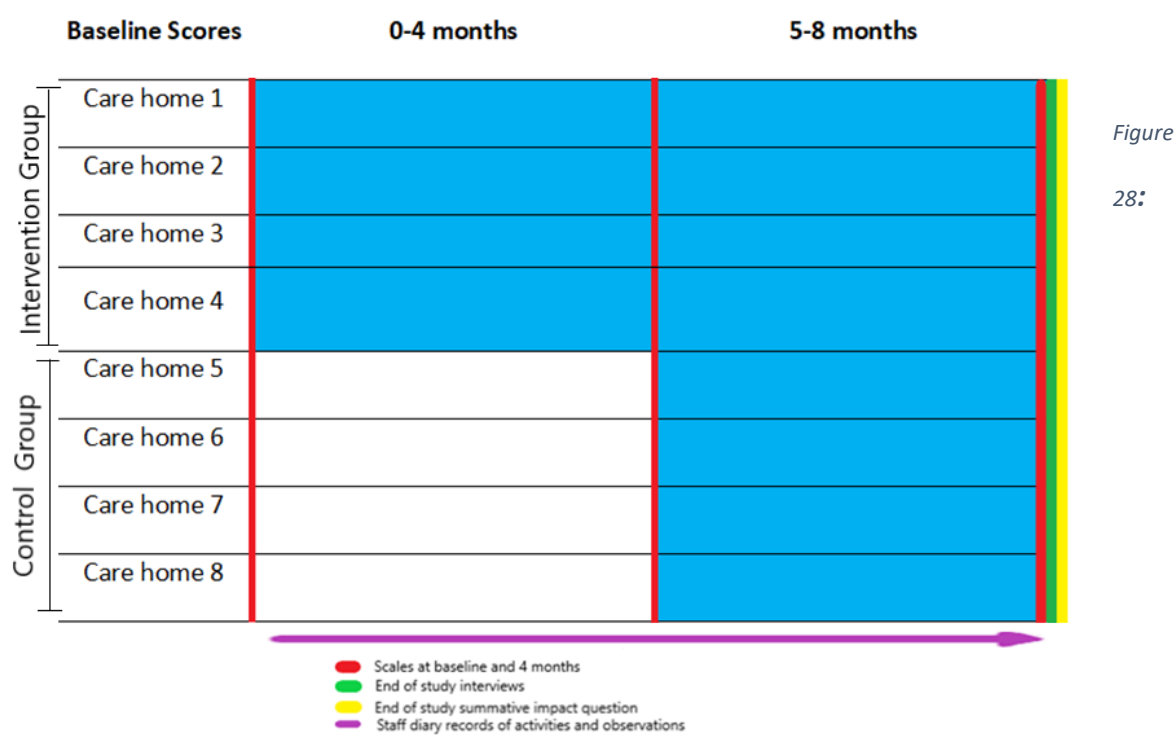
Ethics and Trial Registration

This study received ethical approval from the HRA (13/11/2019, North East – Newcastle & North Tyneside 2 REC), IRAS number: 268571. This study was also registered on clinicaltrials.gov (19/11/2019, reference NCT04168463).

Research Design

This study was planned as a closed-cohort, stepped-wedge, stratified, cluster randomised controlled trial, a relatively new study design which provides an alternative to parallel control cluster trials (Hemming et al., 2015). A simple parallel controlled trial in which the control group never had access to the robots was thought to be less ethical and practical, as all collaborating homes were aware of the research and would like to receive the intervention. Other studies have shown the difficulties of increased drop outs and losses to follow up from controls when it is clear they are not ‘getting anything,’ perceiving randomisation to control as inferior treatment, while provision of an intervention to both arms is viewed as having equipoise (Woodford et al., 2011). Likewise, a comparison of baseline scores with post-intervention scores alone would be problematic, as dementia is a degenerative disease, and outcomes were expected to deteriorate over the course of the study. The stepped-wedge design therefore seemed a fair method of conducting scientific evaluation. Figure 28 demonstrates the planned method. However, the trial commenced in January 2020, and the planned stepped-wedge trial was impacted by the COVID-19 pandemic, with the virus spreading worldwide and a UK lockdown announced by late March

(BBC 2020). The trial was thus adapted to account for limited capacity of care home staff to continue data collection, lack of researcher access to care homes due to visitor restrictions and infection control concerns on shared use of devices (Study 7b). The planned stepped-wedge trial was thus converted to a four month, parallel, stratified, cluster RCT, with the added benefit that all 8 homes received robots following the first four months, and qualitative data could capture robot impact during the pandemic. Data collection was therefore as in Figure 29.



Stepped wedge study design as originally planned.



Figure 29: Study design as carried out as a result of the pandemic, showing the removal of quantitative data collection at 8 months and the ending of staff diaries at 4 months.

Blue shading represents exposure to the intervention (availability of robopets), whilst the white area represents the control phase to receive usual care.

As demonstrated in Figure 29, the quantitative scales represent a parallel control trial, where metrics are collected for residents in the control group and intervention group at baseline and following four months. As care staff capacity was limited by the pandemic, scales were not repeated at eight months. Diary records were maintained in both the control homes and intervention homes for the first four months. Due to limited staff capacity during pressures of the pandemic, diary entries were not recorded from four to eight months. The qualitative impact of robots for all residents in all eight homes was collected at eight months through telephone interviews and a summative question.

Materials

A range of materials were used, including validated scales, time-sampling of qualitative

observations, qualitative interviews and a final summative question, to ensure appropriate capture of all nuances of robot impact.

Quantitative measures included (S = staff complete with researcher, R = resident complete with staff and researcher):

Participant and site information:

Participant/site information was collected only at baseline, before randomisation, for the purpose of stratification.

- Demographics (S) (age, gender),
- Site information (S) (total number of residents, type of home, location, general level of support required by residents)
- Dementia Severity Rating Scale (S) (Clark & Ewbank, 1996), scored 0 – 54, with 0-18 being mild, 19-36 being moderate and 37-54 being severe dementia.

Primary outcome:

- Neuropsychiatric Inventory (NPI) Nursing Home version (S) (Wood et al., 2000), with the total score scored 0-120, with higher scores indicating higher symptom prevalence.

Secondary outcomes:

- Challenging Behaviour Scale (S) (Moniz-Cook et al., 2001), scored 0-400, with higher scores indicating most challenging behaviour,
- Campaign to End Loneliness Measurement Tool (3-item) (R) (CEL, 2015), scored 0-12, with higher scores indicating greater loneliness,
- Holden Communication Scale (S) (Strøm et al., 2016), scored 0-48, with higher scores indicating greater communication challenges,

- NPI subdomain scales (Wood et al., 2000), scored 0-12, and the NPI occupational disruptiveness scale, scored 0-50, with higher scores indicating more disruptiveness.

We also collected:

- 1:1 care application forms, used for care homes to request designated 1:1 support for particular individuals from the local NHS trust,
- Medication records.

Moyle et al. (2017a) noted that behavioural and psychological improvements are not always shown through chosen scales, and that an evaluation should look beyond these for a picture of overall effectiveness, including comments and observations of care staff and family members. For this reason materials also included observational calendars for staff to maintain notes on activities in the home, including robot pet use and reactions, further to ‘usual activities’ in the control homes, to enhance understanding of robot impact (Figure 30). As indicated above, because of the work pressures of the pandemic these were only completed for the first four months of study.

Activities					Weekly Calendar
					WEEK COMMENCING FEBRUARY 3 RD 2020
STAFF MEMBER NAME/ROLE	NUMBER OF RESIDENTS INTERACTING TODAY AND INITIALS (E.G. 2 - MB AND JD)	INTERACTION TIMES (E.G. 8AM-9PM, 1.30PM-1.45PM)	TOTAL INTERACTION TIME TODAY (E.G. 15 MINUTES, 2.5 HOURS, 8 HOURS)	REASON FOR USE (E.G. ENTERTAINMENT, GROUP SESSION, AGITATION, ANXIETY, BOREDOM)	COMMENTS (E.G. ACTIVITY, DID CLIENTS ENJOY THE INTERACTION OR NOT? HOW DID THE INTERACTION WORK? DID STAFF SUPPORT THE INTERACTION OR LEAVE CLIENTS TO INTERACT? WAS THERE ANY IMPACT? WAS AGITATION REDUCED?)
M					
T					

Figure 30: Example calendar for recording of activities

Additionally, we conducted qualitative semi-structured interviews with care staff at eight months (Figure 31). This mixed-method approach highlights the benefits of pragmatism in research, allowing data capture through the most appropriate means depending on context.

- Tell me about your experience with the robot pets here at [name of home]?
- How were the robot pets used?
- Was there any impact? (If benefits are mentioned) How many residents benefited? How?
- Which residents benefited? Would you say there are residents the pets are more suited to based on your first-hand experience?
- Where there any particular features of the pets that you perceived positively based on their use here with residents?
- Were there any particular features of the pets that you perceived negatively based on their use here with residents?
- How did residents engage with the robot pets?
- Has there been any changes in their use over time?
- Has there been any changes in reactions over time?
- Any additional comments or observations?
- Were there any practical considerations (e.g. robustness, cleaning, batteries)?
- How did the COVID-19 pandemic and lockdown affect use?

Figure 31: Interview schedule

Finally, stakeholders were asked in the eight homes to complete a summative question on impact for all residents who had consented to take part. Staff indicated whether each resident had i) no interaction with robots, ii) robots had a negative impact, iii) robots had no impact and iv) robots had a positive impact.

Settings

The research was conducted in eight residential care facilities in Cornwall, comprised of 4 care homes with nursing care and 4 residential only care homes, with total resident population of 253. Furthermore, 16 care staff became collaborators for the purpose of completing scales and recording observations of residents (Table 21).

Participants at baseline

In total, 83 (33%) care home residents (61 females and 22 males) were originally recruited for directly collected data, although qualitative data refers to all residents in the homes, as staff provided observations on general activities, robot pet use and any subsequent impacts across the 253 residents in the eight homes.

Table 21: Demographic make-up of the participating homes

Home	Site Type	Staff Collaborators	Total Residents	Consented Residents	Residents Included in Analysis	Average Age (SD) Consented Residents	Average Age (SD) for Residents Analysed	Average Dementia Severity (SD) for Residents Consented (scored 0-54)	Average Dementia Severity (SD) for Residents Analysed (scored 0-54)
1	Nursing	2	33	9	3	87.67 (6.73)	86.33 (7.37)	40.56 (9.38)	43.33 (9.71)
2	Residential	2	16	11	10	90.73 (7.85)	90.10 (7.97)	19.63 (12.82)	17.30 (10.76)
3	Nursing	2	36	9	4	82.89 (2.51)	83.00 (7.39)	44.11 (8.25)	37.5 (7.59)
4	Residential	2	36	12	9	85.08 (6.33)	85.33 (6.1)	32.58 (15.77)	28.56 (15.58)
5	Nursing	2	36	7	4	86.29 (10.05)	87.75 (9.60)	36.14 (10.07)	35.75 (7.58)
6	Residential	2	27	13	12	90.46 (9.53)	89.42 (9.14)	5.23 (5.93)	4.75 (5.93)
7	Nursing	2	31	13	12	85.15 (8.34)	85.75 (8.41)	46.77 (6.13)	47.33 (6.03)
8	Residential	2	38	9	9	89.44 (8.00)	89.44 (8.00)	31.89 (15.84)	31.89 (15.84)
Totals		16	253	83	63				

Table 21 provides context for the demographic make-up of participating homes. The homes with blue shading represent those in the intervention group. The homes were paired for stratification as 1&5, 2&6, 3&7, 4&8. The pairing and stratification were based on number of residents, average age and average dementia severity of consented residents (n=83). Average dementia severity and age are also presented for the residents included in analysis (n=63). The 20 participants lost following collection of baseline data were unfortunately due to mortality. All eight homes are located in rural town settings.

Randomisation

The eight care homes were stratified into four pairs based on number of residents, average age and average dementia severity (as key factors likely to influence challenging behaviour) using randomly permuted blocks of size 2. Each member of the pair was then randomly allocated to either group A or group B, and finally group A and group B were randomly allocated by a separate researcher using a random number generator to the intervention or waiting list arm in the ratio 1:1. (homes 1-4 and homes 5-8, Table 21).

Follow-up

Although we recruited 83 residents to the trial, during the study, 20 participants passed away, leaving 63 participants for analysis (49 females, 14 males) (Table 21, Figure 32).

There were 37 residents in the control group. The average age of participants was 88.05 (SD=8.48). The average dementia severity in the control homes was 28.51 (SD=19.93). The number of residents in the intervention homes was 26 residents. The average age was 86.92 (SD=7.29). The average dementia severity in the intervention homes was 27.30 (SD=14.89).

An independent samples Mann-Whitney U test showed no significant difference between the control group and intervention group at baseline for dementia severity ($U=513$, $n=63$, $p=.650$) or age ($U=549$, $n=63$, $p=.341$). In parallel controlled trials, a common problem is the imbalance in important characteristics across study arms despite randomisation, particularly with small numbers of clusters as in this study (Copas et al., 2015). Between cluster variation can result in substantial reduction in power, but stratification and matching can help reduce these issues and improve balance and reduce between-cluster variation (Copas et al., 2015).

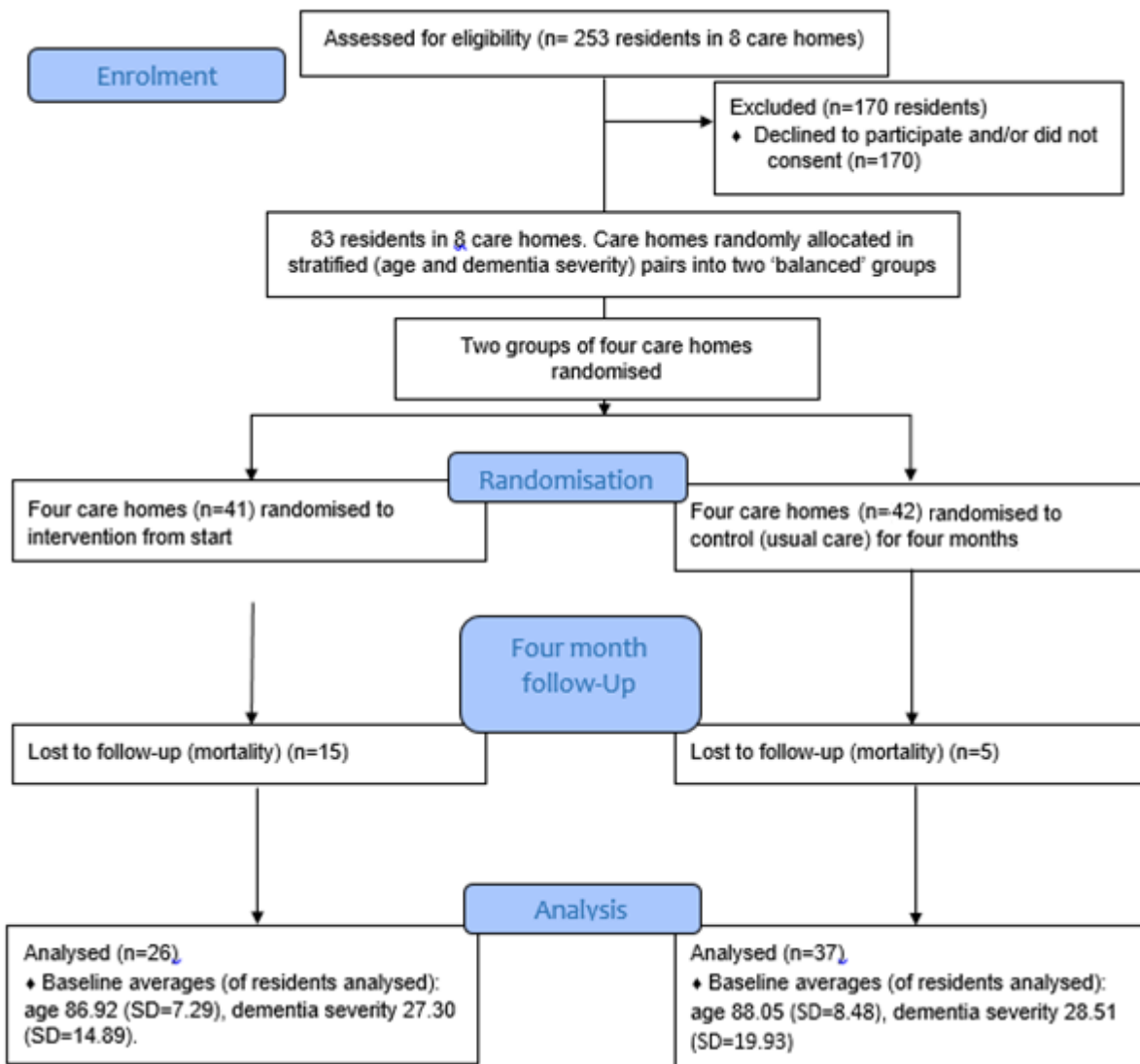


Figure 32: Consort diagram of trial recruitment, allocation and analysis

Recruitment

In November 2019, all care homes were visited by HB and all residents were invited to take part. Care staff assisted in approaching residents or residents' relatives to gauge interest in participation. For those interested, written informed consent was gained, directly from 30 individuals with capacity to consent and from 53 authorised third parties for individuals without capacity. Where consent involved advice from a consultee of a participant, care home collaborators were encouraged to use measures of assent throughout the trial, to ensure participant comfort. Care staff were asked to be mindful not to cause residents upset or distress if they did not like the robots.

Once participants were recruited, HB and fellow researchers (Katie Edwards and Dr Deborah Shenton under direction of HB) attended the homes to complete baseline measures in December 2019. In each home, the psychometrics were completed between researchers and two members of care staff.

Intervention

Homes in the intervention group received a JfA cat and dog for use in their care home, mid-January 2020. The researcher provided the infection control information from Study 7a, providing care homes with the cleaning protocol and informing them of products to use. The researcher provided no intervention dose or specific instruction, with researchers explaining the aim was to observe real-world use, even if robots remained untouched for 8 months. Thus, the robots were gifted to homes to keep indefinitely, and use or not use as the collaborators felt appropriate, thus improving ecological validity. As in Study 10, this study aimed to respond to limitations of trials with highly controlled intervention doses, and explore robot pet effectiveness rather than efficacy (Kim, 2013). Robot pet impact in highly controlled trials demonstrates robot efficacy that can be achieved under optimum

circumstances, often with facilitation from researchers, while here we report on robot pet effectiveness, based on assessment of the intervention under usual circumstances (Kim, 2013; Haynes, 1999), with only partial exploration of flexible intervention recorded previously (Liang et al., 2017). The researcher discussed past research with the collaborators for the purpose of providing examples and ideas, including prior work that implemented robots with daily group sessions (Filan & Llewellyn-Jones, 2006; Jøranson et al., 2015; Moyle et al., 2015; Moyle et al., 2017a), or used robots 'when required' (pro re nata) for reducing loneliness, anxiety, depression or agitation, as in previous research with live animals (Bernabei et al., 2013; Churchill, 1999) and Paro (Bemelmans et al., 2015a; Bemelmans et al., 2015b). The decision on robot use was then left within the professional judgement of care staff. The intervention itself depended entirely on the likely real-world use of the pets, and thus results represent effectiveness that may be expected beyond research contexts.

Data Collection

Simultaneously to receiving robots, both the control homes and intervention homes received a printed, A3, 8-month calendar (Figure 30), on which to record activities that residents partook in each day and observations of subsequent responses. Collecting this data in control homes allowed for comparison of robot pet use with usual activities.

Collaborating care staff in all homes were encouraged to record observations on their calendars using an experience sampling method (Verhagen et al., 2016). This data collection echoes the diaries used in Study 10, however we adapted the diaries (note books), to create calendars for wall hanging, to increase visibility to remind collaborators of data collection. Such methods are referred to as momentary assessment techniques, and allow insight into momentary processes and context sensitivities that are often missed through

questionnaires and psychometrics in trials (Verhagen et al., 2016). The experience sampling method (data collection triggered by an experience occurring, in this case, an activity), allows ecologically valid appraisal of subjective experiences, yielding comprehensive views of activities which may be difficult to assess using cross-sectional questionnaires, or interviews which can suffer from memory strains and aggregation (Verhagen et al., 2016).

Once homes were set up, HB visited all 8 homes weekly to collect the calendar for the prior week, and to clean robots for intervention homes for additional precaution further to the standard cleaning by the care homes following robot use. HB discussed progress with collaborators in intervention homes but did not consciously influence the use or implementation of the robots. In the 9th week of the trial, the Covid-19 pandemic resulted in UK lockdown restrictions (BBC, 2020). Collaborators in the four intervention homes remained in contact with HB, by phone and email. Collaborators were reminded of the importance of cleaning robots and had the option to remove robots from use. However, collaborators were not concerned considering the large number of shared fomites within the home. It is likely the fourth months of the trial in particular resulted in changes to use of robots, with homes tending to reserve robots for specific individuals during specific times from month four onwards, rather than group activities with robots passed between residents. Following four months (17 weeks) of robot implementation, the psychometric scales were (despite lock-down) repeated (mid-May, 2020) and the control homes received their robots through socially distanced, outdoor meetings with collaborators, and were again advised to take precautions. Although two members of the care team conjointly completed the psychometrics for residents at baseline, only one member of staff was able to complete measures at four months due to the pressures of the pandemic. However, the staff member completing measures at four months was always one of the original reporting

staff at baseline. During the fifth month of the trial (May, 2020), as the Covid-19 dangers became increasingly obvious, we produced Study 7b and shared the outcome with all collaborating homes. Study 7b provided a reflection on our cleaning procedure from Study 7a, and concerns around the shared use of robot pets considering any risk of viral transmission.

Diaries were completed during the first four months (mid-January – mid-May) of the research in both control and intervention homes. From mid-May, the care homes were experiencing considerable pressure in adapting to the pandemic and observations on calendars were ceased. The trial structure, considering the impact of the pandemic, is shown in Figure 33.

	Nov. '19	Dec. '19	Jan. '20	Feb. '20	March '20	April '20	May '20	June '20	July '20	Aug. '20	Sept. '20
Homes recruited		Baseline psychometrics collected	Robots delivered to four intervention homes		UK Covid lockdown		Four Month psychometrics repeated				End of study interviews
Residents consented		Stratification and randomisation complete	Calendars delivered to all 8 homes				Robots delivered to 4 control homes				Summative Impact Question
						Restrictions on shared robot use					
						Study 7b completed and shared, decision made to cease calendars and 8 month psychometrics					
			Calendar observations collected								
		Time period reported on in interviews									

Figure 33: Trial structure demonstrating Covid-19 impact

Follow Up

Quantitative scales were repeated for all residents at four months (May, 2020), providing a comparison between control group and intervention group.

Interviews and summative questions were conducted with all homes at eight months, as part of an ‘end of study reflection,’ when the intervention group had been using robots for eight months and the control group had been using robots for four months.

Data Analysis

Quantitative scales were statistically analysed for differences between the control and intervention group in total change from baseline to 4 months. The challenging behaviour, communication and NPI totals are reported, as is the NPI domain of occupational disruptiveness, as an indicator of care provider burden. In addition, each of the individual NPI sub-domains are reported, for understanding of which neuropsychiatric behaviours may have been impacted. Quantitative analysis involved non-parametric tests due to issues of normality within the data, which failed Shapiro-Wilk tests. For example, the histograms in Figure 34 demonstrate normality issues for the primary outcome of Neuropsychiatric symptoms at baseline and four months, in both intervention and control group.

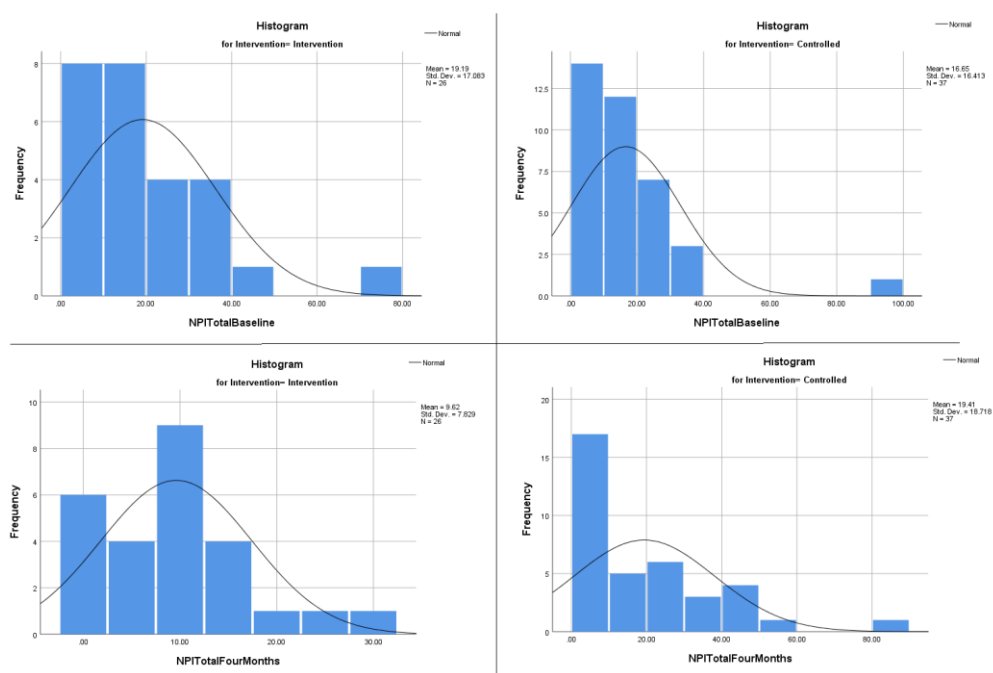


Figure 34: Normality histograms for primary outcome (NPI total) at baseline (top) and four months (bottom) for intervention (left) and control (right) groups

Qualitative diaries and interviews were individually subject to content analysis, and then reported together due to great similarity of themes. Content analysis involves systematic coding and categorising of text to garner trends, frequencies and relationships of words in discourse (Mayring, 2000). Two researchers (HB and KE) undertook a process of data immersion, coding, grouping codes, generating categories and reporting, as prescribed by Elo and Kyngäs (2008).

Content analysis was selected, as it is a process of examining social communication (Berg, 2008), including transcriptions of verbal communications. The ability to blend both qualitative and quantitative analysis through this method was also desirable (Smith, 1975), thus appreciating both frequency and pattern of themes, maintaining the meaning of the communications that would be lost with an entirely numerical approach (Berg, 2008). Numerical counts of textual elements provide a means of identifying, retrieving and organising data, rather than a reductionist interpretation of the data (Berg, 2008). This approach is in line with the pragmatist, mixed-method approach to the doctoral project. The summative impact question is reported descriptively.

It was not possible to compare loneliness scores, as the self-report loneliness questionnaire received only 7 responses at baseline, and none at four months. Similarly, it was not possible to statistically compare requirement for 1:1 allocated care, as only three participants received this measure, and their allocation did not alter throughout the study. We collected medication records for all residents at baseline, but acquiring copies for most residents was unfeasible at four months, due to Covid-19 restrictions on visiting care homes, and care home staff capacity in photocopying, anonymising, scanning and sending multiple-page records, while managing the impacts of the pandemic. Of the records we did receive

however (from two homes), no changes were seen in psychoactive, anti-depressant or PRN medication from baseline to four months.

Results

Quantitative Scales

For the quantitative measures, we first report the summative impact question, completed by a member of staff at 8 months, to indicate overall robot impact for each consented resident (n=83). We then report a comparison of characteristics for residents who did, and did not, interact with robots during the study, to comment on suitability of devices, based on residents who survived till follow up (n=63), due to possibility residents who died never had the opportunity to interact, rather than, for example, rejected robots through lack of suitability. For psychometric outcomes, we then report ‘intention to treat’ (ITT) results, for all residents as randomised who survived to four month follow up (n=63), although recognised that some researchers would include the 20 participants who died in the ITT analysis.

Summative Impact Question

Table 22: Care staff summative estimation of impact of robot pets for each resident at 8 months (n=83)

Care Home	Total number residents	Consented participants	Died by 4 month follow up	No Interaction	Negative Impact	No Impact	Positive Impact
1	33	9	6	4	0	1	4
2	16	11	1	2	0	0	9
3	36	9	5	5	0	1	3
4	36	12	3	2	0	1	9
Totals intervention care homes	121	41 (33.9%)	15 (36.6%)	Over 8 months (n=41)			
				13	0	3	25
5	36	7	3	0	0	1	3
6	27	13*	1	7	0	0	3
7	31	13	1	0	0	3	9
8	38	9	0	2	1	0	6
Totals control care homes	132	42 (31.8%)	5 (11.9%)	Over second 4 months (n=35*)			
				9	1	4	21

All participants	253	83 (32.8%)	20 (24.1%)	22 (27.2%)*	1 (1.2%)*	7 (8.6%)*	46 (56.8%)*
Residents included in RCT analysis at 4 months (n=61*)				15 (24.6%)*	1 (1.6%)*	5 (8.2%)*	40 (65.6%)*

*** Data on interaction missing for 2 people in Home 6**

The summative question asked for care staff perception on robot use and impact for all residents at the 8 month point, once all homes had received robots and been implementing them for either 4 or 8 months. As a reminder for the reader, each care home had two robots and shared use was possible until month 5 when it was recommended to be withdrawn because of the pandemic. Twenty residents died during the 8 month study. Of the residents reported to interact (54/81), 85.2% (46/54) were reported to have a positive experience. Table 22 demonstrates that the majority of residents who survived the 8 months, and were included in analysis (61/81) did interact with the pets (75.4%, n=46/61), and that generally they had a positive impact (65.6%, n=40/61), with only one resident (male) reported to have experienced a negative impact. This summative question provided the perception of one member of staff in each home, and thus there may be inaccuracies based on different staff observing robot use with different residents, although the collaborating staff member was always the staff member in each home with most insight and experience. Additionally, this observation may suffer from memory strain, with staff asked to reflect over the prior 8 months. However, due to Table 22 suggesting nearly a quarter of residents included in analysis (n=15/61) did not interact with robots, next we report a comparison of characteristics of residents who did and did not interact.

Table 22 also indicates that a greater number of deaths occurred in the intervention group than control group. Considering our concerns on infection control, and timing of the trial in the early stages of the Covid-19 pandemic, this requires some consideration. In conversation

with the care homes at 8 months, three of the collaborating homes reported Covid outbreaks (Home 1, 3 and 5), although at different times. Despite the high number of deaths in Home 1, collaborators reported Covid was not present on death certificates of participating residents, but this does not mean Covid was not present considering issues in testing early in the pandemic. It could be a concern that availability of robots contributed towards viral transmission in homes that experienced an outbreak.

Based on Table 22, in the intervention group, 7/15 residents who died were reported to have interacted with robots. This includes 3/6 residents who died in Home 1 and 1/5 residents who died in Home 3. This suggests 4/11 residents who potentially died with Covid interacted with robots. In Home 5, 0/3 residents who died had interacted with robots (due to being in the control group). For a better understanding of deaths in control and intervention homes, Table 23 displays deaths among residents in the trial homes that were not consented to the trial.

Table 23: Resident deaths in participating care homes from baseline to follow-up

Care Home	Total residents	Not consented			Consented			All
		Total	Survived	Died	Total	Survived	Died	Total Died
1	33	24	16	8	9	3	6	14
2	16	5	4	1	11	10	1	2
3	36	27	missing	missing	9	4	5	-
4	36	24	17	4	12	9	3	7
Total	121	80			41	26	15	
5	36	29	13	16	7	4	3	19
6	27	14	10	4	13	12	1	5
7	31	18	missing	missing	13	12	1	-
8	38	29	19	10	9	9	0	10
Total	132	90			42	37	5	

As demonstrated in Table 23, the total number of deaths in the eight homes is comparable between the control and intervention group. Of note, Home 1 has two separate units, a dementia unit and general unit. The general unit is housed in a separate building, although

attached to the dementia unit. The dementia specific unit was the cluster in this trial, referred to as 'Home 1,' with 33 residents in total. The residents in the two units do not interact, and robots were not shared with residents in the general unit. To this regard, the units are comparable in location, size and management. In the general unit, 17/33 residents died during the four-month study period, and had no interaction with robots. This is comparable with 14/33 in the dementia unit, which would suggest the care environments in general were greater contributors to viral spread than robots.

During the early stages of the pandemic, care homes suffered documented shortfalls in personal protective equipment and testing. Care homes also received Covid positive residents discharged from hospital. The three homes that experienced an outbreak are additionally all nursing homes, with a high concentration of vulnerable individuals, greater reliance on agency staff (Chen et al., 2021), further to a great number of shared surfaces and fomites and direct contact between residents. Care home residents were not socially distancing from each other. Covid-19 is more likely to be transmitted as aerosol than surface transmission. Thus, the care environment itself is particularly vulnerable to viral transmission, and it appears likely higher mortality in the intervention group relates to unfortunate timing of Covid outbreaks, and particular residents consented for the research (demonstrated by comparable total deaths in Table 23).

Difference between interacting and non-interacting residents

Table 24: Baseline characteristics of residents who did, or did not, go on to interact with robots

Scale	Did Interact, n=46 M(SD)	Did not Interact, n=15 M(SD)	Did vs Not
Communication	22.22 (13.29)	11.20 (11.98)	U=179, n=61, p=.005
Challenging Behaviour	61.02 (54.73)	22.20 (26.27)	U169.500, n=61, p=.003
Neuro-Psychiatric Inventory	20.28 (18.09)	11.40 (9.06)	U=231.500, n=61, p=.057

NPI Occupational Disruptiveness	6.15 (6.23)	2.27 (2.84)	U=192.500, n=61, p=.010
Dementia Severity	33.46 (15.60)	14.73 (16.03)	U=146, n=61, p=.001).
Age	87.02 (7.68)	88.47 (9.08)	U=404.500, n=61, p=.318

Upon analysis with Mann-Whitney U tests (Table 24), the residents who subsequently went on to interact with robots had significantly higher dementia severity scores than residents who did not interact. On average, residents who did interact would be considered at the higher end of moderate dementia (19-36), while residents who did not interact would be considered to have mild dementia (0-18). The interacting residents also had significantly poorer communication scores and scored significantly higher for challenging behaviours and NPI occupational disruptiveness. There was no difference by overall NPI score, age or gender.

The above would suggest that robots are perhaps more suited to residents scoring higher for dementia severity, who also experience more communication issues and challenging behaviour as associated symptoms.

Of course, with many care homes choosing to restrict shared robot use from four months onwards, this would have influenced some residents not interacting, particularly in control homes where robots were only provided in month 5. However, homes did report aiming to allow interested participants opportunities to interact (individually after robot cleaning rather than group sessions), and robots tended to become 'adopted' by residents who found particular benefit. Staff reported that they did not pursue interactions with residents who were disinterested, feeling they were best placed with 'adoptees' in any case.

Psychometric analysis

Table 25: Baseline and four month scores for the control group and intervention group, for communication issues, challenging behaviour, neuro-psychiatric symptoms and occupational disruptiveness (ITT (n=63)). ITT analysis excludes the 20 residents who died but includes 63 who potentially had access to the robots.

ITT Analysis (as randomised) (n=63)							
Scales (scoring)	Baseline		Follow Up		Mean difference baseline to follow up		Test of difference control vs intervention
	Control (n=37)	Intervention (n=26)	Control (n=37)	Intervention (n=26)	Control (n=26)	Intervention (n=20)	Mann-Whitney U test results
Communication (0-48)	20.57 (15.13)	16.58 (11.85)	21.97 (15.12)	17.23 (15.33)	1.41 (6.00)	0.65 (7.54)	U=576.500, n=63, p=.181
Challenging Behaviour (0-400)	54.86 (56.95)	43.38 (43.02)	48.22 (53.98)	31.85 (38.39)	-6.65 (25.65)	-11.54 (23.92)	U=548.500, n=63, p=.345
Neuro-Psychiatric Inventory (0-120)	16.64 (16.41)	19.19 (17.08)	19.41 (18.72)	9.62 (7.83)	2.76 (9.43)	-9.58 (14.06)	U=773, n=63, p=.000
NPI Occupational Disruptiveness (0-50)	5.51 (6.37)	4.42 (4.86)	5.46 (6.26)	3.19 (4.54)	-0.05 (2.47)	-1.23 (2.53)	U=631.500, n=63, p=.031

For all scales, higher scores indicate greater prevalence of challenges

Table 25, demonstrates that based on 'ITT' analysis, a significant difference in the total change for NPI and occupational disruptiveness scores between the intervention and control group. Neuropsychiatric symptoms increased in the control group, while decreasing in the intervention group. No significant difference is present between control and intervention group for baseline to follow-up for communication issues or challenging behaviour.

Table 26: Domains of the Neuro-psychiatric inventory at baseline and four months for the intervention and control group (minimum 0 – maximum 12)

Scales (scored 0-12)	ITT Analysis (as randomised) (n=63)						
	Baseline		Follow Up		Mean difference baseline to follow up		Test of difference control vs intervention
	Control (n=37)	Intervention (n=26)	Control (n=37)	Intervention (n=26)	Control (n=37)	Intervention (n=26)	Mann-Whitney U results
Delusions	.76 (2.46)	1.57 (3.34)	1.43 (3.18)	.19 (.80)	.68 (2.85)	-1.38 (3.46)	U=602, n=63, p=.034
Hallucinations	.49 (2.04)	.73 (1.95)	1.03 (2.69)	.27 (.87)	.54 (1.48)	-.46 (2.21)	U=575, n=63, p=.064
Agitation	4.68 (3.86)	3.42 (4.20)	3.70 (4.27)	1.00 (2.4)	-.97 (2.93)	-2.42 (3.76)	U=550.500, n=63, p=.216
Depression	2.43 (3.21)	2.08 (2.53)	3.03 (2.94)	1.62 (3.03)	.56 (2.30)	-.46 (3.19)	U=657, n=63, p=.010
Anxiety	2.30 (3.19)	3.31 (4.25)	2.92 (3.55)	.84 (2.12)	.62 (1.93)	-2.46 (4.37)	U=679, n=63, p=.001
Elation	2.30 (3.19)	1.31 (2.65)	.84 (2.28)	.92 (2.61)	.62 (2.00)	-.38 (2.47)	U=592.500, n=63, p=.023
Apathy	2.24 (2.56)	3.58 (3.30)	2.76 (3.55)	2.38 (3.45)	.51 (2.43)	-1.19 (3.14)	U=644, n=63, p=.009
Disinhibition	.78 (2.76)	.37 (1.30)	.78 (2.76)	.0 (.0)	.00 (.00)	-.35 (1.29)	U=518, n=63, p=.084
Irritability	2.62 (3.36)	1.54 (3.05)	2.59 (3.48)	1.19 (2.83)	-.03 (3.47)	-.35 (3.39)	U=520.500, n=63, p=.551
Motor Behaviours	.14 (.67)	1.31 (2.69)	.32 (1.11)	1.19 (2.68)	.19 (.81)	-.12 (.59)	U=524.500, n=63, p=.100
Sleep Behaviours	1.22 (2.85)	1.38 (2.74)	.24 (1.04)	1.27 (2.91)	-.97 (2.98)	-.12 (.99)	U=418.500, n=63, p=.187
Eating Behaviours	.46 (1.10)	1.81 (4.10)	.35 (.92)	.88 (2.80)	-.11 (.66)	-.92 (3.26)	U=506, n=63, p=.344

When looking at the individual domains that make up the Neuro-psychiatric inventory, we can see averages for the various included behaviours based on ITT analysis (Table 26). Mann-Whitney U tests showed a significant difference between control and intervention groups for total change from baseline to follow up, for delusions, depression, anxiety, elation and apathy, all of which decreased in the intervention group and increased slightly in the control group. There was no significant difference from baseline to follow-up between the two groups for other subdomains. While these subdomains give an indication of specific neuropsychiatric symptom under influence, only the total NPI measure has been validated, while use of NPI subscales has been popular, validity and reliability of individual subscales requires further testing (Lai, 2014).

Qualitative Calendar Entries

During the first four months, staff in the four control homes provided 139 days of calendar entries describing usual resident activities and moods. Staff in the four intervention homes provided 109 days of calendar entries. In total, 248 days of calendar entries were collected. The four months spanned 120 days, in eight homes, meaning about 25% of days were captured.

The diaries reported a total of 516.3 hours of interaction with the robots over the four months, with an average interaction length of 3.9 hours. The range of interaction lengths varied from 0.25 hours – 24 hours, where residents kept a robot with them all day and night.

On average, about 4 residents interacted with robots on each reported day (range 1 – 8). The main reasons recorded in 'reason for use' of robots were entertainment, anxiety and agitation (Table 27).

Table 27: Reported reasons for using robots in calendars (n=109)

Reason	N
Entertainment	40
Anxiety	33
Agitation	31
Boredom	30
Group session	10
Company	7
Love	6
Cuddles	4
Nurturing	3
Loneliness	3
Affection	2
Stress	1
Distress	1
Distraction	1
Observation	1
Sadness	1
Reassurance	1

Table 28: Thematic Analysis of Qualitative Interviews and Calendar Entries

Theme	Codes (n in interviews) [n in diaries]
Adoption	Love (11)[13]
	Ownership (18)[6]
	Individual use (9)[14]
	High level of usage [12]
	Jealousies or possessiveness (6)[6]
	No novelty (9)
	Naming (7)
	Group sessions [5]
	Personalising (1)
	Wellbeing effects, particularly mood
Enjoyment (1)[19]	
Anxiety reduced (3)[13]	
Companionship (7)[6]	
Smiles and happiness (1)[9]	
Engaging resident (10)	
Relaxing or settling [7]	
Mood improved (7)	
Provides a focus (5)	
Distraction (3)[2]	
Agitation reduced [5]	
Entertainment and laughter (1)[3]	
Therapeutic (3)	
Reassurance (3)	
Sundowner, (2)	

	Reduced boredom (1)[1]	
	Enabled eating [1]	
Effects on Communication	Communication with pet [25]	
	Communication with others, and speech (19) [2]	
	Reminiscence (5)[1]	
	Interaction (4)	
Isolation and Covid	Covid use (15)	
	Cleanliness and infection control (9)	
	Isolation (5)	
Design	Improvements (11)	
	Realistic (9)	
	Sound off (8)	
	Expectations (8)	
	Weight and size (7)	
	Breakage (7)	
	Battery life (4)	
	Importance of movement (4)	
	Purring as relaxing (2)[2]	
	Heartbeat enjoyable (1)[2]	
	Suitability	Dementia severity (31)
		Limited interest [17]
		Think it is real (14)
Dislike (2)[9]		
Wide appeal (7)		
Reduced mobility (5)[1]		
Previous pets (3)[1]		
Infantilising (4)		
Staff dislike (1)		
Nurture		Cuddled and fussed [29]
	Feeding (8)[5]	
	Care for and nurture the pet (8)[5]	

Table 28 demonstrated the themes resulting from analysis of comments made in the calendars and interviews. The full table of themes with example evidence available in Appendix L. The below section looks at each theme in more depth.

Adoption

The evidence in diaries and calendars strongly supported good robot adoption into the services, and usually by particular ‘adoptee’ residents. Staff noted often that residents “*loved the cat*” (Calendar_home3) or “*loved the dog*” (Calendar_home2), “*as if it was her own*” (Calendar_home4). Staff felt it “*was almost emotional*” (Interview_home4) watching

residents respond to robots. The second most common code was *Ownership*, with certain residents believing “*they were actually their real pet, claim to take possession of them*” (Interview_home1). Care staff described the pets as “*completely and utterly adopted*” (Interview_home5), suggesting good acceptability. Residents often decided on *Naming* the pets, such as “*he’s Ben isn’t he and so he shall be forevermore*” (Interview_home2), or *Personalising* them with “*a little pink bow in his hair*” (Interview_home5). Congruent with residents ‘adopting’ pets, evidence suggested mostly *Individual Use* rather than group sessions. This seemed to result from particular suitability of devices to some, while other residents had a “*nonplussed reaction*” (Interview_home5), meaning “*we don’t need to circulate it around. It’s useful for certain people, so it’s no good sort of having it as house pet*” (Interview_home5). The residents who benefited most were those not “*having conversations with other residents, [...] with dementia*” (Interview_home1), or “*in their rooms*” (Interview_home6). There were 23 counts of evidence towards *Individual Use*, and only five towards *Group Sessions*. Evidence suggested a *High Level of Usage*, with residents keeping “*the dog all day*” (Calendar_home1), and going “*to bed with it*” (Calendar_home2). A consequence of ‘ownership’ however, was occasions of *Jealousies or Possessiveness* which “*can be quite challenging*” (Interview_home7), as residents were reluctant “*to give it back*” (Interview_home7). There were 12 counts of jealousies or possessiveness across calendars and interviews, with residents reported to “*dominate*” the pets (Calendar_home2), even attempting to report staff for “*animal cruelty*” if the pet was removed (Calendar_home4). While these reports are undoubtedly negative, they also demonstrate strong attachments formed by residents. There appeared to be *No Novelty* effect, with interviews following eight months suggesting “*you can see the love in her eyes every day, when she stroked it this morning, there’s no change in how much she adores it*” (Interview_home5). Some staff felt

this effect may result from dementia, meaning residents do not get “*bored*” (Interview_home8), being “*just as interested in them as they ever were*” (Interview_home7).

Wellbeing effects, particularly mood

The interviews and calendars strongly supported wellbeing benefits, with 30 counts of evidence towards the code, *Calming*. Staff suggested pets “*had a calming effect*” (Interview_home8), and “*aided*” residents (Interview_home1). The pets were used “*for de-escalation*” with “*residents that are anxious*” to “*prevent them from getting any worse, it will calm them down and help distract them from having a bit of a meltdown*” (Interview_home7). This was supported through 16 counts of *Anxiety Reduced*, with staff reporting “*we had one particular lady that it worked for every single time, it lowered her anxiety*” (Interview_home4). Additionally, when residents were “*missing own dog*” robot provision meant they were “*less stressed*” (Calendar_home1), with others calming after becoming “*unsettled with another resident*” when encouraged to sit “*with her dog*” (Calendar_home4). Similarly, staff also reported pets as *Relaxing* and provided evidence that *Mood Improved* “*because of Covid [...] residents [...] are missing out on having their own pets. I feel it’s been a God send really having [the robots], especially to [...] de-escalate for certain residents*” (Interview_home7). The pets “*lifted quite a few of their moods*” (Interview_home6). Such benefits may have resulted from pets *Providing a Focus*, “*one of the residents goes to her room and the cat goes with her, and it just [...] gives her a focus*” (Interview_home5). Similarly, staff reported pets were a *Distraction*, as “*the ones who have dementia that tend to get some of the mood swings [...] she will take it which is more of a distraction*” (Interview_home1), thus *Agitation Reduced*, “*[Resident] was feeling very agitat[ed], sat with the dog in lounge and it really calmed her down*” (Calendar_home4). Pets were *Therapeutic*, providing *Reassurance* as “*a tool for giving comfort*”

(Interview_home8), with the *“purring”* and *“heartbeat”* both praised in this regard (Interview_home2). The pets promoted *Smiles and Happiness* which staff described as *“wonderful”* (Interview_home7), creating *“lots of smiles”* (Calendar_home4). Overall, reports support that the pets were engaging, with residents having *“a good old chat”* (Interview_home8). The function for robots to *“[turn] on itself”* or interact to noise was praised, for providing *“another activity you can instantly engage with”* (Interview_home8). Consequently, residents were *“more interactive, not falling asleep [...] instead [...] interacting with the dog and other people about the dog”* (Interview_home2).

Effects on Communication

The evidence strongly supported robot impact on residents’ communication, with; the pets, each other, staff and family, further to improving speech capabilities. Residents appeared to enjoy a *“chat”* (Calendar_home4) with the pets, which also provided *“staff and other residents a reason to talk to them”* (Interview_home4), because they give *“you something to discuss [...] which sometimes can be quite difficult for some staff”* (Interview_home8).

Collaborators felt care staff were *“interacting more”* as pets *“spark conversation”* (Interview_home7), also promoting *“reminiscing”* (Interview_home4). The pets even seemed to improve relationships between *“two ladies who usually spend their day in conflict with each other,”* the staff member suggested the peaceful response *“surprised an old cynic like me”* (Interview_home3).

Some residents were *“able to talk very well, but it’s completely jumbled and it’s really difficult to make sense”* *“however, when you put the animal in front of them [...] then they come out with several, very very clear sentences, so that’s quite critical”* (Interview_home7).

Another member of staff reported on *“one of our ladies who has quite severe aphasia”* who when *“engaging solely with the dog shows no signs of this and communicated clearly with it”* (Interview_home3). The potential for robots to improve speech and communication is a

profound outcome. The reminiscence involved in the communication is also important, *“it engaged conversations [...] about pets that they used to have,” “it’s not just engagement with the animals, it’s also reminiscing about past events as well, which is quite good and a group activity”* (Interview_home4). Interacting with the pets *“gets them to talk about something that’s joyful [...] something that they remember with joy”* (Interview_home2).

Isolation and Covid

The evidence showed particular benefits of robot pets as a supporting strategy against loneliness and isolation in response to the Covid-19 pandemic. Staff reported *“I’m really glad we have [the pets] especially at this ridiculous time. Yeah. I couldn’t have thought of a better time for us to have them”* (Interview_home5). The pandemic meant care homes were *“not allowed to have any real animals in”* so *“since we’ve had the Covid situation”* the pets have *“come in really, really useful, really useful thing to have”* (Interview_home7). The benefits the pets brought through *“covid”* were *“offering comfort, that little bit of social interaction [...] that relationship [...] he’s got his friend”* (Interview_home8). The homes also experienced reduced or ceased family visits, with residents *“not seeing their relatives”* (Interview_home6), meaning staff were *“overjoyed”* (Interview_home5) to have the pets as some small alternative. Staff reported *“who knows what [the residents] would have been like throughout lockdown without them. But I feel 100% that [the pets] have improved the situation, from the point of view of yes company, yes a focus”* (Interview_home5). Staff also discussed using the pets for residents self-isolating in their rooms, *“we had a lady in isolation, [...] she’s kind of had [the pet] to herself for the whole week. And that’s been really helpful in her isolation period”* (Interview_home4). There was consideration given to infection control however and *“the risk of germs spreading”* (Interview_home5), meaning staff had to be *“more vigilant about cross contamination”* (Interview_home8).

Design

Staff suggesting a few possible design improvements based on their experience. One improvement was removable fur, allowing staff to “*take the skin off and wash it or replace it*” (Interview_home8), to be “*fully removable*” (Interview_home7) for hygiene purposes. Staff also felt the dog’s heartbeat could be more pronounced as “*nobody can actually hear it. When you’re holding it, you can’t feel it.*” Although, the dog was praised as being “*sturdier*” with the cat needing more padding, “*is not squishy enough*” (Interview_home2), the *Weight and Size* of the cat was seen as suitable for practical reasons, being “*not so heavy*” as “*a lot of [residents] are [...] quite slim built*” (Interview_home1). The dog was considered disadvantaged, being heavier and “*not so easily sat on someone [...] because it’s upright*” (Interview_home1).

Staff reported the behaviours of the cat were “*very good*” at making robots look “*more realistic*” (Interview_home1). However, one member of staff felt the dog was less realistic, looking “*like a soft toy*” (Interview_home2). Staff also raised concerns over the noises, with eight counts of staff discussing turning the *Sound Off*, describing a resident who “*puts up with it for so long [...] and then she gets fed up*” (Interview_home1). The cat was described as “*more favourable [...] because it’s a little bit quieter*” (Interview_home4). Noises were “*annoying sometimes*” when they sound “*all of a sudden*” “*if you walk past it*” (Interview_home4). Staff reported residents were “*not always wanting the noise on*” (Interview_home1), suggesting “*it could be irritating*” (Interview_home2).

The design was also critiqued in relation to *Expectations*. The cat was perceived as best matching expectations, because it could sit on “*people’s laps*” which is “*normal cat behaviour,*” whereas you wouldn’t normally have a dog “*on the table [...] not a dog*” (Interview_home8). Additionally, the dog design was felt incongruent with being a puppy, as “*a puppy wouldn’t sit still [...] whereas an older dog will*” (Interview_home8). Thus the design may be better “*if it didn’t look so much like a puppy [...] maybe a small dog, a small*

older dog" (Interview_home8). Expectations of dog behaviour also meant some residents put their dog "*on the floor, because that's where she expects a dog to be*" (Interview_home5).

The robustness of devices was questioned, with seven counts of evidence on *Breakages*, for example one dog "*stopped working*" and was replaced, only for the next dog to also encounter a "*problem in it*" where it made beeping and clicking noises (Interview_home5).

The cat in another home experienced "*two broken legs*" (Interview_home2).

The discussion on *Battery Life* produced variable evidence, with some homes feeling they "*weren't too bad actually*" (Interview_home8) and "*were pretty substantial [...] we only ever changed them once*" (Interview_home1), while another home "*had to keep changing them because they were used so much*" (Interview_home4).

A number of design features were praised, including the *Purring as Relaxing, Enjoyable Heartbeat*, and the *Importance of Movement*. The movement of the robots was considered important, as a collaborator noticed a resident "*interacted with [broken robot] much less*" and "*responded much less to it when it stopped moving,*" "*when it broke, [...] she sort of lost interest sort of started to ignore it almost when it didn't move*" (Interview_home5). The purring was praised alongside movement, for being "*quite soothing*" and "*relaxing in itself*" (Interview_home4), with similar comments made around the heartbeat being "*reassuring*" (Interview_home2).

Suitability

The data gave some insight into the most suitable use context for use with residents.

Generally, staff felt the robots were most accepted and useful for "*people further along*" the dementia journey (Interview_home8). Some staff felt the memory issues encountered with dementia meant "*each time that they see the pet it's quite new [...] they will never grow tired of them*" (Interview_home7). Other homes with varying levels of dementia felt "*more*

advanced dementia” residents respond better (Interview_home4). Another home felt that benefiting from the robots required people to “*see it as an actual animal,*” more likely for those with dementia, “*who don’t see it as a toy*” (Interview_home2). Evidence did suggest some residents believed robots were real, with one threatening to “*call the RSPCA*” as the cat wasn’t allowed outside (Interview_home4). The pets also seemed particularly suitable for residents with *Reduced Mobility* who had “*restricted movement*” or were “*bed bound*” (Interview_home8), producing “*adorable moments*” (Calendar_home4) with residents in their rooms and beds.

The limited appeal among residents with no, or mild dementia may also explain the evidence towards *Limited Interest* such as a resident who “*enjoyed the dog company for a while before getting bored*” (Calendar_home2). Regarding *Dislike*, one resident would ask staff to “*point it away from me, I don’t like it*” (Interview_home5). Some of the dislike may be explained through confusion, with one resident carrying the dog and cat around while saying “*I’m going to kill these bloody kids*” (Calendar_home4).

There were also four staff comments around robots as *Infantilising*, as people “*that just have mild dementia*” may see them “*as toys*” (Interview_home4). Another resident with only mild dementia would comment on “*silly people, [...] sat talking to a toy*” (Interview_home4). Others reported a robot pet was “*a silly thing*” (Interview_home5). One member of staff also took a dislike, being “*freaked out, scared of it*” and asking “*for them to be removed*” (Interview_home5).

Overall, when asked, staff did however report *Wide Appeal* of the devices, such as “*about 15*” of 16 residents (Interview_home2) or “*more than 90%*” (Interview_home4) enjoying the pets, which did seem more accepted if residents had *Previous Pets*, “*if they’ve had dogs, they relate to the dog*” (Interview_home2).

Nurture

The final theme was Nurture, referring to resident's manor of interaction with the pets. Staff reported that residents *Cuddled and Fussed* the pets, "*cuddled as a real one*" (Calendar_home1), which demonstrates some level of treating the pet as a living animal. There were also 13 counts of residents *Feeding* the pets, including "*peaches and cream*" (Calendar_home4), "*chocolate biscuits*" (Interview_home5), or "*a puree diet*" (Interview_home8). This again shows residents believed pets were real, and an element of care in trying to feed them. The result however was that pets "*were always very covered in food*" (Interview_home4). There were an additional 13 counts of evidence towards the code *Care for and Nurture* such as "*one lady who likes to take it into her room, to care for it, she will put it in her bed and cover it over*" (Interview_home7). Other staff members describe the pet being something a resident "*loves and cared for*" (Interview_home8), and "*would look after*" (Interview_home2).

Discussion

This work strongly supports the usefulness and benefit of implementing affordable robot pets into care homes for older adults. This study contributes towards limited literature in this area, with most prior companion robot research focusing on Paro (Moyle et al., 2017a; Pu et al., 2018; Kachouie et al., 2014), a device with impaired acceptability among older people (Study 3 and 4), additionally being too expensive to have implications for real-world practice (Study 5 and 6). Furthermore, previous work considering alternative, more affordable, robots were mainly conducted within the community (Pike et al., 2020; Tkatch et al., 2020) or hospital settings (Brecher, 2020; Schulman-Marcus et al., 2019), with limited generalisability to care home residents (Moore et al., 2019; Siniscarco et al., 2017). This research also furthers prior work with smaller samples and short time frames (Marsilio et

al., 2018; McBride et al., 2017). Additionally, much previous work has involved highly controlled intervention doses (Moyle et al., 2017a; Petersen et al., 2017) thus assessing efficacy rather than potential real-world effectiveness (Kim, 2013), as here. This study therefore provides an important and novel contribution to companion robot literature.

The summative impact question demonstrated that, encouragingly, 85% of residents who interacted with robots received a positive impact based on carer observations, and 74% of residents included in analysis did interact with robots. However, with almost a quarter of residents included in analysis not interacting with robots, this indicates devices lack universal appeal. This result, combined with 11 qualitative counts of robot dislike, is congruent with previous research reporting variation in response to Paro (Moyle et al., 2017a,b), described as a 'therapeutic tool that's not for everybody' (Birks et al., 2016). In contrast to the prior work with Paro however, where acceptability was reported to be 50% (Birks et al., 2016), the JfA devices seem more generally acceptable.

Results demonstrated residents who did interact with robots had on average, more severe dementia, communication issues and challenging behaviour. Previous work has also suggested companion robots were more suitable for individuals with dementia (Birks et al., 2016; Robinson et al., 2013). This could suggest cognitive impairment and dementia severity as predictive of likely robot acceptance and benefit; however, this contradicts our earlier work, which demonstrated robot pet acceptability among independent older adults (Study 3), and care home residents without dementia (Study 4). It is possible the impact of Covid-19, and restriction on sharing robot pets in groups led to prioritisation of interactions for more impaired residents. In the qualitative data, evidence suggested robots were most enjoyed and beneficial to older adults who had dementia, but also those who were bed bound (due to mobility or illness), less socially engaged (due to dementia), or in isolation

(due to Covid shielding). Additionally, residents who were disinterested in robots were more socially engaged, preferring to play games and socialise with other people. While social engagement appears negatively correlated with dementia severity, results may indicate that both dementia severity and social isolation predict likelihood of accepting and benefiting from robot pet interventions. This could explain acceptability of robot pets by more independent older people in Study 3, as despite not having dementia, the older people lived in individual flats and reported requirement for company. In previous work with independent older adults living in the community, 4/12 robots were rejected (Pike et al., 2020), with community dwelling older people less vulnerable to isolation and loneliness (Siniscarco et al., 2017). Additionally, Pino et al., (2015), reported on healthy older adults feeling too able to benefit from SAR support, while Tkatch et al. (2020) reported positive benefits of JfA devices for 'self-reported lonely individuals' despite them living in the community. Loneliness and dementia severity are thus likely to be predictive factors in the acceptance and benefit of robot pets in future implementations.

Regarding robot impact, psychometric results demonstrated significant differences in mean change from baseline to follow up between the control and intervention group, for the primary outcome of neuropsychiatric symptoms and secondary outcome of occupational disruptiveness, based on ITT analysis. The reduction in neuropsychiatric symptoms is an encouraging result suggesting important effects of affordable robot use. There were no significant differences for the secondary outcomes of communication impairments or challenging behaviour. The NPI subscale of occupational disruptiveness was used as an indicator of care provider burden, the reduction seen here is congruent with results from Saito et al. (2003) who suggested Paro could decrease care provider burden. We did not use a specific care provider burden scale, with the stigmatising wording felt to discourage carer

responses in the pilot study, but the significant difference between control and intervention homes in reported occupational disruptiveness could suggest robot impact on carer burden. When analysing the individual NPI sub-domains, results suggested significant differences in mean change from baseline to follow up between intervention and control for delusions, depression, elation, anxiety and apathy. This would suggest JfA devices can achieve similar wellbeing outcomes to those reported for Paro, particularly around reducing depression (Jøranson et al., 2015; Saito et al., 2003; Petersen et al., 2017; Robinson et al., 2015). The support for impact on delusions is also congruent with the work of Schulman-Marcus et al., (2019), who reported on stakeholders feeling JfA devices were useful for hospital patients with delirium. The potential for these vastly more affordable devices to produce promising therapeutic benefits is an important result. Interestingly, we did not find a significant impact for agitation, as previous work did for Paro (Jøranson et al., 2015). Similarly, in the cluster RCT conducted by Moyle et al. (2017a), there was no significant effect on agitation in the Paro intervention group. Moyle et al. (2017a) did suggest chosen psychometrics can sometimes miss behavioural improvements, and suggested complimenting scales with qualitative feedback.

The evidence from qualitative calendars would suggest a robot effect on anxiety and agitation, as the second and third most common 'reasons for robot use' respectively, strengthening the suggestion affordable robot pets can produce wellbeing outcomes. Furthermore, interview and calendar comments demonstrated robots were calming, reduced anxiety, improved mood, relaxed residents, reduced agitation and provided reassurance.

The calendars also demonstrated the primary 'reason for use' of the pets was thus providing a meaningful activity. This is congruent with the significantly greater reduction in apathy

from baseline to follow up in the intervention group, compared to the control group. The importance of meaningful activities for older adults in care homes cannot be overstated, impacting physical and mental wellbeing (Moyle et al., 2015; Smith et al., 2018). Related to meaningful activity, is purpose. Purpose in life refers to some form of goal or responsibility to be fulfilled (Hedberg et al., 2010), and is associated with greater life satisfaction and physical health outcomes (Wnuk et al., 2012). The calendar and interview data suggest older adults cared for and nurtured robots, perhaps providing a sense of responsibility and purpose. Although most nurturing seemed to involve cuddling and fussing the animals, there were also counts of residents feeding the pets and providing care for the animals.

Despite many encouraging results, no significant impact was demonstrated on communication issues quantitatively. This contrasts prior work suggesting robots could improve communication and interactions (Wood et al., 2015; Liang et al., 2017). However, our qualitative results did suggest robots encouraged communication, mediating social connection, as shown in previous work with Paro (Wood et al., 2015). The communication scale we selected provides a measure of resident speech and conversational ability (Strøm et al., 2016), a possible limitation of our work. Future research may seek to employ measures of social cohesion and quality of interactions. Interestingly, the qualitative results did demonstrate evidence of speech and conversational ability improving in some instances, such as residents with severe aphasia showing no signs of the disease upon communicating with the dog. This is a profound result, although not replicated in the chosen scale, thus requiring further exploration in future research. It is possible any effect on communication results from some mechanism of reminiscence, with prior evidence suggesting reminiscence therapy promotes perceived improvements on communication measures (Woods et al., 2018; Yamagami et al., 2007).

The experience sampling of observations through calendars (Verhagen et al., 2016), also provided insight into the type of use robots received. As we did not provide an intervention dose, this aids in understanding the likely real-world use of devices. The calendars demonstrate a range of uses, from short 15 minute sessions, to 24/7 use by some residents who 'adopted' the pet, keeping them day and night, until care staff retrieved them to be cleaned and shared. This result highlights a limitation of prior robot pet trials with highly controlled intervention doses (Petersen et al., 2017; Moyle et al., 2017a), as real-world use is likely more flexible. Our results demonstrate robots received high levels of use, and were clearly well adopted into daily practice. Observing staff reported evidence of residents loving pets and displaying ownership tendencies. Importantly, Study 11 was congruent with Study 10 in demonstrating no novelty effect for devices over 8 months, providing further evidence against novelty effect as a concern for robot pet research and implementation (Sparrow & Sparrow, 2006; Kachouie et al., 2014; Baxter et al., 2016).

Regarding use-type, there were only 10 counts of group sessions recorded as the 'reason for use,' however these were all recorded prior to Covid-19 restrictions. Evidence in interviews after the 8-month study suggests most robot use was on an individual basis. Previous work has varied in either group (Jøranson et al., 2015; Robinson et al., 2013; Heerink et al., 2013) or individual robot intervention (Pike et al., 2020; Brecher, 2020; Hudson et al., 2020). While our work suggests individual intervention was most common, we are unable to comment on the generalisability of this result to non-pandemic contexts. However, the results of Study 5 also suggested the importance of availability of multiple devices for many individuals, due to foreseen issues in sharing and jealousies, supported here with some evidence of jealousies and possessiveness in our qualitative results.

The qualitative evidence also gave some further insight into robot design, based on longitudinal experience with robot pets. As in our previous work (Study 4 and 5), stakeholders commented on hygiene as a design limitation of current devices, requesting removable shells for easier cleaning. Participants again supported the importance of realistic design, life-simulation features and interactivity. Congruent with Study 6, stakeholders felt the JfA cat had more appropriate vocalisations, although the importance of mute options (which the JfA devices have), was highlighted. Ultimately, design preferences seen here in longitudinal work are consistent with results of our previous, cross-sectional design studies, supporting the validity of our earlier results (Study 3, 4 and 6).

In contrast to our previous work however (Study 10), suggesting devices were suitably robust, this study reports cases of breakages (as was a concern in Study 5). We know of five broken pets throughout this trial, from a total of 18 pets (16 original and two replacements). One JfA cat sustained broken limbs (cause unknown), without hindering its use, another cat was dropped in urine, becoming unusable, and three dogs had technical malfunctions. The variance between reported robustness in Study 10 and the cases of breakage/malfunction here could result from the different settings (supported living vs care homes), and due to more thorough exploration with more devices, creating greater opportunity for issues to become evident. Despite the issues, only two devices required replacing as the other three remained mainly usable.

Due to the timing of this trial, we were able to gather some understanding of use and impact of robot pets during the Covid-19 pandemic, and resultant lockdown and isolation, which is entirely novel. The evidence suggests, in line with Study 7b and our suggestions, that homes took extra precautions on shared robot use. Despite this, pets provided a highly valuable tool during the pandemic and lockdown, with care staff reporting strongly on the

value during the unprecedented times. Pets aided in reducing loneliness and providing company, comforting for residents experiencing long periods without visitors or usual excursions. Pets were also used for residents shielding in self-isolation, beneficial for residents alone in their bedroom. This is a positive result and has implications for care homes and other aged care services, suggesting provision of robot pets for individual use during the current pandemic may support wellbeing during the challenges of lockdown and isolation. Isolation is particularly pertinent for care home residents (Simyard & Volicer, 2020), highlighting the value of this finding. Despite these benefits, use during pandemic situations must be thoroughly risk-assessed, in light of the risks detailed in Study 7b. Here, our results demonstrate high numbers of mortalities in collaborating homes. While our enquiries suggest deaths appear unrelated to robot presence, the risk needs considering appropriately, as with all shared surfaces, social contact and cleaning procedures in the homes.

Strengths and Limitations

A strength of this work is the pragmatic, mixed-method approach. The use of calendars to support interviews and psychometrics allowed for ecologically valid appraisal of subjective experiences, yielding comprehensive views of activities which may be difficult to assess using cross-sectional questionnaires, or interviews which can suffer from memory strains and aggregation (Verhagen et al., 2016).

A further strength is the, somewhat novel, approach to this trial, in not specifying an intervention dose. This allowed for ecological validity, assessing effects on resident wellbeing based on the likely real-world use of robot pets, with intervention dose reflecting real-world circumstances. To this regard, our results thus demonstrate effectiveness, the impact robot pets may genuinely achieve with real-world implementation, rather than

efficacy, the impact of robots under highly controlled research contexts with specified intervention doses (Kim, 2013). Furthermore, not defining an intervention dose removed the ethical concerns of encouraging robot interaction when residents are resistant and removing robots when they are being enjoyed, as encountered previously (Moyle et al., 2017b).

One limitation of this work is the lack of participant responses to the loneliness measure, creating an inability to assess impact on loneliness quantitatively. A further limitation is the impact of Covid-19 on accessibility of medication records. Prior work with Paro had suggested resultant decreases in use of psychoactive and analgesic medication (Petersen et al., 2017), thus this remains a topic for future research. Additionally, our analysis reports on the NPI subdomain scores, further to the NPI total, with previous work cautioning that while use of NPI subscales has been popular, validity and reliability is mainly established for the total measure, with validity of individual scales requiring further testing (Lai, 2014). A further methodological limitation results from the inability to blind collaborators to conditions. It is possible the significantly lower outcome measures in the intervention group are a consequence of the inability to blind collaborators. This challenge has been reported on prior Paro RCT's, whereby the influence of participating in the research itself raised staff awareness to improvements and contributed towards the positive findings (Jøranson et al., 2015). It is not possible to distinguish this effect from the intervention. Thus there is some possibility of positive reporting bias from our collaborators. Additionally, the inability for two care home staff to co-jointly complete the four-month outcome measures may have reduced validity of the four-month scores.

The inability to blind collaborators to trial conditions in companion robot research highlights the importance of research with physiological measures. Previous work with Paro has

shown decreases in blood pressure (Robinson et al., 2013), and heart rate (Robinson et al., 2015), urinary tests of stress markers (Saito et al., 2003), and pulse oximetry (Petersen et al., 2017). We discuss future research exploring physiological impact of JfA devices in Chapter 6.

The use of a cluster RCT may also be perceived as a limitation over standard RCT's (Jøranson et al., 2015). However, research with older adults and in care home environments presents specific challenges, differing greatly from clinical environments or labs. Residents often have dementia, and the ability to randomise residents individually within homes to receive/not receive robot intervention would be challenging and unethical. Creating clusters from care homes, as units, rather than randomising residents individually, thus allows for research such as this (Moyle et al., 2017a; Jøranson et al., 2015). A further consideration is that the psychometric scales we selected are all designed and validated for older adults and those with dementia. Not all of our participants had dementia, however, the scales were deemed appropriate by our collaborators due to the high prevalence of dementia in long-term care facilities such as care homes (Moyle et al., 2017a), with 70% prevalence reported for care settings (Matthews et al., 2013). Additionally, the content of the chosen scales appears appropriate for older adults with and without dementia, and even those without diagnosed dementia are sometimes experiencing onset-symptoms. Indeed, very few of our participants received a very low score on the dementia severity scale.

A final limitation of this work is the statistical analysis, because as yet, the analysis does not take account of the cluster effects (the effects of intra-cluster correlation in individual care homes), nor baseline effect (as a covariate). Further analysis will be undertaken for publication, however, although the most suitable analysis is likely to be a random effects model (Creanor et al., 2016), to take account of clusters (random effects) and baseline

measures (fixed effects), this analysis is complicated by issues of normality in the data. Indeed, guidance is available on analysing normal data from cluster-RCT's (Creanor et al, 2016; Hemming et al., 2014), but more complicated for non-normal data. Such analysis falls beyond the scope of presenting this study within the thesis, and the non-parametric tests used are sufficient for interpretation of the non-normal data.

Conclusion

Our results suggest affordable robot pets may produce important wellbeing effects for older adults, including reduced neuropsychiatric symptoms (depression, delusions, elation, anxiety and apathy), with qualitative accounts also supporting reductions in agitation. This work also suggests robot use impacted occupational disruptiveness, as an indicator of care provider burden. However, limitations of this study mean future confirmatory research with physiological measures could be of value. This work also suggests no novelty effect for affordable robot pets, but does support best practice is permanent availability of multiple devices. One key finding is the contribution to the discussion on suitability of robot pets. Previous work has suggested robots are best suited to residents with more severe dementia. This was supported in our work, however, we also suggest subjective loneliness may be a predictive factor in the acceptance and benefit of robot pets. This work has also demonstrated the important value of individual use of robot pets during Covid-19, easing the challenges of isolation through providing social companionship.

Study 11 Reflection with Collaborators

Following completion of Study 11, HB and collaborators engaged in the final *Reflective* phase of the work. The reflective conversations shed light on subsequent purchases of

companion robots (due to perceived success in the trial), demonstrating how the CAR filtered results directly into practice. This provides evidence for the value of researching collaboratively. Further to collaborating sites, I was informed of wider real-world purchases and implementations, as a result of the developing interest in robot pets throughout this doctoral project. Of particular note, I engaged in a reflective conversation with the dementia liaison lead who had been collaborating and advising on Study 11. The details are included in Chapter 7, but as a result of this doctoral project, JfA devices have now been implemented in the local secondary care hospital, thus the implications of this work have branched beyond care homes and supported living facilities. Excitingly, this development creates scope for much further research, and likely commences a new phase of CAR and user-centred design.

Non-research robot purchases following completion of thesis studies

Following participation in Study 11;

- Home 1 purchased two additional JfA cats,
- Home 2 purchased an additional JfA cat and dog,
- Family members at Home 3 purchased two dogs for relatives and the manager purchased two more cats and two more dogs (total six additional JfA devices),
- One relative at Home 4 purchased a relative their own JfA cat,
- Home 5 purchased two 'Biscuit' robot dogs (not JfA, were purchased second hand locally),
- One relative at Home 8 purchased a relative their own JfA cat.

Additionally:

- A separate care home collaborating on other projects in EPIC, who attended robot pet presentations, purchased three JfA cats.
- Royal Cornwall Hospital Treliske are providing JfA devices in constant supply on the dementia ward, based on the dementia liaison lead collaborating on Study 11 and observing perceived effects.

- A care home in Devon reached out to share that they were also implementing JfA devices in their care home.
- Lancashire County Council contacted HB, having seen media coverage and publications of robot pet work, and had implemented robot pets in 20 care homes throughout Lancashire (Lancashire County Council, 2019). We did commence longitudinal diary data collection with the 20 homes, with ethical approval, however Covid-19 hindered data collection, although we may be able to re-commence work with these 20 homes as future research.
- Devon and Cornwall police reached out to HB (February 2021) to share that they were exploring use of robotic cats for 'high intensity service users' such as individuals with delusional episodes resulting in frequent 999 calls.

The above implementations demonstrate the impact and implications of the collaborative action research and the growing interest in affordable robot pets, it would be interesting for future work to explore the changing role of care staff as a result of the introduction of these technologies. Collaborating homes continue to use and report benefits from their robot pets, and during email exchanges, I received the below image of one of the residents, who agreed for the picture to be shared and included in the thesis.



Figure 35: Resident in collaborating care home with JfA dog 'Benjamin'

5.3 CAR Cycle 3 Reflection

The studies included in Cycle 3 provided the *user-based assessments* of the JfA devices, selected as most suitable currently available devices. Cycle 3 also allowed insight into real-world robot purchases and implementations, allowing for documented evidence of the impact of work in this thesis on current health and care practice for older people.

Regarding the collaboration with Robotriks, Cycle 3 provided evidence to support the value of removable skins for the new prototype, due to older adults feeding their pets, which consequently became unclean. Further support was provided for life-simulation features, as an additional tactile response with perceived benefits. While the JfA devices were certainly the most suitable from the robots considered, they are not without requirement for improvement. Indeed, Cycle 3 demonstrated that vocalisations can become irritating,

particularly from the dog. Furthermore, collaborators again commented on the robotic 'feel' inside devices, requesting robots feel more realistic under the surface.

Study 10 and 11 combined demonstrate significant potential for affordable robot pets to serve as beneficial and therapeutic tools in the care of older people and people with dementia. In improving wellbeing, the results of Cycle 3 would suggest affordable robot pets may have implications for practice beyond those studied within this project, (e.g. for hospital settings), some of which is discussed in Chapter 7.

Chapter 6 provides a brief overview of the *Producing a Prototype* action of the user-centred design cycle. Although the JfA devices were selected as the most appropriate, currently available devices tested in *user-based assessments*, the devices are not without requirement for improvement (as seen in the design improvements requested in Study 11). The issue still remained that older adults have always been implicated in the design of companion robots (being the intended user), but not involved (Frennert & Östlund, 2014). This project aimed to rectify this issue through collaboration with Robotriks and subsequent development of a prototype robot, designed from the feedback of end-users and stakeholders, essential due to the mismatched design perceptions between end-users and roboticists, as demonstrated in Study 3, and as highlighted through the development and use of Paro, a device poorly matched to intended *user and organisational requirements*.

Chapter 6: Collaboration with Robotriks to develop new companion robot, COMpet

The research conducted has influenced design of a new companion robot, in collaboration with Robotriks¹. Specifically, while Robotriks are developing the robot, results of this project have directly informed design choices. This represents the *development of prototype* phase of Daly-Jones et al. (2000) user-centred design activities.

Discussions between researchers and collaborators

As this project demonstrated infection control as a key concern of collaborators, we formulated the idea of a customisable robot with removable fur. HB proposed the idea of a standard internal robotic structure, with a waterproof, wipe-able, non-removable skin and interchangeable furs to represent different animals and personal choice, and Professor Ray Jones proposed the idea of a person-centred approach to creating and gifting the interchangeable furs. Subsequent studies (3 and 4) suggested end-users and stakeholders highly valued these proposals, which were shared with Robotriks to allow prototype development. This proposal was felt congruent with user-centred design, through allowing personalisation of an individual companion. Choice of live pet is a personal and significant experience, and appearance of the animal is one of the primary influences for adopters across all species (Carla et al., 2012), and thus perhaps a similar approach should be undertaken for robotic pets.

¹ The collaborating company can be viewed here; <https://www.robotriks.co.uk/the-com-pet>

Main Findings and recommendations for Robotriks based on the work presented in this thesis

- Changeable skins for customisation and hygiene (Study 4 and Study 11)
- Crafting of skins for self or gift (Study 3 and 4)
- Skeletal feeling surrounded by padding to improve robot 'insides' (Study 4 and 8)
- Soft/cuddly exterior (Study 2, 3, 4, 6, 9)
- Realistic aesthetics (Study 3, 4, 6)
- Familiar animal (Study 3, 4, 6)
- Large/cute eyes (Study 3, 4, 6)
- Eye contact – looking towards user (Study 4 and 6)
- Expressive face (Study 4 and 6)
- Command response (Study 3 and 4)
- Interactivity – recognisably responding to user, particularly through touch and sound (Study 3, 4 and 6)
- Vocalisations or tactile feedback, life simulation (e.g. purring/warmth/heartbeat) (Study 3, 4 and 6)
- Data recording on use of robot (reflection from Study 10 and designing Study 11)

Research Communications

The findings were shared with Robotriks Ltd. via email and face-to-face meetings, further to Robotriks attendance at data collection and conference dissemination, throughout 2018-2020.

The resultant prototype from Robotriks can be viewed in Figure 36. The device is named COMpet, and represents an internal robotic structure, easily adapted to cat, dog, or other creature with removable and changeable skins. This responds both to hygiene concerns and personalisation/customisability of devices. This resultant prototype is entirely unique in this regard. The device also features 'ribs' to protect the electronics, but also to provide a more realistic feel beneath a soft exterior. The device features very large animated eyes, sound sensors, a colour camera, and is interactive to touch. The device responds with movements,

although vocal response remains undefined, as do any prototype 'skins.' The device is programmed to direct its gaze towards users, deflecting occasionally in line with realistic animal behaviour. At present, collaborators at Robotriks believe the device would cost < £300, with price decreasing as production methods improve, keeping cost in line with care sector stakeholder's recommendations (Studies 5 and 6).



Figure 36: COMpet, prototype robot internal structure

COMpet will be evaluated with end-users once the prototype is ready for testing. However, this will fall outside of the scope of this doctoral project, mainly due to product development ceasing during the pandemic, with priorities shifted to producing personal protective equipment. This will provide literature on acceptability, engagement and effectiveness of a new companion robot, unique in user-centred design, and will also provide the *user-centred assessment* phase of a product designed based on user-centred principles to continue beyond completion of this thesis (Daly-jones et al., 2000). It is likely

further design recommendations will result from the assessment, therefore commencing the cycle again. It is a key outcome of this collaborative PhD project that a new prototype product has been developed, and the user-centred design cycle has been commenced for robot pets aimed at older people. It is hoped, future robot pets will hold even greater potential for improving the lives and wellbeing of older adults, more adequately meeting user's needs and desires, being more acceptable and affordable, improving chances of widespread adoption.

Chapter 7: Discussion

This thesis has explored the design, use and impact of companion robots for older adults.

Chapter 7 provides an overall discussion based on all 11 studies included in this work.

7.1 Key findings and knowledge contribution in relation to original aims

Referring back to the aims of this project (Chapter 1), this section reflects on to what extent each aim and associated studies has contributed towards the state of the art in this field.

Originality is also discussed by reflecting on literature gaps responded to, or methodologies improved upon.

- **Assess requirement and acceptability of socially assistive robots in health and social care generally**

Study 1 and 2 furthered previous SAR acceptability studies, through methodological improvements including; larger samples, inclusion of a range of stakeholder categories (Heerink et al., 2013; Pino et al., 2014), and live device demonstration rather than passive methods (brochures or PowerPoints) (Pino et al., 2015; Jung et al., 2017; Wu et al., 2014), restricting validity of participant opinions towards devices. In response, Studies 1 and 2 involved live interactions with a range of SAR, including a humanoid robot, a telepresence robot, and two different robot pets with contrasting embodiments. Studies 1 and 2 therefore furthered previous work, justifying the requirement and desire for social robots in H&SC and establishing 'higher-level' acceptance of such devices among H&SC decision makers (responsible for procuring or implementing SAR). This is essential before understanding perceptions of ultimate end-users, who would not receive interaction opportunities should higher-level acceptance among staff and decision makers be absent. As such, in the post-reflective Study 9, I additionally aimed to further inform optimum 'base

design' for SAR to ensure such 'higher-level' acceptability is promoted in future developments.

- **Establish the necessity and value of user-centred design in the companion robots field**

Study 3 provided an entirely novel piece of work, being the first to the authors' knowledge directly exploring necessity of user-centred design in the field of companion robots. While theoretically user-centred design has been reported as desirable (Moyle et al., 2018), no confirmatory research has been undertaken. Study 3 thus responded to this literature gap, reporting on necessity of this approach and justifying subsequent studies on user and stakeholder perceptions of robot design. As such, Study 3 demonstrates the work throughout this thesis may aid in the difficult translation between theory and practice (Green et al., 2000). Indeed, the reflection following Study 11 highlighted a number of real-world robot implementations as implications of robot pet interest generated throughout this project. Such real-world implications were a result of the user-centred design and CAR approach, with CAR reported to bridge the gap between research and practice (Nichols, 1997).

- **Compare a range of companion robots and alternatives, to respond to an identified literature gap, and compare device acceptability and preferences**

The lack of available comparison studies for companion robots has been noted previously (Kachouie et al., 2014), and thus the studies included in this thesis involving a range of robot pets, SAR and alternatives responded towards this literature gap (Studies 1, 2, 3, 4 and 6). To the authors' knowledge, this thesis has provided the most comprehensive companion robot comparison to date, as the limited number of previous studies also lacked full involvement of all relevant stakeholder categories, lacked inclusion of Paro or age-specific

robots, or used less valid methods (Heerink et al., 2013; Pino et al., 2015). Indeed, this thesis has demonstrated an issue with available companion robot research, and selection bias towards Paro, considering the limited acceptability shown towards this device when alternatives are available. Consideration of more affordable and acceptable devices in future research could have implications for more wide-spread use of these potentially therapeutic tools.

- **Understand user-requirements of key stakeholders for companion robots, to inform user-centred design of economical and improved devices**

While there is much research available on outcomes of interaction with Paro (Jøranson et al., 2015; Saito et al., 2003; Liang et al., 2017; Petersen et al., 2017; Robinson et al., 2015; Senju et al., 2009), little is understood about the features or abilities required. There is limited research available on end-user perceptions towards companion robot design. As noted previously, few design studies directly involve older people (Lazar et al., 2016). The limited number of existing studies generally employ care providers as participants, or only involve end-users in final design stages. The studies in this thesis responded through involving a range of key stakeholders (older adults themselves, care staff, resident family members, H&SC professionals and roboticists), in comparisons of available robots and discussions on most suitable designs (Studies 2, 3, 4 and 6). The results of this thesis have significant implications for future companion robot design and choice of robots for real-world implementation. Indeed, the studies in this project demonstrate clearly, from a user-centred perspective, Paro is very poorly matched to *user and organisational requirements and context of use*, making real-world implications unlikely.

- **Feed user-centred design preference results into development of a new robot, to more accurately reflect user-requirements**

The development of a new robot prototype based on research findings is a further novel outcome of this project and direct result of the user-centred design approach (Daly-Jones et al., 2000). The prototype designed by Robotriks is unique in reliance upon end-user and stakeholder feedback to inform subsequent design features and abilities.

- **Develop understanding of context for companion robot implementation, including costs and procurement models, ethical concerns, longer-term 'real-world' use and practical factors such as robustness and infection control**

Wider understanding of the context of companion robot implementation itself is largely missed within the literature, identified as a literature gap in recent reviews (Hung et al., 2019; Koh et al., 2020a). The studies included in this thesis (Studies 5, 6, 7a, 8, 10 and 11) have responded to this literature gap through enhancing the understanding of use context, and exploring practicalities of real-world robot implementation. This thesis contributed work to respond to identified literature gaps on; infection control (Studies 7a, 7b), ethical concerns (Study 8) and theory to guide implementation (Hung et al., 2019), including on appropriate cost (Studies 5, 6, 10 and 11). The inclusion of these more novel research questions was again a result of the CAR approach, with *Reflection* phases of the project informing future research questions (Kemmis and McTaggart, 1988).

- **To explore effectiveness of affordable and acceptable robot pets in achieving health and wellbeing outcomes through user-based assessment, responding to**

limitations of previous short-term, highly controlled studies focusing mainly on the unaffordable Paro

There is very limited outcome research available for companion robots and devices other than Paro. Most research with alternative JfA devices focused on older adults in the community (Pike et al., 2020; Hudson et al., 2020), or in hospital (Brecher, 2020; Schulman-Marcus et al., 2019). The context thus differed greatly from care home residents and individuals with dementia, who are reported to be more vulnerable to loneliness and isolation (Siniscarco et al., 2017), encountering very different challenges to older adults in other settings. Furthermore, care home residents appear to be the most common target audience for companion robot implementation (Abbott et al., 2019; Pu et al., 2018). The work throughout this thesis therefore informed selection of the most appropriate currently available alternatives, based on design and practicalities. Study 10 and 11 then provided much required research evidence on wellbeing potential for the selected devices, with implications for wider implementation of companion robots in care. The studies additionally contributed towards the limited availability of longitudinal research, helping dispel fears of a novelty effect (Sparrow and Sparrow, 2006). Additionally, previous work with Paro reported highly controlled intervention doses, thus exploring efficacy rather than effectiveness of robots (Kim, 2013), again limiting the relevance of research results to real-world implementations. This limitation was responded to within this project, focusing on real-world stakeholders, ecologically valid longitudinal work and effectiveness of robots rather than efficacy.

Ultimately, a relatively recent review on Paro research concluded the users' needs and experiences remained unexplored (Hung et al., 2019), and authors have previously suggested older people are implicated in the design of social robots (being expected to use

and accept them), but not involved (Frennert & Östlund, 2014). The studies included in this thesis have therefore made important contributions to the companion robot field of literature, and improved upon the state of the art in robot pet research.

7.2 Implications for further research

This section aims to provide some short reflections on interesting factors arising during the project. Namely, the below reflections have implications for future research on robot pets in hospitals and for end of life care, further to highlighting value in future physiological studies.

Brief commentary on potential for companion robots use in secondary care

During the *Reflection* phase of CAR following Study 11, the collaborating Clinical Dementia Liaison Lead shared her experience of implementing JfA robot pets within the hospital, following their perceived success in the care homes. The JfA devices are now available in constant supply on the older people's complex care ward, for any patient who may benefit. The conversation is summarised below.

Our collaborator described how they "*gave a cat to the lady at the hospital*" who was "*so anxious, all over the place, very demented, verbal fluency was poor.*" However, our collaborator observed "*every time the cat meowed, she would speak normally, like you and I,*" supporting some effect of robot pets on communication impairments, allowing our collaborator to engage in conversations with patients first appearing unable to converse. Our collaborator suggested one patient would "*pick [the cat] up and look after it, and it would ease her anxiety.*" The patient's dementia and impairment to short term memory meant the cat never became boring, and thus would "*ease her anxiety every time.*" As with residents in Study 11, the patient would "*nurture and feed*" the robot cat.

Our collaborator explained how the hospital had arranged a budget allocated to permanent provision of the pets, based on their observations of perceived benefits. In the initial

assessment of patients entering the ward, nursing staff ask patients or family about experience with pets and gauge value of a robot pet for each patient. Having the robots available appeared important, as nurses did not *“want to wait for family to buy one.”*

Our collaborator felt nursing staff themselves benefited, as they sometimes *“feel at a loss when people are impaired and anxious”* while the pets provided an enjoyable distraction.

Our collaborator reported on another nurse placing a robot dog besides a male patient who *“totally took to it, and thought it was his dog.”*

Our collaborator felt pets had been most beneficial for patients with delirium further to advanced dementia, being profoundly confused. Our collaborator suggested reductions in agitation were clinically short lived, but were repeatable throughout the day. The robots are currently provided to individual patients and their allocation is identified with a hospital wrist band. Upon patient discharge, the patient takes the robot home and it is theirs to keep. The Ward then purchases a new cat or dog to replace the discharged pet, through the budget and hospital fundraising schemes.

Our collaborator reported nurses had been trialling robot pets instead of medications for anxiety, an outcome we had hoped to observe in Study 11. One nurse reported positive feedback on providing a robot cat to an agitated female patient instead of PRN medication, which ensured her agitation was lowered but she remained able to accept feeding and fluids (which she may have been too sedated for with medication).

Our collaborator felt the beneficial impacts of robots may result from some form of parental instinct to care, suggesting it was *“different to a soft toy”* as the interactivity implied a social entity, *“that needed assistance.”* Our collaborator felt the device gave patients *“purpose and value”* in caring for something.

On a complex care and dementia ward, our collaborator felt the devices were particularly appropriate as some *“patients waiting for placement [to a care home] could be waiting a few weeks or a few months,”* and in that time *“levels of agitation can increase with all the changes and stress,”* as the environment is *“very noisy, [and] can be distressing.”* Our collaborator was additionally hoping to use the robots for trauma ward patients with dementia or delirium in the future. She suggested; *“it doesn’t happen often that people come to hospital, and go out with something helpful like that, just for them.”*

This insight from our collaborator demonstrated how CAR can have implications to real-world practice, even beyond the care home context of the project. The insight also demonstrates implications for future research. Some research has explored the use of affordable robot pets in hospitals previously (Brecher, 2020), including for delirium (Schulman-Marcus et al., 2019). However, scope remains to further the limited availability of such work. This feedback also highlights the importance of ethical considerations, as the patients referred to experience severe levels of dementia and cognitive impairment. Issues such as infantilisation and deception, as discussed in Study 8, would of course be worth exploring further when proposing use of robots for hospitalised dementia patients.

Brief commentary on robots for end of life and palliative care

As with the potential for further work in secondary care settings, some interesting future research may look at the value of robot pets during end of life. Previously, Brecher (2020) reported on a JfA device provided to an end of life patient. The case study reported stakeholders felt the robot aided in a comfortable and dignified death, remaining present throughout the active dying phase. Additionally, during the pilot study for Study 11, I met a resident who engaged with the JfA cat over the 8 week pilot. The resident had no visiting relatives and was reported to be non-verbal, however during the 8 week pilot was recorded

by collaborators speaking fully formed sentences having formed a strong bond with the pets. Following completion of the pilot study to assess feasibility of methods for Study 11, HB purchased a JfA cat to gift to the pilot home. The resident under discussion entered end of life care in the months following the pilot, but collaborators reported continued enjoyment, comfort and benefit from the robot throughout. While this evidence is anecdotal, it provides interesting implications for future work.

Brief commentary on companion robots for physiological wellbeing

As noted in Study 11, it is not possible to blind collaborators to the conditions for companion robot RCT's, as would be the gold standard for research trials (Jøranson et al., 2015). An issue with the lack of blinding is the potential for positive response bias. In Study 11, the pragmatic and mixed-method approach allowed for psychometric scales to be complimented with two forms of qualitative data collection. As the qualitative results provided strong support for the psychometric results, this gave some support to the validity of the quantitative measures. However, it remains possible collaborators over-state the impact of devices due their own perceptions and beliefs. As suggested in Study 11, one implication for future research is including physiological methods to avoid subjective bias, allowing a more objective assessment of robot pet impact. Previously, Robinson et al. (2015) suggested interactions with Paro had an adaptive effect on blood pressure. Considering the results of our work, suggesting improved acceptability and affordability of JfA devices, further to promising wellbeing results, future work may therefore conduct a comparison of Paro and the less sophisticated JfA devices with a focus on physiological effects, to complement the available research on psychosocial and behavioural outcomes. Design ideas for future research investigating robot impact on blood pressure are documented in Appendix F.

Of further interest to robot impact on physiological response; Steptoe et al. (2015), suggested the relationship between physical health and subjective wellbeing is bidirectional, suggesting psychological wellbeing may have a protective role, with eudemonic wellbeing being associated with longer survival. This association may be related to cortisol. Positive wellbeing is associated with lower cortisol output over the day (Steptoe et al., 2015). Elevated cortisol has a role in lipid metabolism, immune regulation, central adiposity, hippocampal integrity and bone calcification, and thus links with physical health (Steptoe et al., 2015). Steptoe et al. (2015), concluded health care systems should thus not only be concerned with illness/disability in old age, but also methods of improving positive psychological states. Regarding potential for companion robots to reduce depression symptoms (Study 11, Jøranson et al., 2015), research has demonstrated depression is linked to premature mortality, coronary heart disease, diabetes, and disability, with positive psychological wellbeing a protective factor (Steptoe et al., 2015).

Therefore, further to the proposed blood pressure study (Appendix F), it may also be interesting for future research to investigate any impact of robot pet use on measured cortisol levels. Hodgson and Granger (2013), suggested salivary cortisol measures are increasingly emerging in bio-behavioural research due to ease of collection, minimal invasiveness and inexpensiveness in providing markers for stress. Hodgson and Granger (2013), suggested this method can allow for comparison of treatment groups and of effectiveness of interventions. Woods et al., (2010), utilised Salimetrics saliva cortisol tests with nursing home residents with dementia, the results demonstrated morning cortisol levels were related to behavioural symptoms. Prior research by Woods et al. (2008), supported viability of saliva cortisol testing for people with dementia living in nursing homes. Jøranson et al., (2015), found twice a week sessions with Paro for 12 weeks resulted

in reduced agitation and depression compared to a control group, and the work in this thesis supported the ability of affordable JfA devices to achieve similar (Study 11). Jøranson et al., (2015) suggested Paro may have affected the human stress response, suggesting oxytocin, released in positive social settings, can reduce cortisol levels and lower blood pressure, resulting in reduced stress response, although this study did not measure cortisol or blood pressure. This therefore presents a further literature gap which future research may respond too, such research would need to control for extraneous variables such as body size, diabetes, Cushing's and cardiovascular disease when assessing robot impact on cortisol.

Brief discussion on mechanism of robot impact

While the works in this thesis have provided a comprehensive exploration of companion robot design, use and impact for older adults and people with dementia, one unexplored factor is the mechanism responsible for the apparent benefits of robot interaction. Thus, this creates a further implication for future research. Perhaps, as with live animals, devices provide a buffer to protect from stresses of daily life through engaging people in comforting interactions, offering unconditional social support (Eachus, 2001). Alternatively, perhaps devices provide a sense of purpose and responsibility, not dissimilar from research demonstrating benefits of having responsibilities such as caring for a plant (Mallers et al., 2013). Purpose in life refers to some form of goal or responsibility to be fulfilled (Hedberg et al., 2010), and is associated with greater life satisfaction (Wnuk et al., 2012), mobility and physical health (Ibrahim & Dahlan, 2015; Boyle et al., 2010; Kim et al., 2013). Evidence in Study 10 and 11 demonstrated resident tendency to nurture and care for robots, thus perhaps the benefits result from some consequential sense of purpose. This mechanism of

impact would provide additional requirement for realistic and familiar embodiment to maintain the best chance of triggering schemas of nurturing and caring for a living organism.

A further theory for consideration is that benefits may stem from reminiscence, of past positive experience with pets. Evidence of reminiscence was provided in Study 10 and 11. Previous work has indeed suggested reminiscence therapy may improve wellbeing, depression (Moon & Park, 2020), and communication abilities (Woods et al., 2018; Yamagami et al., 2007), however, reminiscence therapy research often has small samples and inconsistent results (Woods et al., 2018), and research has demonstrated lack of impact on behavioural or cognitive issues (Yamagami et al., 2007; Moon & Park, 2020). Perhaps linked to reminiscence and memory, robot pets provide some form of continuity which is beneficial for older people. In Study 4, residents suggested devices would be something 'there for them every day,' so they 'knew where they were in the world.' Similarly, in Study 11 stakeholders commented on robot pets appearing to reassure residents with dementia they were in the right place, as their pet was there with them. This continuity and permanence is perhaps beneficial during the confusion associated with dementia, life changes when moving to a care home, and dealing with high staff turnover (Costello et al., 2020). A further memory based theory could suggest animal robots trigger a schema on the potential for a loving relationship, based on either personal or vicarious experience of past pets. It is also possible robot pet benefits result from a physiological response, as discussed above. The lack of understanding on the mechanism of robot impact thus has implications for future work and further debate, and perhaps involves a number of factors including reminiscence, physiological response and sense of purpose.

7.3 Implications for robot design and development

The results of this thesis have significant implications for design of future SAR and robot pet developments. Indeed, the studies in this project demonstrate clearly, from a user-centred perspective, Paro is very poorly matched to *user and organisational requirements* and *context of use*, making real-world implications unlikely.

The results of Studies 1, 2 and 9 have implications for social robot ‘base-design,’ to ensure higher-level acceptability among H&SC decision makers, and include biomorphic (particularly zoomorphic) design, androgynous aesthetics, interactivity and practical considerations (e.g. long batteries, robust, easy to use, no issues of mobility). Beyond the broader considerations, the comprehensive comparison of available robot pets and user-centred approach to this thesis has aided in understanding optimum pet design.

The results of studies within this thesis with a range of stakeholders and mixed-method approach has allowed identification of relatively novel design considerations on removable skins, life-simulation features, type of interactivity (respond to sound and touch), and robot size and weight (Studies 3, 4, 6). Appealing eyes and eye contact are also design recommendations based on work in this thesis. During Study 3, 4 and 6, large, cute eyes and directed gaze were noted as important features for inclusion, perhaps increasing social relevance of the robot, particularly when eye movement is intentional rather than random (Abubshait & Wiese, 2017), as eye contact can modulate activity in the brain’s structures and networks responsible for social behaviour and is important in social communication (Senju & Johnson, 2009). Again in Studies 3, 4 and 6, life-simulation features were supported (including breathing, purring, warmth, heartbeat), congruent with the previously reported

assumption of care-providers that a simulated heartbeat would be valuable (Jung et al., 2017).

Studies 2, 3, 4, 5, 6 and 9 all supported use of realistic, familiar animal form as a definite aesthetic requirement. Previous research revealed criticism from carers towards Pleo for lack of familiarity (Heerink et al., 2013), however the intentionally unfamiliar Paro (Shibata & Wada, 2011) is the most often utilised companion robot in research (Pu et al., 2019).

Based on work in this thesis, unfamiliar forms appeared incongruent and infantilising, perhaps explaining the tension Lazar et al. (2016) found towards their selection of unfamiliar animals. The issue of infantilisation, and some residents feeling foolish for interacting with such devices in Study 4 does support ethical concerns of Sparrow and Sparrow (2006), strongly suggesting against continued use of unfamiliar robot pets.

Further to concerns with unfamiliar design, Sparrow and Sparrow (2006) suggested enjoying any robot pets required people to deceive themselves as to the realness of the interaction. However, Study 8 demonstrated ethical concerns highlighted during philosophical debate of companion robot use (Sharkey, 2014; Chiberska, 2018; Sparrow, 2002, Sparrow & Sparrow, 2006; Sharkey & Sharkey, 2010; Sharkey & Sharkey, 2012) may differ from those voiced by real-world target groups. The majority of younger adults in Study 8 would purchase a companion robot for an elderly relative and demonstrated limited ethical concerns. The acceptability of familiar designs (and absence of ethical concerns as a barrier), thus has implications for future developments.

Study 6 also explored most appropriate robot size, confirming Paro is too big for older people, as noted previously (Pu et al., 2014). Older adults are often slight and frail, and commonly engage with robots on their laps, with Paro being too heavy for comfortable use, potentially helping to explain some negative reactions to Paro in previous work (Moyle et

al., 2017b). The work in this thesis also provided insight on suitable price for companion robots aimed at care homes and older adults. Paro had been reported as too expensive for care homes to purchase (Moyle et al., 2016). Study 5 and 6 both supported this suggestion, finding appropriate prices from £100 - ~£226, far below the £5000 cost of Paro. This finding has implications for future robot designs, in limiting the amount of technology included in a device, should it increase price beyond the appropriate threshold.

Collectively, the works in this thesis have provided much needed user-centred design insight with implications for future robot developments (Moyle et al., 2018). The results of the studies in this thesis strongly support familiar, realistic, lap-sized, soft and furry robot embodiment, including large, cute eyes that direct gaze towards the user and interactivity based on touch and sound, further to inclusion of life-simulation features and warmth where possible. Additionally, removable skins and hygiene considerations are of value. This thesis has also strongly supported the removal of unfamiliar devices from practice, with Study 4 demonstrating the negative impact unfamiliar embodiment can have, resulting in feelings of foolishness and infantilisation for older adults. Such strong feelings had not been reported previously, in the many works employing the unfamiliar Paro robot (Moyle et al., 2017a; Robinson et al., 2018; Petersen et al., 2017). However, it is possible the distinct lack of companion robot comparison studies (Kachouie et al., 2014), meant end-users had been unable to provide fully informed opinions, without seeing available alternatives. While the comparison studies included in this thesis demonstrated unfamiliar devices were perceived as 'toy-like,' this was perhaps only achieved through the availability of more familiar and realistic alternatives. This result is important for companion robot literature. Previously, authors have reported Paro's unfamiliar, seal embodiment was an intentional design choice to reduce expectations of the robot's behaviour and chances of negative reactions (Shibata

& Wada, 2011). This logic was also demonstrated among roboticists in Study 3. However, further to being infantilising, studies throughout this project showed Paro triggered some surprising schemas and expectations, with a participant in Study 3 suggesting he could eat Paro with pepper sauce, echoed by a care home resident in Study 4. Additionally, another two residents in Study 4 were reminded of baby seals being skinned, an unpleasant thought, thus suggesting the unfamiliar design does not negate negative responses. The studies in this thesis suggest familiar embodiments created expectations in line with the living animal, such as participants in Study 3 expecting the dog to give its paw, or participants in Study 11 placing the dog on the floor. However, these expectations did not hinder interactions. In fact, as robot embodiment biases the subsequent interaction through social expectation (Fong et al., 2003), the animal expectations appeared to aid in creating a natural and familiar engagement with the robot and allowing for reminiscence.

There are a number of robot features this thesis has been unable to conclude on. One such feature is inclusion of speech capabilities on robot pets. While some older people in Study 3 and 4 demonstrated interest in this feature, opinions were usually divided, and care stakeholders worried talking animals would be confusing for older people (Study 4), and did not consider speech as a priority feature for inclusion (Study 6). Of course, end-users and care stakeholders can vary in their opinions towards robots (Bedaf et al., 2018; Pino et al., 2015), and the interest in speaking robots among older adults may represent an area of unmet need underestimated by care staff. However, van Maris et al., (2020) have shown recently that older adults struggled to understand a robot speaking, despite understanding a researcher. A limitation of the work included in this thesis is that a conversational agent was only present in Studies 1 and 2 (Pepper), thus restricting ability to conclude on inclusion of speech. Only Furby demonstrated recognisable speech in other studies, however this device

speaks mainly nonsense. The previous work by van Maris et al., (2020) suggested older adults even blamed themselves for not understanding the robot, suggesting their hearing was at fault. With this in mind, any benefit of verbal communication with a robot would have to outweigh the risk of negative feelings. Until speech recognition and conversational capabilities of robots improve (Study 2), in humanoids and machine-like robots initially, there would be little merit in translating the technology to robot pets.

Adaptable features is also a design possibility this work has not concluded on, but may be interesting for future research. Further to being aesthetically personalisable, it is possible future robots could be functionally adaptable. Many of the participants in Study 3, who are more independent and able than care home residents, valued command responses from robots, further to talking and high level interactivity. Care home residents without dementia in Study 4 also valued active and lively robots. However, staff responses in Study 11 suggest for residents with moderate to severe dementia, robots are mainly used to be soothing and calming. Robots could thus be adaptable for the level of stimulation required, being fun and lively when required for entertainment, and calm and soothing when required to reduce agitation. Such adaptability may also mean a robot could sustain use through an individual's entire dementia journey, with functions being altered as the disease progresses. This level of sophistication would of course increase cost, however, such devices could prove economical should use span many years. This concept has interesting implications for future developments.

7.4 Implications for health and social care practice

The work included in this thesis has a number of implications for real-world practice.

Although previous work with Paro demonstrated beneficial impacts, this thesis highlighted Paro as too expensive for a therapeutic tool aimed at older adults and care homes, creating

an unethical denial of therapeutic benefit. Thus, to date Paro has failed to promote implications for practice. This thesis responded by identifying acceptable and affordable alternatives, studying them in real-world settings, and demonstrating the impact and implications to real-world practice through subsequent robot purchases in a number of settings (Study 10 and 11). The implication therefore is the potential for wide spread implementations of affordable robot pets (such as the JfA devices or similar), into settings such as care homes, nursing homes, hospitals and supported living facilities. Study 11 provided an important and novel contribution to companion robot literature, and demonstrated significant impacts of affordable robot pets on resident wellbeing (neuropsychiatric symptoms; depression, anxiety, apathy, delusions, elation), and carer wellbeing (occupational disruptiveness). As care homes experience higher than average levels of staff turnover (Costello et al., 2020), any improvement on carer wellbeing to improve retention would be beneficial.

Comments on robot pet suitability also have implications for practice. Previous work with Paro has focused mainly on device use for people with dementia (Robinson et al., 2013; Moyle et al., 2017a), and Moyle et al. (2018), suggested further work was necessary to assess what person characteristics are required for devices to have an impact. Study 3 demonstrated older adults living more independently in supported living apartments showed good acceptability towards the pets. However, Study 10 appeared to indicate most suitability of robot pets for people with cognitive impairment. Indeed, in Study 11, the comparison of baseline characteristics demonstrated significantly higher dementia severity scores for older adults who went on to interact with robots than those who did not. However, this does not explain the acceptability of robots in Study 3 (with independent older adults), and Study 4 (with care home residents without dementia). In Study 11, it was

suggested loneliness and social isolation may also be people characteristics predictive of likely acceptance and benefit from robot pets. Study 10 also included participants with learning disabilities. Thus it is likely robot intervention has a broad suitability with implications on future robot adoptions. Providing robots for individuals who are subjectively lonely could have further health implications (Tkatch et al., 2020), as work by Sundström et al., (2020) suggests perceived loneliness can actually increase the risk of all-cause dementia, highlighting the importance of targeting perceived loneliness for older adults in all settings; community, supported living and residential care.

7.5 Implications for health and social care policy

To our knowledge, Study 7a in this thesis is the first of its kind in confirming, through initial empirical evidence, the strong requirement for adequate infection control procedures when using companion robots or toys in health and social care contexts. Our results demonstrated interaction with robots in a care home produced a microbial load higher than the accepted level, identifying the importance of adequate infection control, particularly with vulnerable people such as older adults (Montecino-Rodriguez et al., 2013), living in care homes (Jordan et al., 2006). This finding has obvious implications for policy surrounding use of robot pets in either research or real-world adoptions, in ensuring adequate cleaning is implemented. The cleaning procedure resultant from Study 7a is thus of real value, with implications for real-world policy when adopting robot pets. Of note, we were contacted by the Joy for All company, who had adapted their recommended cleaning protocol, conducted additional laboratory tests and emphasised individual use of their products in response to Study 7a and 7b.

7.6 Final thoughts

Although the strengths and limitations of each included study have been discussed in Chapters 3-5, there is one significant over-arching strength of the work included in this thesis; the inclusion of older adults themselves in the research, particularly, people living in care homes and individuals with dementia. The research conducted for this thesis would not have been possible without the strong collaborative relationships formed with care home staff and residents throughout the CAR project. Conducting research in care settings encounters unique and plentiful challenges (Lam et al., 2018). Some of which include the high tendency for staff turnover (Costello et al., 2020), making longitudinal work difficult, as does the unfortunately high attrition rate, due to hospitalisations and high mortality rates (Lam et al., 2018). Additionally, challenges are faced in data collection itself, with many residents with dementia being cognitively impaired and lacking capacity to consent to research. This however, should not be a reason to exclude people with dementia from research, doing so would be discriminatory and remove contribution opportunities (Nygård, 2006). The care setting and staff themselves also pose challenges for research (Lam et al., 2018), with social care settings being entirely different to health care settings. Indeed, Moyle et al. (2017a), reported difficulty in their cluster RCT in attaining complete data for one agitation scale from many members of staff. This highlights the achievement of the care home staff collaborators in Study 11, who completed a battery of psychometrics for the participating residents, and who have supported this collaborative action research project throughout. This approach has resulted in 11 studies, reporting on a collectively large sample of key stakeholders, including older adults in supported living and care homes, people with dementia, care resident relatives, care staff and management, health and social care professionals, students of care professions, technologists and roboticists and even

secondary care clinicians. Coupled with the array of robots included during design based studies and number of literature gaps responded to, this body of work has produced a comprehensive exploration of robot pet design, use and impact for older people.

7.7 Conclusion

In conclusion, the work included in this thesis has contributed towards the field of companion robots for older adults. Based on a number of studies exploring optimum design with a range of relevant stakeholders, this thesis can suggest user-centred design for future robots aimed at this audience is essential, and such devices should include soft, furry, realistic, zoomorphic, familiar embodiments. The devices should be interactive to touch and sound, and direct their gaze towards the user. The devices may also possess life-simulation features and emit warmth, further to having large, cute eyes and appealing facial features. Future devices must also consider removable skins and suitable infection control to respond to hygiene concerns. This research has strongly suggested unfamiliar robot devices are unsuitable for older people, and risk negative responses and infantilisation. As such, the most appropriate currently available devices appear to be robots with familiar embodiments, such as the JfA cat and dog, which also match stakeholder requirements in being the appropriate size and weight for older people, and affordable enough for real-world use. This thesis has also demonstrated such affordable devices hold significant potential as therapeutic, psychosocial tools, demonstrating no novelty effect, and significant wellbeing outcomes such as reduced depression and anxiety.

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Appendices

Appendix A: Media coverage of PhD studies

- Press coverage on Heart FM Radio, interview on 01/09/20
- Press coverage on Radio Cornwall, live interview on 01/09/20
- BBC Spotlight News <https://www.bbc.co.uk/news/av/uk-england-cornwall-44945933>
- Shared article with internationally leading companion robot researcher, Wendy Moyle <https://www.createdigital.org.au/robot-pets-help-people-same-way-real-thing/>
- <https://www.plymouth.ac.uk/news/research-urges-caution-in-shared-use-of-robotic-support-pets-during-pandemic>
- Press coverage in New Zealand <https://news.aut.ac.nz/news/robot-hygiene-important-too>
- <https://www.sciencedaily.com/releases/2020/08/200826140907.htm>
- Press coverage in New Zealand <https://newzealandonlinenews.co.nz/dont-forget-to-clean-robotic-support-pets-study-says-science-daily/>

- Press coverage in Scientific American, Arabic
<https://www.scientificamerican.com/arabic/articles/news/robotic-support-pets-cleaning-stop-infection-spread/>
- Press coverage in America <https://www.mcknights.com/news/clinical-news/robotic-support-pets-may-carry-microbes-disinfection-works-study-finds/>
- <https://electronics360.globalspec.com/article/15606/clean-your-robotic-pets>
- <https://medicalxpress.com/news/2020-08-dont-robotic-pets.html>
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- <https://www.thetechstreetnow.com/tech/dont-forget-to-clean-robotic-support-pets-study-says/15862638883717403772/15862638883717403772/>
- <https://exbulletin.com/world/health/329626/>
- <https://mc.ai/dont-forget-to-clean-robotic-support-pets-study-says/>
- <https://news.knowledia.com/AU/en/articles/research-urges-caution-in-shared-use-of-robotic-support-pets-during-71f81f29d2e6710087205d51464511cab4627803>
- <https://www.radioplymouth.com/news/local-news/plymouth-led-study-suggests-that-robotic-support-pets-pose-infection-risk/>
- *Many more outlets for the infection control paper

Appendix B: Further examples of evidence from Study 2

Table A: Example evidence supporting the Attitude Towards Technology component

Workshop Themes	Frequency	Example Evidence
Likeability	24	“I love him” [Miro] “I would visit [hospital] just to see that!” [Pepper] “Fascinating” [Pepper] “Brilliant” [Pepper]

		<p>“Interesting” [Padbot] “Very good” [Miro] “I just love the way he turns his head” [Miro]</p>
Aesthetics	24	<p>“It’s not got hard edges [...] that can scratch us, no it’s lovely, very, very nice” [Pepper] “Change how hard it is, like if it was softer” [Pepper] “I love how soft he is” [Paro] “I like him but I like tactile you see, he doesn’t feel warm” [Pepper] “Are you able to make it [...] not quite so robotic?” [Pepper] “I think it’s important it’s clearly a robot.” “He is very height appropriate” [Pepper] “Is a good height” [Padbot] “I like the ears” [Miro]</p>
Intelligence	7	<p>“Wow, very clever!” [Pepper] “Paro! Aw he’s looking at me!” “It’s brilliant, for a companion, I feel like he’s looking right at me” [Paro]. “Very bright” [Pepper]</p>

Table B: Example evidence supporting the Perceived Usefulness component

Workshop Themes	Frequency	Example Evidence
Potential Uses	77	<p>“His eyes are cameras, if someone falls on the ground, and says, phone that person up, that person can see [through the cameras].” [Miro] “Something to put [service users] in touch with various experts, they would love this.” [Pepper] “If someone needed to exercise, they [service users] could imitate that” [Pepper] “I work with people with learning difficulties, so for someone with autism, to connect to a machine like this, but the person on the autistic spectrum could struggle with this screen, so they would rely on voice commands.” [Pepper]</p>

“It would be lovely wouldn’t it, and aids people staying in their homes instead of going somewhere.” [Pepper]

“In the community which I’m [...] they are so fragmented around the country, [...] so something to keep in touch with each other.” [Padbot]

“Some of our patients facing loneliness might use it.” [Padbot]

“he can entertain us, like in a residential home.” [Pepper]

“Some people become anxious and Pepper and this [Paro] could be able to relax that anxiety.”

“Programmed reminders [...] medication prompts” [Pepper]

“I suppose you could program an app [on Pepper], something a therapist wants the person to remember; think, feel, act prompts.”

“I was just thinking for somebody with dementia, do you program it to what the persons needs are?”

“at the [community centre] we could have someone like Pepper greeting people and showing them where they need to go and contact”

“I consider benefits with all the loneliness and that” [Paro]

“Prevent falls” [Pepper]

“We could have him in the staff room” [Paro]

“A patient could ask him, read out a shopping list, and he could go online and do shopping for them” [Pepper]

“If someone was quadriplegic, locked in, they could still have a conversation” [Padbot]

Comparison to Known Products

17

“It’s like Skype, but with the usefulness of having a stand alone robot” [Padbot]

“Like the benefits of live animals, [...], this is sorta [...] fantastic at reducing anxiety and my stress.” [Paro]

“I like that he doesn’t bark, a real dog barks all day” [Miro]

“It would be more hygienic, easier maintenance than an animal” [Paro]

“It can’t understand me. The Xbox has to learn me as well because also I have a regional dialect.” [Pepper]

		<p>“Does he come with different accents? There are many different accents in this country.” [Pepper]</p> <p>“I’d turn off and back on, well, this is what you can do with a phone or computer” [Pepper]</p>
Mobility	13	<p>“Does he have the same problem as Daleks? These things that took over the world, but unfortunately they can never go upstairs.” [Pepper]</p> <p>“What about dealing with a carpet, a rug” [Pepper]</p> <p>“What you need is bigger wheels isn’t it?” [Pepper]</p> <p>“What about carpet and irregularities in the floor?” [Pepper]</p> <p>“He wouldn’t be able to get around” [Pepper]</p>

Table C: Example evidence supporting the Almere Model Perceived Ease of Use component

Workshop Themes	Frequency	Example Evidence
Ease of Use	55	<p>“You would have to know, when you get to the menu, there is a lot” [Pepper]</p> <p>“Oh that works” [Pepper’s software on laptop]</p> <p>“Simple” [Paro]</p> <p>“That’s nice and easy” [Miro’s app]</p> <p>“Amazing, you can control this from wherever, just like that” [Padbot]</p> <p>“How long does it take for someone to kind of learn, you can imagine some people just sit and go oh it’s a bit too scary I can’t, do you need quite a lot of training to?” [Pepper]</p> <p>“Just on and off” [Paro]</p> <p>“How do you clean them?” [Paro, researcher shows cleaning products] “that would be okay then”</p>

Table D: Example evidence supporting the Perceived Enjoyment component

Workshop Themes	Frequency	Example Evidence
Enjoyment	15	<p>“I think he’s wonderful actually [laughs] he makes you laugh” [Pepper]</p> <p>“Wonderful. I want to hug him!” [Pepper]</p> <p>“Cute, aww! We could have these for us” [Paro]</p> <p>“He just cheered me up” [Pepper]</p> <p>“I get it, I didn’t understand it before but now I get it” [after holding Paro]</p>
Humour	151	<p>[Pepper: I’m ticklish today] Participants laugh</p> <p>“You could get him to do evil stuff [laughs]” [Pepper]</p> <p>“Does that work for children, you just touch their head for off! [laughs]” [Pepper]</p> <p>[Pepper gives hand to participant] “[laughs] absolutely brilliant”</p> <p>[Miro drives into participants foot] “[laughs] oh he loves me!”</p> <p>“Can he teach me tango [Pepper]”</p> <p>[Pepper dances] [group of participants laugh]</p>

Table E: Example evidence supporting the Trust component

Workshop Themes	Frequency	Example Evidence
Usability	18	<p>“What’s his battery like?” “That’s really good, you could just charge him at night, and he’d last when [residents] wanted him” [Paro]</p> <p>“[connect] with a USB, yeah that works well” [Pepper]</p> <p>“Does he go on standby” [Pepper]</p> <p>“Can two people control him?” [Pepper]</p> <p>“When he is like, within 15 minutes of running down, does he automatically go back to a homing station?” [Pepper]</p> <p>“What is the battery like?” “If it ‘died’ it could be unsettling for care home residents” [Paro]</p> <p>“I think it needs a lot more work to be able to interact with people” [Pepper]</p> <p>“Does he come knowing different accents?” [Pepper]</p> <p>“Can two people control him?” [Pepper]</p> <p>“So it wouldn’t be practical in a residential home?” [Pepper]</p>

Table F: Example evidence supporting the Intention to Use component

Workshop Themes	Frequency	Example Evidence
Ownership	17	“He can come to my home” [Pepper] “I want one” [Paro] “We could have him in the staffroom, never mind the patients!” [Paro] “We could have someone like Pepper greeting people” “Now I have to take it home” [Miro] “I’d have one” [Paro]

Table G: Example evidence supporting the Perceived Adaptiveness component

Workshop Themes	Frequency	Example Evidence
Adaption	5	“The more information that you give him, the more helpful he can become, some more applications, he’s only gonna be as good as the information it’s fed.” [Pepper] “I was just thinking for somebody with dementia, do you program it to what the persons needs are?” [Pepper] “When he is like, within 15 minutes of running down, does he automatically go back to a homing station?” Researcher: “No, he is not that kind of product...” Participant: “Well I think it’s an adaption.” [Pepper]

Table H: Example evidence supporting the Anxiety construct

Workshop Themes	Frequency	Example Evidence
Damage	3	<p>“I didn’t want to be too... you know” [Pepper]</p> <p>“I’ve killed him!” [Pepper]</p> <p>“Yes I crashed the robot! I didn’t drive into it though!” [Pepper]</p>
Fear	16	<p>“It’s worrying to have a conversation with a robot” [Pepper]</p> <p>“Spooky eh?” [Pepper]</p> <p>“What springs to mind is that sci-fi movie, taking over the planet, going rogue, doing their own thing, making mistakes” [Pepper]</p> <p>“I’m almost kind of scared of it” [Pepper]</p> <p>“Stalker!” [Pepper]</p> <p>“It’s just too fast, technology is too fast these days” [Pepper]</p> <p>“Old parents, they will freak out” [Pepper]</p> <p>“Pepper is scary, no it’s cute, I have to get used to it... if you turn the lights out I’m not sure”</p> <p>“You could have nervousness about interacting with him” [Pepper]</p> <p>“I couldn’t touch it” [Pepper]</p> <p>“It’s a bit too scary I can’t” [Pepper]</p> <p>“I was a bit cautious” [Pepper]</p>

Table I: Example evidence supporting the Social Presence component

Workshop Themes	Frequency	Example Evidence
Anthropomorphism	17	<p>“Very human then” [Pepper]</p> <p>“He’s got better manners than my kids” [Pepper]</p> <p>[Participant squeezes Paro’s flipper, Paro vocalizes] “Ohh no he didn’t like that” “Did you just nip him then!”</p> <p>“How are you Pepper?”</p> <p>“Pepper are you happy?”</p> <p>“He’s looking right at me” [Paro]</p> <p>“Are you having a bad day?” [Miro]</p> <p>“Sounds like me” [Pepper]</p> <p>“Pepper are you tired?”</p> <p>“Hello, how are you?” [Paro]</p>

**Gendering/Object
ifying**

89/35

“He is dancing” [Pepper]
“Definitely a lady” [Pepper]
“I love him” [Miro]
“He said the robot is him [...] and I said her”
[Pepper]
“She must be a girl with those eyelashes” [Paro]
“He’s so cute” [Paro]
“It looks friendly” [Pepper]
“Are you quite close to it?” [Pepper]
“It’s a good height” [Padbot]
“as he said to me, the robot is him, and I said her,
because it’s androgynous” [Pepper]
“What does he do?” [Miro]
“He loves me” [Miro]
“I want to hug him” [Paro]
“We could have him in the staff room” [Paro]
“I like him as he is” [Pepper]
“I think it needs a lot more work to be able to
interact with people” [Pepper]
“It looks friendly” [Pepper]
“It is amazing” [Padbot]

Table J: Example evidence supporting the Perceived Sociability component

Workshop Themes	Frequency	Example Evidence
Friendliness	15	“Oh he’s very polite yes” “It’s funny too!” [Pepper] “Friendly isn’t he” [Miro] “Beautiful kind eyes” [Paro] “Okay he can listen and have a conversation with people” [Pepper] “He has sensors so he knows I’m cuddling him” [Paro] “He’s looking right at me” [Paro] “Be a good boy, he’s so good” [Miro]

Appendix C: F Further examples of older people’s and roboticists’ responses during focus group discussions in Study 3

Theme	Example Evidence	
	Older People	Robotocists
Interactivity	<p>“it [Pleo] interacted more so you could spend loads of time just playing” (OP4)</p> <p>“If you’re sat there on your own, you want some reaction” (OP6)</p> <p>“He [Joy for All dog] had more interaction, he was doing more of less what I wanted him to do” (OP15)</p> <p>“I’d like it to respond to me” (OP7)</p> <p>“That one [Joy for All cat] is almost perfect, but perhaps if you could say, do you want to play, and then it could then do something, a little bit more interactive” (OP13)</p>	<p>“The more sensors it has, and the more functionality it has the better, so they wouldn’t get bored so easily, more it interacts” (R1)</p> <p>“I think something passive, that doesn’t make a lot of sounds, it could be stressful, too much [...] You could have a sack that’s warm and purrs” (R3)</p> <p>“I think it should have high level interaction, because it would keep the interaction longer as well, if you just have a pet like this with one or two features, it’s done, it’s limited” (R9)</p> <p>“I don’t know, thinking of older people, I like the idea of a cat, it could just be on your lap and purrs, it doesn’t have to look at you, cats don’t generally” (R18)</p>
Soft fur	<p>“Day to day cleaning, you could wipe over it [Pleo], furry thing would be harder” (OP5)</p> <p>“Soft furry face, the dinosaur interaction was good but it’s still like dragging your hand over rubber” (OP6)</p> <p>“you can’t stroke plastic” (OP10)</p> <p>“Furry, the seal [Paro] was lovely” (OP12)</p> <p>“Fur I think so. The plastic I found very cold, not something you would, sorta, cuddle” (OP13)</p> <p>“if you’re having an animal, it has to have animal fur” (OP14)</p>	<p>“It should be soft” (R4)</p> <p>“Definitely have the fluffiness of the seal, around the same level of interactivity” (R5)</p> <p>“The dinosaur is cute but the texture is horrific” (R8)</p> <p>“The fur is attractive” (R10)</p> <p>“I don’t think so, because it isn’t cleanable, if you wanted something to cuddle you could just buy a stuffed toy” (R14)</p> <p>“Nice and furry, you could kinda cuddle it” (R18)</p>
Talking		

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

“I think that’s brilliant” (OP3)

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

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

“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 [...], when you see the finished product without knowing how, it’s sometimes better” (R2)

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

	<p>“Yeah, different ones, a Persian cat” (OP11)</p> <p>“It’s quite a good idea, yeah I do, someone who’s got a particular animal” “We were talking about colours, I like that one, she’s always had black cats, It would be nice to have a choice of different colours” (OP13)</p> <p>“If you had someone in mind, so and so really liked black cats” (OP17)</p>	<p>“People get more attached to it because they created it” (R6)</p> <p>“I’m not sure if it’s a little patronising” (R7)</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> <p>“my mum has a cat, she gets quite lonely, but if you had her make a fake cat, it just wouldn’t work” (R14)</p> <p>“it could take away from the magic of the thing” (R15)</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>“yeah realistic” (OP9)</p> <p>“For older people, stick to cats and dogs” (OP12)</p> <p>“I would prefer life like” (OP11)</p> <p>“It’s better to have something that’s familiar, and real” (OP16)</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>“I think it matters less how it looks” (R3)</p> <p>“I think it could not be so realistic, because (inaudible) expectations” (R9)</p> <p>“As long as they’re animals, I don’t see an issue with it being realistic or non-realistic” (R11)</p> <p>“I’m not sure it does, if anything the cat is too real without looking quite right” (R13)</p> <p>“I feel like it has to look cute but that doesn’t necessarily mean it has to look realistic” (R15)</p> <p>“No it can be whatever, 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>“for older people stick to cats and dogs, like, might not know what a squirrel is perhaps” (OP10)</p>	<p>“for the elderly it should be something familiar” (R2)</p> <p>“interactivity is more important, you are not interacting with these animals by looking [...]” “I don’t think it has to be recognisable, it’s more important how it</p>

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

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

feels, the movements, sounds, purring, but you could put it in a Pokemon” (R3)

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

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

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

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

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

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

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

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

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

“Maybe in five years time..” (OP16)

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

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

Life simulation	<p>“Warmth under belly to keep your knees warms!” (OP1)</p> <p>“Yes I like the Purring” (OP2)</p> <p>“Make you feel comforted” (OP13).</p> <p>“If it was breathing, it would be almost a real cat, and again, it’s a soothing thing” (OP14)</p>	<p>“It would [...] make them [older people] want to pet it more” (R2)</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>
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Appendix D: Full table of themes and example evidence for free interactions in Study 4

Theme	Codes	Example Evidence
Familiar	Plastic and Unfamiliar as Infantilising	<p>“[Laughs at JfA dog barking] this is crazy!” (P1_Home_4)</p> <p>“Have you shown these ones to children? [Miro]” (P1_Home_5)</p> <p>“I’m talking to him, we must be crazy! [Miro]” (P7_Home_5)</p> <p>“You’re making fools out of us, do you know that? [Paro]” (P4_Home_5)</p> <p>“[Looks at seal] [laughs] you’re joking” (P5_Home_5)</p> <p>“They’d be lovely for children, because children have got vivid imaginations” (P2_Home_5)</p> <p>“More appropriate for young children, they’d love this [Paro]” (P2_Home_5)</p> <p>“The seal is lovely and ideal for a young child” (P2_Home_5)</p> <p>“[Laughs] that’s very amusing isn’t it [Miro]” (P3_Home_5)</p> <p>“I should think that’s something from outer space [Miro]” (P2_Home_5)</p> <p>“Is he off the moon [Miro]” (P2_Home_5)</p> <p>“Ohhh I know, I know you’re beautiful.. you’re making me look stupid do you know that! [JfA dog]” (P4_Home_5)</p> <p>“Steady monster [Miro]” (P2_Home_5)</p> <p>“Very soft, quite pretty too [Furby], good for somebodies children” (P2_Home_4)</p> <p>“This one would be popular with young children [Miro]” (P2_Home_4)</p> <p>“Younger child would like to play with these [Miro]” (P2_Home_4)</p> <p>“[Laughs] you’re like kids all of you!” (P1_Home_4)</p> <p>“People will think I’m stupid if they see me now [JfA dog and Paro]” (P1_Home_2)</p>

	<p>“They’re amusing, they’re not a silly thing” (P3_Home_5)</p> <p>“Well, that’s alright for children [Pleo]” (P5_Home_1)</p> <p>“My great granddaughter would love that [Pleo]” (P11_Home_1)</p> <p>“A tiny little boy might like [Miro]” (P11_Home_1)</p> <p>“I should give a child something like this [Furby]” (P6_Home_1)</p> <p>“That’s lovely for children, I should imagine [JfA dog]” (P5_Home_1)</p> <p>“You’re beautiful aren’t you, not saying very much [...] we’re all mad, what are all these people here, eh? (Paro)” (P5_Home_3)</p> <p>“[Stroking Paro] We’re nuts! We’re nuts!” (P5_Home_3)</p>
Prefer Familiar	<p>“I’m not keen on any except the little one [Perfect petz]” (P4_Home_5)</p> <p>“Well, nobody could love you like your mother could they [to Pleo], no no no, I’m sorry” (P1_Home_5)</p> <p>“It’s not the sort of creature you’d find in a home [Paro] but it’s still my favourite because it’s so soft” (P3_Home_5)</p> <p>“This one could be real [Perfect petz], something that looks like an animal” (P5_Home_5)</p> <p>“The cats very good” (P2_Home_5)</p> <p>“I prefer the more natural things, the best one is that cat” (P1_Home_4)</p> <p>“She’s looking so worried! [about Pleo]” (P2_Home_4)</p> <p>“Oh well you live in the water and I hate the sea [Paro]” (P4_Home_5)</p> <p>“I don’t know that I particularly like that. I don’t like that [...] I don’t like it because it’s blue [Furby], but I do like the others” (P5_Home_3)</p> <p>“[Dislike] because it’s not natural [Paro]” (P7_Home_3)</p> <p>“Most unusual isn’t it [Hedhehog]” (P5_Home_3)</p> <p>“The dog is lovely, I like dogs, we had all sorts of dogs” (P3_Home_3)</p> <p>“[holding dogs] we used to have dogs, I have a picture of my mum and dad with our dog” (P1_Home_4)</p> <p>“It’s lovely [dog] but I like the cat, I’ve had a dog all my life, I’ve only ever had one cat” (P4_Home_5)</p> <p>“I’ll have you for tea tomorrow night [Paro]” (P1_Home_1)</p> <p>“I suppose really you’re quite a beautiful animal, to think they skin you to make a coat [Paro]” (P4_Home_5)</p> <p>“What is that, a baby seal? [...] You know, baby seal, they are skinned alive when they are born” (P5_Home_1)</p>
Unfamiliar are Unrecognisable	<p>“What’s it supposed to be? Bat? [Furby]” (P1_Home_5)</p> <p>“Oh look, is that, I think it’s a seal? Making eyes at me [Paro]” (P1_Home_3)</p> <p>“The only think, you look at that, see that [hedhehog] and you wonder what on earth, you know, bit strange” (P4_Home_3)</p> <p>“[hedhehog] it could be a duck” (P1_Home_3)</p> <p>“[shown Pleo] oh that’s a lamb, that’s a baaa lamb” (P1_Home_3)</p>

		<p>"I've never seen anything like this before [Pleo and Miro]." (P6_Home_1)</p> <p>"Is that a seal? [Paro]" (P6_Home_3)</p>
	Robot Rejection	<p>"I don't want it [Furby]" (P4_Home_3)</p> <p>"[offered hedgehog] no" (P4_Home_3)</p> <p>"[Shown pleo] [bats it away] not for me" (P4_Home_3)</p> <p>"[Offered dinosaur] not particularly" (P2_Home_1)</p> <p>"Don't sit him by me, he might eat me [Pleo]" (P5_Home_1)</p> <p>"What is it? [Furby] [...] very clever but I wouldn't want it" (P11_Home_1)</p> <p>"Don't like the other ones. No good at all. They're not good at all [Has dog]" (P5_Home_1)</p> <p>"I wouldn't want him [dinosaur], I like the other one [cat]" (P6_Home_1)</p> <p>"the white one I wouldn't go for. I don't know. She's a bit, no, there's nothing to encourage me to touch it. No I couldn't do it. No I would go away from it [Paro]" (P5_Home_3)</p> <p>"[shown Pleo] I wouldn't like to" (P5_Home_3)</p> <p>"It's like a toy, I don't know that I'd want it as a toy [Miro]" (P5_Home_3)</p>
Robot Actions	Important Expressions and Behaviours	<p>"I like him actually, I think because of his activity and his response it's like he's talking to you" (P5_Home_5)</p> <p>"They're almost alive aren't they" (P1_Home_5)</p> <p>"I think they're ideal for blind people, ideal" (P2_Home_5)</p> <p>"[Cat meows] ideal for somebody who is blind" (P2_Home_5)</p> <p>"The cats very good isn't it, active, this isn't so active [JfA dog]" (P3_Home_5)</p> <p>"Look at him, he's moving his face [JfA dog]" (P3_Home_3)</p> <p>"[cat rolls] yeah, oh yeah, oh! Meow, meow, meow, be good, be careful, you're alright" (P1_Home_3)</p> <p>"[cat rolls] oh my goodness!" (P4_Home_3)</p> <p>"You're talking to me aren't you [JfA dog]" (P1_Home_3)</p> <p>"He's talking to me [Furby] don't swear" (P1_Home_3)</p> <p>"Oh a lot of fun you are, funny boy [Furby]" (P2_Home_5)</p> <p>"Nice animated eyes, that's really special [Furby]" (P3_Home_5)</p> <p>"Hetty (hedgehog) is just an ornament really. I like the movement ones. And the cat in particular was absolutely gorgeous" (P2_Home_1)</p> <p>"Hear her purring!" (P5_Home_1)</p> <p>"When you talk, it will answer. When you talk it will answer, because it can hear the vibrations from your voice. That's why she answers." (P5_Home_1)</p> <p>"Oh look at the eyes closing" [Paro]" (P1_Home_4)</p> <p>"The eye blinking is lovely [Cat]" (P2_Home_4)</p> <p>"One of them, he's sleeping all the time [perfect pets] [...] does it work?" (P5_Home_3)</p> <p>"He's the liveliest, fantastic [Pleo]" (P7_Home_3)</p> <p>"He's more active than the other one [Pleo]" (P7_Home_3)</p>

		<p>"I should think he's dead, the way he's lying. Poor old sod. Never mind my love [Perfect pets]" (P5_Home_1)</p> <p>"I don't think they do wake up [Perfect petz]" (P2_Home_1)</p> <p>"Is he alive or sleep [Perfect petz]" (P5_Home_1)</p> <p>"He doesn't wake up more than that does he? [Perfect petzzz]" (P6_Home_3)</p> <p>"It's a bit annoying, you want to know what he's saying [Furby]" (P2_Home_1)</p>
	Less Vocalisations	<p>"You've got an awful lot to say for yourself young man [Miro]" (P2_Home_5)</p> <p>"You make a lot of noise [JfA dog]" (P4_Home_5)</p> <p>"I think the barking would irritate the other residents" (P2_Home_4)</p> <p>"Barking aren't you, you don't have to bark" (P1_Home_3)</p> <p>"No barking" (P2_Home_4)</p> <p>"He's a good animal but he's not supposed to bark" (P2_Home_4)</p> <p>"Can't you shut up?" (P2_Home_1)</p> <p>"I quite like him actually [picks up Miro] Oh! Heavy! Quite noisy" (P2_Home_1)</p>
Embodiment	Desirable Aesthetics	<p>"What are you called? You got a beautiful face you do [JfA cat]" (P6_Home_5)</p> <p>"I like the eyes [Furby]" (P6_Home_5)</p> <p>"Lovely work! Very clever! [Hedgehog]" (P1_Home_4)</p> <p>"It's a nice thing, to hold [Hedgehog]" (P2_Home_4)</p> <p>"His eyelashes too! [Paro]" (P2_Home_4)</p> <p>"Those great big eyes, yes those great big eyes [Paro]" (P2_Home_2)</p> <p>"I think the cat looks real. That looks real" (P11_Home_1)</p> <p>"I love this hedgehog" (P11_Home_1)</p> <p>"Cats beautiful" (P2_Home_1)</p> <p>"Whose this one? [Furby] I like his coat, the colour, I like it" (P1_Home_3)</p> <p>"Beautiful eyes, great big eyes [cat]" (P5_Home_3)</p> <p>"Something about their eyes. Beautiful [JfA cat]" (P6_Home_3)</p>
	Not too big or heavy - lap size	<p>"It is a bit big [Paro], but that one certainly appeals to me" (P4_Home_5)</p> <p>"This one's too big, takes up too much room [Paro]" (P4_Home_5)</p> <p>"Big isn't he? [JfA dog]" (P3_Home_3)</p> <p>"Quite heavy [Paro] I've never seen anything like it, I think they're very good, they're so realistic" (P1_Home_4)</p> <p>"He's quite heavy isn't he [Paro]. No not for me [hands seal back]. I don't like the weight of him" (P2_Home_1)</p> <p>"Very heavy, a bit of an armful [Paro]" (P2_Home_1)</p> <p>"I quite like him actually [picks up Miro] Oh! Heavy! Quite noisy" (P2_Home_1)</p> <p>"His body is heavy [...] he doesn't feel real [Paro]" (P5_Home_1)</p> <p>"Quite heavy [Seal]" (P7_Home_1)</p>

		<p>“He’s too big [Miro]” (P6_Home_3) “Yeah he is really isn’t he” (P7_Home_3)</p>
	Soft feel	<p>“Oh how odd, it’s rubber! I don’t like it rubber” (P6_Home_5)</p> <p>“I like the fact they’re soft, it’s really nice [Paro]” (P3_Home_5)</p> <p>“Feels like rubber skin of a kind, and tough as cement inside I should think” (P2_Home_4)</p> <p>“Oh the feel! [Paro]” (P1_Home_3)</p> <p>“You can’t cuddle it [Miro]” (P11_Home_1)</p> <p>“No, I like the fur [Miro]” (P1_Home_4)</p> <p>“No I don’t like that feeling [Pleo]” (P1_Home_4)</p> <p>“You’re all rough aren’t you? [Pleo]” (P1_Home_2)</p> <p>“I aren’t so much for him, he looks as if he’s dead [JfA cat]” (P6_Home_3) “He’s really solid [JfA cat]” (P7_Home_3)</p>
	Anthropomorphism	<p>“it won’t bite will it?” (P1_Home_3)</p> <p>“Do you like your belly scratched eh? You’re a cheeky thing” (P6_Home_5)</p> <p>“Oh it’s lovely, he likes that [strokes cat under chin]” (P2_Home_5)</p> <p>“he’s obviously gone to sleep [breathing dog]” (P1_Home_3)</p> <p>“[Strokes dinosaur] don’t bite, no don’t bite, good boy, good boy, good, yeah nice, he’s winking his eye” (P1_Home_3).</p> <p>“He don’t, he doesn’t bite? [Miro]” (P1_Home_3).</p> <p>“That is like having a breakfast [Pleo]” (P1_Home_3).</p> <p>“Maybe sick [when Miro not active]” (P1_Home_3).</p> <p>“Oh pussy cat, it’s a she isn’t it?” (P1_Home_3)</p> <p>“Go to sleep if you want [JfA dog]” (P1_Home_3)</p> <p>“Go meow and go to sleep [JfA cat]” (P1_Home_3)</p> <p>“Does it like having a wash?” (P1_Home_3)</p> <p>“[to JfA dog] don’t chase the cat! If you do they’ll scratch you, then you’ll bleed, we can’t have that can we? No, good boy” (P1_Home_3)</p> <p>“He’s been eating too much I expect [JfA cat]” (P1_Home_3)</p> <p>“I won’t hurt you my darling [JfA dog]” (P1_Home_3)</p> <p>“They like their necks tickled don’t they [Pleo]” (P6_Home_3)</p> <p>“You watch he don’t do something when he lifts his tail” (P5_Home_1)</p> <p>“He’s blinking his eyes, are you comfortable” (P2_Home_4)</p> <p>“Oh yes that’s very much like a seals cry” (P2_Home_4)</p> <p>“He likes it underneath the chin [Paro]” (P2_Home_4)</p> <p>“You want your belly stroked don’t you” (P1_Home_4)</p> <p>“They respond the way they should, I’m stroking him away [JfA cat]” (P1_Home_4)</p> <p>“Hello, you’re back again, want your tummy rubbed [JfA cat]” (P2_Home_5)</p>

		<p>“He can hear what you’re saying, did you hear that, that’s not fair is it what [resident] said, poor sausage” (P5_Home_5)</p>
Acceptability	Likability	<p>“they’re lovely aren’t they” “he is beautiful [breathing dog]” (P3_Home_3)</p> <p>“Lovely it is, you’re beautiful aren’t you? Yes you are [breathing dog]” (P1_Home_3)</p> <p>“Handsome isn’t it, oh look at that” All that hair [...] isn’t that lovely?” (P3_Home_3)</p> <p>“Oh look at him. Isn’t that lovely [Miro]” (P3_Home_3)</p> <p>“Look at that, it’s beautiful, it’s such a big beautiful. I think that’s lovely” (P3_Home_3)</p> <p>“Handsome isn’t he [Paro]” (P3_Home_3)</p> <p>“[Cat purring] isn’t he beautiful, I could keep it like that, if it’s trouble you can take them home again” (P3_Home_3)</p> <p>“They’re beautiful. Yes, they are.” (P6_Home_1)</p> <p>“A lot of work gone into these” (P11_Home_1)</p> <p>“You are beautiful [cat], and you [dog]” (P1_Home_2)</p> <p>“Isn’t that wonderful [Paro]” (P1_Home_4)</p> <p>“Very nice, very well made” (P1_Home_5)</p> <p>“Lovely, isn’t it? [JfA Cat]” (P2_Home_5)</p> <p>“You are quite beautiful” (P4_Home_5)</p> <p>“Very cute” (P5_Home_5)</p> <p>“Lovely girl aren’t you, you’re obviously a lady [JfA cat]” (P5_Home_5)</p> <p>“Lovely” (P6_Home_5)</p> <p>“They’re uncanny really aren’t they” (P7_Home_5)</p> <p>“They’re lovely” (P7_Home_5)</p> <p>“Oh they’re lovey, gorgeous you are, oh I could sit here all day” (P7_Home_5)</p> <p>“you purr, you purr, lovely” (P7_Home_5)</p> <p>“I love it, I love the wool [kisses hedgehog five times and cuddles]” (P8_Home_5)</p>
	Ownership	<p>“He’s mine [breathing dog]” (P1_Home_3)</p> <p>“Blue eyes, [Furby], lets call him Frank Sinatra” (P6_Home_5)</p> <p>“You’re my puppy aren’t you [JfA dog]” (P1_Home_3)</p> <p>“This is my pussy cat [...] I’m going to have it today [JfA cat]” (P1_Home_3)</p> <p>“[JfA dog] Lassie, that’s a good name, you’re lovely aren’t you, you wouldn’t hurt me would you, you’re a good boy” (P1_Home_3)</p> <p>“I’m going to miss him, miss him won’t I, they said, you’ll be alright, I want one, oh my darling, very lovely” (P2_Home_3)</p> <p>“[strokes cat] I could do this all day” (P5_Home_3)</p> <p>“How much for one? [Dog]” (P6_Home_3), “About 80” (Researcher), “Oh my gosh! Bit pricey” (P6_Home_3)</p> <p>“Don’t you take mine [dog]” (P5_Home_1)</p> <p>“Sold, I would like that [hedgehog]” (P11_Home_1)</p> <p>“I’d like to take him home [JfA dog]” (P1_Home_2)</p> <p>“What are you called, Snowy? [Paro]” (P1_Home_2)</p> <p>“What are you called, Chatterbox? [JfA dog]” (P1_Home_2)</p>

		<p>“This is mine [holds up cat]” (P1_Home_4) “I’ll call him fluffball” (P2_Home_5) “Are you Ginger, or do we call you Ginge?” (P5_Home_5) “Is your name Dillon, is it? Or do they call you Cowboy [Jfa dog]” (P5_Home_5) “I’d like you in my bed! [Paro]” (P8_Home_5)</p>
	Interest in Technology	<p>“Are they electric?” (P2_Home_3) “What is the energy source?” (P2_Home_4) “How does it work?” (P2_Home_2) “They are robots” (P4_Home_3) “Oh I see, the more you stroke them it starts off their repertoire” (P2_Home_4) “They’re so well made” (P2_Home_4) “Who made these then?” (P1_Home_5) “I’d like to see what’s on the inside of them” (P5_Home_5) “Tremendously well done [Miro]” (P1_Home_5) “Look at this one, electric, this one’s electric [Paro]” (P4_Home_3) “They aren’t real are they, robots!” (P6_Home_3)</p>
Focal Point	Conversation	<p>P6_Home_1: You wouldn’t bite me would you? P5_Home_1: He wouldn't. P6_Home_1: You would! (to dog) You would bite me? P5_Home_1: He said, “Try me and see.” [Laughs] P6_Home_1: You would bite me would you? Hey?</p> <p>P5_Home_1: Do you know what it is? P6_Home_1: I don't actually. Do you? P5_Home_1: A seal. P6_Home_1: I thought they lived in the water.</p> <p>P2_Home_4: Oh you’ve got the seal, I used to see the off the Scottish coast P1_Home_4: Yes, I can feel him rubbing into my side, oh yeah I’ve seen lots of these</p> <p>P1_Home_5: Mind my cat! P2_Home_5: It’s a dog darling [laughs] P1_Home_5: [laughs] I do need to see the optician don’t !!</p> <p>P6_Home_5: How much is that doggy in the window P7_Home_5: The one with the waggily tail P6_Home_5: How much is that doggy in the window P8_Home_5: I do hope that doggies for sale</p> <p>P6_Home_5: He’s laughing at you [Furby] P8_Home_5: He’s laughing because I’m tickling his belly P6_Home_5: Oh I thought he was laughing at your face! [laughs] P8_Home_5: [Laughs] he might be!</p>

Appendix E: Full table of themes and example evidence for focus groups in Study 4

Favourite?	P2: Cat (Home_2)
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P1: Breathing dog (Home_2)
 P2: Cat (HOME_1)
 P1: Dog, or cat (HOME_1)
 P3 (HOME_1): Hedgehog, cat, dog
 P4 (HOME_1): cat
 P5 (HOME_1): dog
 P6 (HOME_1): "the cat is yeah"
 P7 (HOME_1): dog "this one here"
 P8 (HOME_1): "I think that little dog (joy)"
 P1 (Home_3): "I think I'll have a pussy cat, we got our precious moments"
 P4 (Home_3): "Yeah the dog"
 P2 (Home_3): I don't honestly know, I don't mind that [cat], beautiful, my darling, treasure pet"
 P7 (Home_3): "I'd rather have that one" (Cat)
 P6 (Home_3): "The cat"
 P5 (Home_3): "I think the big white one"
 S2 (HOME_1): "The cat, definitely the cat"
 S1 (HOME_1): "The sit up dog"
 F1 (HOME_1): "The kitten"
 F3 (HOME_1): "The cat yeah"
 F2 (HOME_1): "The one that turned over and meowed and purred"
 S1 (Home_2): The cat the dog and sleeping dog
 S2 (Home_2): "The seal, the dinosaur and the dog"
 S3 (Home_2): "Yeah same [seal, dinosaur, dog]"
 F1 (Home_2): "I preferred the seal, I like seals, very soft and strokable"
 F2 (Home_2): "I actually liked the Furby because I thought it was quite amusing"
 S1 (Home_3): "the cat, I think, most popular, we're never gonna get a seal in here"
 S2 (Home_3): "The cat"
 S3 (Home_4): "I think the cat is pretty amazing
 F1 (Home_4): "That's the best [dog]"
 S4 (Home_4): "The dinosaur"
 S5 (Home_4): "I think the cat"
 S6 (Home_4): "I would say dinosaur"
 S7 (Home_4): "The seal, it's amazing, I want one"
 S8 (Home_4): "I can see the appeal of the Furby, the seals lovely"
 F2 (Home_4): "The cat, actually I'm going to put the cat in my bag"
 S9 (Home_4): "I like the dog in the basket over there, I like that [Perfect petz]"
 P1 (Home_4): "The best is the cat"
 S10 (Home_4): "The cat is amazing"
 F1 (Home_4): "The puppy"
 P2 (Home_4): "The dinosaur"
 S11 (Home_4): "The cat, or dog"
 S12 (Home_4): "The cat"
 S13 (Home_4): "I like the cat and the dog"
 F3 (Home_4): "Oh I like this one [Paro] but she likes the cat the most"
 F4 (Home_4): "The seal is the best one"
 P5 (Home_5): "My favourite would be the cat"
 P1 (Home_5): "I think the seal"
 P6 (Home_5): "Furby"
 P7 (Home_5): "I don't really like them"
 S4 (Home_5): "The big dog, with the neck tie"

	<p>S3 (Home_5): "Yeah I prefer the dog as well"</p> <p>S6 (Home_5): "I like the cat"</p> <p>P1 (Home_5): "I can't say that I have a particular favourite because they're so good all of them"</p> <p>P3 (Home_5): "Him [Furby]"</p> <p>P2 (Home_5): "For children"</p> <p>P4 (Home_5): "The dog in the basket [Perfect petz], but now I've got him against the cat, the cat takes over"</p> <p>P5 (Home_5): "Probably the cat"</p> <p>P7 (Home_5): "I haven't got a favourite, I like them all"</p> <p>P8 (Home_5): "I like them all"</p> <p>P6 (Home_5): "I like them all, I haven't got a favourite"</p> <p>S7 (Home_5): Seal</p> <p>S8 (Home_5): Seal</p> <p>S9 (Home_5): Cat</p> <p>S10 (Home_5): "cat and [Perfect Petz] dog"</p> <p>F1 (Home_5): "Cat"</p>
Why	<p>P2 (Home_2): Realistic</p> <p>P1 (Home_2): "So real"</p> <p>P2 (HOME_1): "it was so much a cat" "so real" "seems so real" "Very realistic" "And the cats size as well, not like that seal"</p> <p>P3 (HOME_1): "It's so real and so clever (hedge)" "very realistic" (cat) "it's strong and it's movements, it's so real (dog)" "you've got all the mannerisms in the dog, it is a dog"</p> <p>P5 (HOME_1): (dog) "the one I talk to, ain't it mate, that's right I agree with you (to dog)"</p> <p>P5 (HOME_1): "because he talks to me and he tells me, he bloody talks to me, believe me, aint you, you're watching and you're listening, yes"</p> <p>P4 (HOME_1): "You'd think he was a real cat, looking like that there, you'd think he was a real cat"</p> <p>P6 (HOME_1): "well he's so real looking"</p> <p>P8 (HOME_1): "I just liked the way he moved"</p> <p>P1 (Home_3): "Not too yappy"</p> <p>P4 (Home_3): "Beautiful"</p> <p>P2 (Home_3): "They're beautiful"</p> <p>P5 (Home_3): "I think they're all lovely [...] beautiful"</p> <p>P7 (Home_3): "You can't do anything else but love the cat"</p> <p>P5 (Home_3): "Natural, but that one is a waste of time [Furby]"</p> <p>S2 (HOME_1): "Everybody [...] will stroke a cat or a dog, who strokes a seal? Nobody does do they"</p> <p>S1 (HOME_1): "they, they were more interactive and made the noises like they should make and they were like looking at the residents."</p> <p>S2 (HOME_1): "They were nice and easy"</p> <p>S2 (HOME_1): "They could sit on your lap comfortably"</p> <p>F1 (HOME_1): "Absolutely brilliant. Yeah very tactile"</p> <p>F2 (HOME_1): "They engaged the people that they are intended for as well, which I think is an important thing"</p> <p>F2 (HOME_1): "She liked the one that turned over and meowed and purred I think"</p> <p>S1 (Home_2): "I think they're more realistic, they are more something that they would be used to. They're not likely to have come across seals"</p> <p>S2 (Home_2): "I think those three would be more interactive for the residents that we've got"</p>

	<p>F1 (Home_2): "Very soft"</p> <p>F2 (Home_2): "Amusing"</p> <p>S1 (Home_3): "Looks more realistic, the cat looks most realistic and I think that's what they respond to and the cat is more responsive [...] it does more, they get more response from it"</p> <p>S2 (Home_3): "She was like oh my beauty, she's a cat lady"</p> <p>S3 (Home_4): "Cat because it can sit on a lap and do thing"</p> <p>S2 (Home_4): "For people without sight, or, that's a really quite comforting feeling, that's quite reassuring and really makes you feel calm I think"</p> <p>S4 (Home_4): "I like it when he clings to you when you hold him up [Pleo]"</p> <p>S5 (Home_4): "I think cats are comforting, and feeling the purring, for someone who couldn't visualise or see it, you've got that kind of tactile"</p> <p>S6 (Home_4): "[Pleo] I like the way he reacts to everything, he seems to do a lot, and he grips you when you pick him up"</p> <p>S7 (Home_4): "It's just gorgeous, lovely"</p> <p>S8 (Home_4): "The weight on the seal if quite comforting, if someone's agitated"</p> <p>F2 (Home_4): "[Husband] always liked cats"</p> <p>F1 (Home_4): "Well, he does everything he should do, he wags his tail, moves his head, he's the right size, dog like that's it yeah"</p> <p>F2 (Home_4): "I think you had a dog yeah, do you see what I'm getting at, the association"</p> <p>P1 (Home_4): "What I liked about the cat, I mean, a lot of things, his face was very good, eyes are, and the wrinkles in his ears, and the furs just fine"</p> <p>S11 (Home_4): "Seems the best effect"</p> <p>S12 (Home_4): "This is the lovely but the cost is too much, and they're tactile as well, they make noises and"</p> <p>S13 (Home_4): "Because that's what the residents have had at home (cat or dog) and that's what they're used to, especially those that come in and can't bring their dog with them"</p> <p>F3 (Home_4): "Very realistic, the feel and what it does"</p> <p>F4 (Home_4): "Just so realistic with what it does, and the eyes and the fur"</p> <p>P2 (Home_5): "[Paro] because it's so cuddly"</p> <p>P6 (Home_5): "[Furby] it just looks nice"</p> <p>P2 (Home_5): "The eyes are so animated [Furby]"</p> <p>P5 (Home_5): "Because I just love cats"</p> <p>P4 (Home_5): "At the risk of being thought stupid, because it looks like a cat!"</p> <p>P7 (Home_5): "They're just acting like they're real, yeah the movement I think"</p> <p>P6 (Home_5): "I like the feel of them"</p> <p>S7 (Home_5): "I just like cats, and how it is realistic like"</p> <p>S9 (Home_5): "How it [Paro] feels"</p> <p>S10 (Home_5): "They're the right shape, the right size, the right texture, they've had cats and dogs, but that dog is too raring to go [JfA] might be a bit intimidating"</p> <p>F1 (Home_5): "We are both cat people, it would be comforting and calming and the texture is important, when you're losing a lot of senses, the ones you have, if they can be stimulated it's really important"</p>
New robot design?	<p>P1 (Home_2): "Already got my favourite!"</p> <p>P2 (Home_2): "A cat maybe"</p> <p>P2 (HOME_1): "a little bit of thought to the cat to start with – I've never seen a cat that colour"</p> <p>P2 (HOME_1) realistic? "Yes, oh absolutely"</p>

P1: "I like the way they done this one at the front and made him very realistic"
 "I like the green eyes"

P3 (HOME_1): "the cats fur is a bit too long"

P3 (HOME_1): "the dog should sit up and beg"

P4 (HOME_1): "have it walk" "go round your legs"

P1 (Home_3): "No sounds, wakes somebody up"

S1 (HOME_1): "Quite robust as well"

S1 (HOME_1): "They will probably need to be washable to a point"

S2 (HOME_1): "Covers come off"

F3 (HOME_1): "When they have their snooze and they drop off, it drops off and doesn't disturb them"

F3 (HOME_1): "The fabric, what, can you take it off and wash it? Because you know, they're coming away after dinner, they forget because they're old and, it gets greasy and mucky"

F2 (HOME_1): "The odd bit of apple crumble you know. I could see it getting quite dirty after a while"

S1 (Home_2): "I think breathing is good, the noise, whatever animal it is, it makes and then a little bit of movement, I like the cat moving his paw and things like that"

S2 (Home_2): "Maybe softer, softer feeling I think. In the body. So robotic. If you added something a bit softer it will feel more, like that they're touching real animals really."

F1 (Home_2): "I think the cat or the dog, I found it wasn't as soft as the seal, so maybe it didn't feel, it felt a bit more kind of"

F1 (Home_2): "I guess wanting to play like a dog, engage in some kind of play [...] and wanted it's tummy rubbed and things like that [...] being able to feed it something"

S1 (Home_3): "I think interactive is good, because I think they get more out of it, and I think it has to be reasonable weight, I think weight is important, [...] some older people are quite frail, so they could sit with the cat, who's still quite heavy but more accessible than if you put Paro on them because it might be too heavy and then they're not going to interact with it as much"

S1 (Home_3): "The right shape to go on their lap, the cat, is perfect to go on a lap, you can just have it there but the dog it too upright, too rigid"

S6 (Home_4): "It needs to be washable"

S5 (Home_4): "Hm yes it needs to be washable and not white"

S8 (Home_4): "The weight of an animal"

F1 (Home_4): "It could be a bit lighter, that's only my opinion"

P2 (Home_4): "I think repetitive friendship, not too many activities"

F4 (Home_4): "Quite realistic looking, not too much, way they move, could do rabbits"

S4 (Home_5): "I just think they need to be more realistic pets, with the fur, and animal noises"

P2 (Home_5): "You want a Labrador that opens the fridge and gets you a beer"

P5 (Home_5): "What about a fish. I'd still go for something like the cat"

P4 (Home_5): "Well it was lovely to see the cat moving. It's gotta meow hasn't it"

S9 (Home_5): "Realistic"

S10 (Home_5): "Look like something they had in the past or it will be alien to them, stick to cat or dog, they're not into hamsters or chinchillas, something for their lap, help calm them down and relax them"

	<p>F1 (Home_5): "Soft is appealing, the response, it's nice when the cat will meow, turns its head towards you, loved it turning over for tummy to be tickled"</p> <p>F1 (Home_5): "Something warm, purring on her lap"</p>
What would you like it to do?	<p>P1 and P2 (Home_2) "no" to being non-interactive</p> <p>P2 (HOME_1): interactive? "Yes that's the idea of a robot"</p> <p>P2 (HOME_1): "he turned over just now" "well that was good"</p> <p>P3 (HOME_1): "all that is very clever, they all do that kind of thing, cats don't do much"</p> <p>P5 (HOME_1): he talks at me and he looks at me</p> <p>P11 (HOME_1): I think the one that's breathing [...] you want it to play, a bit more action"</p> <p>P4 (Home_3): "Teach them not to bite anybody because they'll get into trouble"</p> <p>S1 (HOME_1): "[Paro] probably too complex really for their needs"</p> <p>S1 (HOME_1): "It would be nice if it could say [...] roll over or beg"</p> <p>F3 (HOME_1): "It should have sound [...] you want to touch it, you want to hear it and you want to see it move"</p> <p>F2 (HOME_1): "I think movement is actually a good thing [because if you then tell it to stop moving or sit or something it gives them vocabulary that they might have forgotten"</p> <p>F3 (HOME_1): "But to have something that is there and the cat is going to turn over and still keep breathing"</p> <p>F1 (HOME_1): "And to be able to feel the purring"</p> <p>S3 (Home_2): "They like the noises in the background. Because they like interacting"</p> <p>S2 (Home_2): "It got to be interactive [...] so residents have something to have their minds think about as well"</p> <p>S2 (Home_2): "The lights on the dog, I liked. I think that was pretty cool"</p> <p>F1 (Home_2): "Kind of like temperature, like warmth"</p> <p>S1 (Home_3): "I think they're looking for responsiveness to hold their attention span, [...] oh it's looking at me or oh it's vibrating or purring"</p> <p>S1 (Home_3): "For me, it's that looking for them, I'm not sure how many times they'd notice the tail wagging because they're probably looking at its face [...] the heads moving, eyes opening and closing"</p> <p>S6 (Home_4): "It has to be interactive, that [hedgehog] is fun but in time you'd lose interest"</p> <p>F2 (Home_4): "I don't think it needs to be any bigger than this really [JfA dog], lap size, because most people spend their time sitting down"</p> <p>S13 (Home_4): "Movement, looking at me"</p> <p>S12 (Home_4): "interactive to the person"</p> <p>S10 (Home_5): "Adaptable to the person, something like that [Perfect petz] that is so peaceful and relaxing to look at, but it can do other things when needed, if you're gonna make something make it wide ranging, make it as adaptable as possible"</p> <p>S10 (Home_5): "Size and weight, this [Paro] is far too bulky, so big and heavy for the older ladies"</p> <p>F1 (Home_5): "Respond to her"</p>
Feel?	<p>P1 (Home_2): "Soft I think"</p> <p>P2 (Home_2): "Yeah"</p> <p>P2 (HOME_1): "that one" (soft) "I've always had a cat you see"</p> <p>P3 (HOME_1): "rough haired and smooth haired" "it's a question of choice" "I don't like the plastic ones"</p>

P4: "the furry ones I think" "that looks a lot better... you'd look at it and think it was a real one"

P6 (HOME_1): definitely soft ones

P12 (HOME_1): Just like the plastic one

P11 (HOME_1): "I don't like the plastic ones"

P6 (Home_3): "[dinosaur] that's very unusual feel"

P6 (Home_3): "[Pleo] feels quite hard"

P7 (Home_3): "Oh the soft ones"

P5 (Home_3): "I think it's gorgeous." (cat)

P5 (Home_3): "That one I think is very natural"

P5 (Home_3): "This one is lovely because of it's hair"

S2 (HOME_1): "they were pleasant to touch, the furry ones"

S1 (HOME_1): "Soft"

S1 (HOME_1): "The plastic ones aren't quite so. Sort of sit on your lap sort of thing"

S2 (HOME_1): "Soft to the touch and they could stroke it"

S1 (Home_2): "Soft"

S3 (Home_2): "Really fluffy"

S2 (Home_2): "The dinosaur quite good. That's got quite a soft but hard texture. And the seal and the dog and the cat, they are quite soft. Really fluffy, so something like that I think would be more. It would be soft and fluffy"

F2 (Home_2): "I think furry myself"

F2 (Home_2): "I think actually stroking something soft if quite beneficial"

S1 (Home_3): "Soft"

S6 (Home_4): "Fur, I think so"

F1 (Home_4): "I like the fur"

P2 (Home_4): "The dog has got the best fur"

P1 (Home_4): "The fur is fine"

S10 (Home_4): "The fur is more tactile"

F2 (Home_4): "I think it needs to be something furry like this"

S13 (Home_4): "The hair, tactile ones"

F3 (Home_4): "The fur"

F4 (Home_4): "Furry ones probably best"

S4 (Home_5): "Fur, I would think so"

S3 (Home_5): "Yes fur"

P6 (Home_5): "Yeah fur"

S5 (Home_5): "I don't like the things that look like toys, I prefer the furry things"

S1 (Home_5): "The fur is more therapeutic"

P2 (Home_5): "I wouldn't like plastic, it would be too cold"

P4 (Home_5): "Furry"

P5 (Home_5): "I prefer the furry, personally"

S1 (Home_5): "For residents, the fur"

P8 (Home_5): "I like the furry ones"

P6 (Home_5): "No I don't like the rubber ones, the furry ones look more real, you don't get rubber animals, you get furry ones"

P7 (Home_5): "The rubber one interacted anyway so I've got no preference"

S7 (Home_5): "Soft fur"

S8 (Home_5): "Soft furry stuff"

S9 (Home_5): "Soft fur"

S10 (Home_5) "Furry"

F1 (Home_5): "I think [...] it needs to be something that can be stroked, soft, it's nearer to the animal, the texture is comforting"

<p>Expressions? Behaviours?</p>	<p>P1 (Home_2): "Mouth moving" "walking" P2 (HOME_1): "that one" (cat) "It's got an expression and it looks at you" P5 (HOME_1): "Ones that talk to you" "I like the ones that talk to you" P4 (HOME_1): "I was going to say [...] seeing how he turns his head" P5 (Home_3): "They've all got their own thing about them" S1 (HOME_1): "The one sat in the basket was just heart beating and no one was particularly that interested" S1 (HOME_1): "Head movements as well, the way it's like looking at them or looking then looking back at them" F1 (HOME_1): "Give me a paw" F1 (HOME_1): "Probably wagging the tail for the dog, because that's like, the dogs excited to see you type of thing isn't it? I suppose cat purring you would get that, but then cats waggle their tails too don't they?" S1 (Home_2): "Do the cats eyebrows move and eyelids move or anything? Because that would be quite good" S2 (Home_2): "Open his mouth, move his eyes, wag his tail. Maybe some sounds, like when it's sad or happy. Yes, some moods I think. [...] they all have different mood swings sometimes, so it would be nice to have something where, if they are feeling sad we can say, right well here you do [...] lights up to show their moods, so we could set it on, so that is will make them more chilled, or happy, placid mood" F1 (Home_2): "Something that's a bit playful and happy, maybe a bit comical" F2 (Home_2): "Facial, I think because it's the first sort of thing" F1 (Home_2): "Yeah I think facial but I think more body as well, so if yes, with the dog, you can have rolling over or wagging tail" S2 (Home_3): "Breathing, once she realised it was breathing, she was like aw, she wanted to listen" F1 (Home_4): "The mouth, opening, closing" S5 (Home_4): "The looking, the looking, that sort of interaction, and I mean the tail, the rolling over to have its tummy tickled" P2 (Home_4): "Older people are not so interested in the flexibility and that sort of thing, only something you come home to, and have every day and you know where you are in the world" P1 (Home_4): "The eyes, the eyes" P2 (Home_4): "Faces are supposed to be what people look at, see the eyes moving" S10 (Home_4): "It's not just the head movement, it's all of the features, makes it so realistic for" S12 (Home_4): "To look towards you" F3 (Home_4): "Realistic animation, but softer fur, similar to Paro, the cat feels quite course, normally smooth" F3 (Home_4): "React like a normal animal would, like the cat is" F4 (Home_4): "When it opens its eyes, it's like it's talking to you, the Furby is a child thing" S5 (Home_5): "The breathing is relaxing" S4 (Home_5): "I like the animated eyes" P6 (Home_5): "I like the eyes" P2 (Home_5): "I think so, that's very amusing" P3 (Home_5): "Nice to have the animation, I think the animation makes everyone engaged" P2 (Home_5): "The more it does the more interesting it is" P7 (Home_5): "Yes they've got to, and their movement that's what makes them look real"</p>
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	<p>P6 (Home_5): "I like them purring"</p> <p>P8 (Home_5): "I love to hear them purr"</p> <p>S7 (Home_5): "Interactive is better"</p> <p>S8 (Home_5): "Blinking, wagging tail, moving, purring, even when stroking you can feel the cats purring even if they can't hear it"</p> <p>S10 (Home_5): "Rolling over is lovely"</p>
<p>Features to avoid?</p>	<p>P3 (HOME_1): "I think that one which breaths. It looks as though it's breathing, you want it to play" "it could do with being a bit more"</p> <p>P4 (HOME_1): "I like them all"</p> <p>S2 (HOME_1): "Paro tended to be a bit big and heavy"</p> <p>S1 (HOME_1): "Plastic"</p> <p>S2 (HOME_1): "Moving it around the floor"</p> <p>F3 (HOME_1): "The dog [...] nice but it just sits there"</p> <p>F2 (HOME_1): "[Dog] it could do a bit more"</p> <p>F3 (HOME_1): "[Dog] it could do with being a bit more mobile"</p> <p>F2 (HOME_1): "Anything plasticy"</p> <p>F2 (HOME_1): "That is unreal"</p> <p>F3 (HOME_1): "The dinosaur looked like a plastic toy, it wasn't particularly attractive. It felt like gooey rubber"</p> <p>F2 (HOME_1): "You wouldn't want to pick it up and cuddle it, would you? [Pleo]"</p> <p>S2 (Home_2): "I think they would get bored with that one [Perfect petz]"</p> <p>S3 (Home_2): "I think they're going to get bored with that [Hedgehog]"</p> <p>F1 (Home_2): "I don't think lights"</p> <p>F2 (Home_2): "Something that doesn't do anything"</p> <p>F1 (Home_2): "Hard shell or lights"</p> <p>S1 (Home_3): "The Furby has been very unpopular"</p> <p>S1 (Home_3): "Anything running around the floor is a trip hazard, you've got people that are unstable, [...] they can't always see"</p> <p>S1 (Home_3): "The movements can't be too fast, you've got people with sight impairments, cognitive impairments, they can't process it quick enough [Miro]"</p> <p>S1 (Home_3): "Not, not touchy feely, you haven't got that sensory feel like you've got with the animals"</p> <p>S1 (Home_3): "A quiet little purr is fine, but you don't want a dog barking away, but maybe a volume as if someone was hard of hearing or visually impaired they might need that to make it more responsive"</p> <p>S5 (Home_4): "Movements too quick"</p> <p>F1 (Home_4): "Too loud"</p> <p>S6 (Home_4): "I think we don't want any hazards, you know it could trip you up if it moved too quickly"</p> <p>P2 (Home_4): "The barking would irritate the other residents, not talking all the time"</p> <p>S13 (Home_4): "Avoid something like that, hard [Miro] this is nicer for them [soft]"</p> <p>F4 (Home_4): "Spiders, snakes, I think well"</p> <p>S1 (Home_5): "I'm not keen on these because they're like toys [Pleo and Miro]"</p> <p>P1 (Home_5): "I'm not keen on those two [Pleo and Miro] because I'm used to animals"</p> <p>S2 (Home_5): "Plastic"</p> <p>S3 (Home_5): "Plastic"</p> <p>P5 (Home_5): "I think this is like a childlike thing really [Miro] kids would like that"</p> <p>P7 (Home_5): "Plastic no"</p>

	<p>P6 (Home_5): "No rubber ones, don't get a rubber animal anyway"</p> <p>S6 (Home_5): "Plastic"</p> <p>S7 (Home_5): "Take itself for a walk around the building"</p> <p>S8 (Home_5): "Rubber"</p> <p>S8 (Home_5): "Too fast, too erratic, too loud"</p> <p>S10 (Home_5): "Not too heavy, no ants, insects, spiders"</p> <p>F1 (Home_5): "Plastic, it would be alien to what she would expect"</p>
Talking?	<p>P1 (Home_2): "they all talk like you, we wouldn't get a word in edge ways"</p> <p>P1 (Home_2): "Well can't understand an animal language can you?"</p> <p>P1 (Home_2): "We get to know what they want, you know, movements and that"</p> <p>P2 (HOME_1): I don't think I would go with speech, that's a bit fanciful, I think, I just like the... just the animal noises"</p> <p>P3 (Home_3): "I like both (talking or animal noise) anything you do with it, they're lovely"</p> <p>P4 (Home_3): "I don't think it matters" "I like to listen to the English being spoken, there's times when I think, of well, I'd rather listen they talk to me than me just listening there to them [...] but as I say, don't matter to me whether they"</p> <p>P6 (HOME_1): I would think that's wonderful, wouldn't you? I wouldn't want them answering back though" "because I'd get cross in the end I expect"</p> <p>P5: "I'd say you were nuts and I was nuts" "round the bend good and proper"</p> <p>P7 (HOME_1) " wouldn't do any good that"</p> <p>P1 (Home_3): "They can't talk to us, I'd like it if he spoke back"</p> <p>P4 (Home_3): "I think you'd get tired of them"</p> <p>P5 (Home_3): "No, don't know"</p> <p>P7 (Home_3): "I think you're always aware that they are what they are, that's the trouble" "So they're better barking and meowing?" "Yes"</p> <p>S1 (HOME_1): "I think the animal, the noise of the animal. I don't think they want to get into conversations with it. Just a bit of companionship"</p> <p>F1 (HOME_1): "I think it should just make animal noises"</p> <p>F3 (HOME_1): "How much is a dementia patient going to understand? [...] So an animal speaking to them is no different to a human being"</p> <p>F2 (HOME_1): "The only thing with Furby's, you can talk to them and then they will repeat what you said, can't you? So I suppose somebody whose language is going that could encourage them to speak"</p> <p>F1 (HOME_1): "Maybe for speech therapy yeah. You could link that with speech therapy [...] and then that would work for stroke victims as well"</p> <p>S2 (Home_2): "I think that would be ideal. I think so. Because they might be able to express their feelings more than what they can do to a carer or to a doctor. They, you know, they might be able to express more if it's something"</p> <p>S3 (Home_2): "Yes"</p> <p>F1 (Home_2): "I don't know whether it will be good to have that's like a real animal talking, whether they'll think that's just too weird or"</p> <p>S1 (Home_3): "I don't think that's going to be good necessarily, because it's an animal making the noise, so processing that information might be a sensory overload, like processing why is a cat talking to me"</p> <p>S5 (Home_4): "I think probably the animal noises, to make it more realistic"</p> <p>S6 (Home_4): "Yes I agree, I think it could be a bit disturbing having a human voice coming out of an animal"</p> <p>them"</p> <p>P1 (Home_4): "No, the sound of the animal"</p> <p>P2 (Home_4): "No, not worth the effort"</p>

	<p>S12 (Home_4): "No I don't think so no"</p> <p>S13 (Home_4): "No, animal noises"</p> <p>F3 (Home_4): "Stay with animal noises"</p> <p>F4 (Home_4): "For people who do talk, yeah, some people their language is a bit, could be a good idea"</p> <p>S1 (Home_5): "I don't think that's necessary"</p> <p>P2 (Home_5): "Yes if they could interact with you, hold a conversation, that would be very interesting"</p> <p>P3 (Home_5): "Yes would be interesting, as long as it had an off button as well"</p> <p>P5 (Home_5): "Talk, yeah, he could [Furby] but don't talk my word for it"</p> <p>P4 (Home_5): "I'd rather they made animal noises"</p> <p>P7 (Home_5): "Yeah I think it's great, but if they want to bark let them bark, but he's great [Furby]"</p> <p>S8 (Home_5): "Not talking, a lot of them are deaf and don't understand a lot of the time anyway"</p> <p>S10 (Home_5): "Language would be difficult, deadness is a huge problem, but even if hearing isn't that bad it needs to be slow and clear, it gets lost, they wouldn't expect an animal to talk"</p> <p>F1 (Home_5): "I don't know, it is, I'd be quite happy if it conversed with me, but it's possible a furry creature talking back to mother might freak her out, again, her hearing is going"</p>
Personalisation?	<p>P1 (Home_2): "Sounds alright" "I knit, I knit everything" "Yeah why not"</p> <p>P2 (Home_2): "I knit yeah"</p> <p>P2 (HOME_1): "That's okay if people want to do that yes" "you can choose your own colour then."</p> <p>P6 (HOME_1): "How I like, which animal I'd like, that's nice"</p> <p>P11 (HOME_1): "I think they're done well enough aren't they"</p> <p>P11 (HOME_1): "A teddy bear would be good doing that [...] yes a rabbit, I like rabbits"</p> <p>P7 (Home_3): "Well I suppose I would personally"</p> <p>P5 (Home_3): "No I think they're all lovely"</p> <p>S1 (HOME_1): "It would be nice if they could choose. But is that robot going to be personable to them or is it just going to be a robot in a home, everyone's going to have different opinions"</p> <p>S1 (HOME_1): "it would be nice if they could choose their particular features what they would like their cat to look like or dog or"</p> <p>S1 (Home_2): "I suppose they could have it so it looks like a pet that they've had in the past. But then you've also got the thing of, when that persons gone, that animal is not going to be significant for anyone else, so cost wise, it wouldn't be cost effective, unless you could change the outer"</p> <p>S3 (Home_2): "That would be good because we have quite a few here that like knitting."</p> <p>S2 (Home_2): "I think a couple of them can actually knit and crochet, so that would be quite a nice idea. They can knit their own companion, or for the others that don't, obviously they can tell their ideas to someone and hopefully they could make. I think so, it would feel like they're then part of something then."</p> <p>S3 (Home_2): "They will just get more attached."</p> <p>F1 (Home_2): "I think it's a really good idea"</p> <p>F2 (Home_2): "I think it would give them a purpose, because, you go in most of them are sleeping every time [...] you know they need something"</p> <p>F1 (Home_2): "Yes it's cool. They've put something into it and make it, reflect their personality and more wanting to engage and look after it I think"</p>

	<p>S1 (Home_3): "I think that would be good for some, like [resident] who had a ginger cat, but for some people it might be upsetting, [...] but for others it might be more comforting"</p> <p>S2 (Home_3): "It's like [resident] and her dog [teddy], that is her dog, but then with this one she said oh it's electric"</p> <p>S1 (Home_3): "It's almost like you need a robotic framework that goes into every animal, and then the shell you could change"</p> <p>S1 (Home_3): "A rabbit could be another idea"</p> <p>S5 (Home_4): "That would be brilliant, I think, if they've had a cat, or whatever"</p> <p>F1 (Home_4): "Yes, yeah"</p> <p>P2 (Home_4): "If they were able to"</p> <p>S12 (Home_4): "Good yeah"</p> <p>S13 (Home_4): "Yeah I think that's a good idea"</p> <p>F3 (Home_4): "[Resident] would always prefer a black cat, if it was an option it would be good"</p> <p>F4 (Home_4): "Yeah that would be good, Mum and Dad used to have a spaniel, red setter colour, something like that would be good for them, memory not great but might spark something off"</p> <p>S4 (Home_5): "Having an input on the colour and things yeah"</p> <p>S5 (Home_5): "There will be some residents that would like to be involved, more hands on"</p> <p>P2 (Home_5): "Good yes"</p> <p>P3 (Home_5): "Good if you can pull it off"</p> <p>P5 (Home_5): "People could even gift it, yeah I agree with that"</p> <p>P4 (Home_5): "Yes, definitely"</p> <p>S1 (Home_5): "Yeah, I would like a grey coloured cat"</p> <p>P5 (Home_5): "I would like a black cat, although this one is beginning to weasel in"</p> <p>S1 (Home_5): "People could make covers that were washable and removable and be involved in the making of it"</p> <p>P7 (Home_5): "Yeah I suppose it does"</p> <p>S7 (Home_5): "I think that's a good idea, they'll have a connection with it, they'll enjoy it"</p> <p>S6 (Home_5): "They've made it themselves"</p> <p>S8 (Home_5): "If they have dementia and live in a certain time period, they could create an animal from their time"</p> <p>S10 (Home_5): "I think it's absolutely brilliant if people can and would want to do that"</p> <p>F1 (Home_5): "I think that's a lovely idea, colour is important, if they've had an animal in their past that means something more to them"</p>
Prefer realistic or unrealistic?	<p>P1: "Real one"</p> <p>P2: "Don't know, that's a knitted one?"</p> <p>S1 (HOME_1): "I think real"</p> <p>S2 (HOME_1): "Real [...] it sort of stimulated their memories"</p> <p>F1 (HOME_1): "I think it just goes back to a normal, domestic, animal or pet that you would have"</p> <p>F3 (HOME_1): "It does all the things that you would hope you domestic cat would do probably"</p> <p>F1 (HOME_1): "It's easy to identify with the cat, whereas the seal, I think, well, why have you got a seal in a home? You wouldn't necessarily have one"</p> <p>S1 (Home_2): "It's too futuristic [Miro], I think it needs to be more realistic"</p> <p>S1 (Home_2): "A cat and a dog, with this generation"</p>

	<p>F2 (Home_2): "I think the domestic animal, [...] I don't know whether the seal would go down as well"</p> <p>F1 (Home_2): "The dog or the cat yes"</p> <p>F1 (Home_2): "I would have thought they would prefer something that's a bit more realistic, although I thoroughly like the dinosaur"</p> <p>S1 (Home_3): "The dinosaur, because it's not reality, people just see it as a bit of fun as opposed to a companion"</p> <p>S1 (Home_3): "If it's realistic they can relate to it more than Paro"</p> <p>S2 (Home_3): "Yeah he thought the cat was just lovely, he used to have a cat very similar"</p> <p>F1 (Home_4): "Realistic, I think"</p> <p>S5 (Home_4): "Realistic yes"</p> <p>P2 (Home_4): "People have more knowledge of cats and dogs"</p> <p>S11 (Home_4): "I think most people would go for a cat and a dog because they're used to it"</p> <p>P1 (Home_4): "I don't like the unrealistic ones"</p> <p>S12 (Home_4): "Yeah I would have thought so [realistic]"</p> <p>S13 (Home_4): "Yeah definitely [realistic], more realistic than futururistic"</p> <p>F3 (Home_4): "The more realistic the better, a cat or a dog, the dinosaur is good as a novelty, it's more therapeutic if they recognise it"</p> <p>F4 (Home_4): "As realistic as possible really, a Furby would appeal to children more"</p> <p>S1 (Home_5): "These are more like the real thing because they've got fur [JfA]"</p> <p>P2 (Home_5): "I think I like something I recognise, for me"</p> <p>S2 (Home_5): "That's more realistic [cat] that's important"</p> <p>S3 (Home_5): "Yes I think so too"</p> <p>P2 (Home_5): "Unrealistic is interesting, it would hold your gaze because it's different"</p> <p>P3 (Home_5): "It raises expectations if it's realistic doesn't it"</p> <p>S1 (Home_5): "Replicating a real animal that may even bring back memories of their own animals"</p> <p>P4 (Home_5): "Lifelike"</p> <p>P5 (S): "I think the real animal myself"</p> <p>P7 (Home_5): "I don't mind, he's making me laugh [Furby]"</p> <p>P8 (Home_5): "I like them realistic"</p> <p>S6 (Home_5): "These are better for people with learning disabilities [Miro and Pleo]"</p> <p>S6 (Home_5): "Realistic"</p> <p>S7 (Home_5): "Yeah [realistic]"</p> <p>S8 (Home_5): "Yep [realistic]"</p> <p>S10 (Home_5): "Very, very realistic, I think it should be"</p> <p>F1 (Home_5): "It could be something less recognisable, although, perhaps, some of the residents would take against something they perceive as a toy"</p>
Keep one?	<p>P1 (Home_2): "The dog" (breathing)</p> <p>P2 (Home_2): "The cat"</p> <p>P2 (HOME_1): "the cat"</p> <p>P3 (HOME_1): "the hedgehog"</p> <p>P5 (HOME_1): "naturally it would be you (d0g)"</p> <p>P6 (HOME_1) "I like the cat"</p> <p>P7 (HOME_1) "I would say this one" (cat)</p> <p>P11 (HOME_1): "I wouldn't want one"</p> <p>P19 (HOME_1): Cat</p> <p>P1 (Home_3): Cat</p>

	<p>P4 (Home_3): "Cat, I enjoyed it up to a point"</p> <p>P2 (Home_3): "Dog, yes it's a love"</p> <p>P7 (Home_3): "I would go for the cat"</p> <p>P5 (Home_3): "A pretty looking cat"</p> <p>S2 (HOME_1): "I think the dog or the cat"</p> <p>S1 (HOME_1): "Yeah it would be the dog or the cat"</p> <p>S1 (Home_2): "I think the cat and maybe the dog in the basket"</p> <p>S2 (Home_2): "The dog, the dinosaur and the seal"</p> <p>S3 (Home_2) Dog, dinosaur and seal</p> <p>F1 (Home_2): "The dog or cat"</p> <p>F1 (Home_3): "I'd keep the cat and the seal"</p> <p>S5 (Home_4): "Cat"</p> <p>S6 (Home_4): "Dinosaur"</p> <p>S11 (Home_4): "The one that [resident] likes [cat]"</p> <p>P2 (Home_4): "The little hedgehog"</p> <p>P1 (Home_4): "Cat"</p> <p>S12 (Home_4): "Yeah, the cat or the dog"</p> <p>S13 (Home_4): "The cat or dog, out of everything"</p> <p>F3 (Home_4): "For me the seal, for [resident] the cat, to be honest for the reactions, I'd pick the cat"</p> <p>F4 (Home_4): "The seal actually"</p> <p>S6 (Home_5): "Yes I'm taking this one [cat]"</p> <p>S4 (Home_5): "I'd probably have the cat"</p> <p>S5 (Home_5): "Yes I'd have the cat"</p> <p>P6 (Home_5): "Cat"</p> <p>P7 (Home_5): "No"</p> <p>P2 (3): "Furby"</p> <p>P1 (Home_5): "Furby is as good as any"</p> <p>P3 (Home_5): "He's the one [Furby]"</p> <p>P4 (Home_5): "Cat"</p> <p>P5 (Home_5): "It would be the cat, I've got to admit that"</p> <p>S1 (Home_5): "That one [Cat]"</p> <p>P7 (Home_5): "I'd pick the lot, but the dog I think"</p> <p>P8 (Home_5): "I'd keep them all"</p> <p>S7 (Home_5): "Cat or seal"</p> <p>S6 (Home_5): "Cat or seal, dog possibly"</p> <p>S10 (Home_5): "Cat and Perfect Petz dog"</p> <p>F1 (Home_5): "Cat"</p>
Technology experience	<p>P1 (Home_2): None</p> <p>P2 (Home_2): None</p> <p>P2 (HOME_1): iPad</p> <p>P1 (HOME_1): No</p> <p>P3 (HOME_1): No</p> <p>P5 (HOME_1): No</p> <p>P2 (Home_4): "I did use a tablet"</p> <p>P2 (Home_5): No</p> <p>P1 (Home_5): No</p> <p>P5 (Home_5): "no"</p> <p>P4 (Home_5): No</p> <p>P6, p7, p8, no</p>
Pets	<p>P1 (Home_2): "Yeah, always had a dog" "And we've had a cat sometimes"</p> <p>P2 (Home_2): "Always had a dog"</p> <p>P3 (HOME_1): "oh, cat, cat or a dog, I always had a dog"</p>

	P2 (HOME_1): "yes cat" P5 (HOME_1) dog P8 (HOME_1): "I was a dog man" P10 (HOME_1): cats and dogs P2 (Home_4): "We always had a cat"
Ages	84, 92, 96, 101, 98, 93, 92, 88, 90, 70, 89, 78, 86, 87, 91, 97, 77, 90, 91, 99, 75, 89, 95, 92, 91, 96, 92, 86

Appendix F: Details of future research design ideas

Ideas for furthering implementation model research (Study 5).

In this section, suggestions are provided for future research to further the results of Study 5.

Further exploration could involve an online survey, with a considerable sample, aimed at key stakeholders (care home staff, management, owners, organisations, funders). The survey should aim to:

- 1) Explore current procurement methods and reasoning,
- 2) Explore future procurement scenarios to inform potential business model.

The surveys could use scenarios built based on data collected in Study 5, using the initial insight as a basis of further enquiry. Scenarios as tools have been used in research previously (Ramirez et al., 2015). Scenarios can be useful for researching possible futures, allowing conceptualisation of future modes in an innovative way (Ramirez et al. 2015).

Building scenarios based on the input of stakeholders creates plurality in knowledge building and can allow translation of initial creative thinking (as from Study 5) into pragmatic operational guidelines (Ramirez et al., 2017).

A proposed survey structure is presented below.

Online Survey

- 1) **Please identify your current role:**

Care Home Manager

Care Home Owner

Care Home Staff (E.g. Care worker/activities coordinator)

Care organisation staff (e.g. larger organisation with multiple care homes)

Other (please specify)

2) In which UK County is your care home situated?

3) Please provide some general details about the home you work at/with (size, number of residents, any provision of nursing, dementia care)

4) Robot pets have shown potential in improving wellbeing for older adults and people with dementia living in care homes, they may reduce agitation, depression, loneliness, create more adaptive stress response, lower blood pressure, reduce the use of medication and reduce care provider burden. Examples include Paro the robot seal and the Joy for All cat and dog. (include pictures)

Have you previously heard of, or experienced, use of robot pets for older adults?

1) Yes experience

2) Yes knowledge but no experience

3) No

5) Do you currently have use of a 'robot pet' or interactive animal toy in your care home?

Yes/No

If Yes

5b) How many devices do you have?

5c) How did your care home acquire the device(s)? (tick each that applies)

Care Home funds bought a device

Resident relative purchased a device for an individual

Charitable donations/fundraising were used to purchase a device

External organisations donated a device (e.g. local Council)

A device was provided through a research project

Other (please specify)

5d) Please explain the decision around this method of procurement (please include why the device was purchased by the source responsible, e.g. the device was purchase by a relative because a particular resident wanted a device)

5e) Please explain the decision behind the number of devices you have in your home (e.g. We purchased 2 devices as 1 device would be tricky to share, or, we purchased 1 device as it was too much outlay to purchase multiple)

- 6) We have previously spoken to care home stakeholders around the best method of implementing robot pets in care homes, we would appreciate your thoughts. Please read the two scenarios below.**

Your care home wishes to procure one or more robot pets for their residents.

Scenario 1: The decision is made to purchase one or more devices that the home would own outright. Residents may feel more attached to devices if they were purchased and owned by the home and you did not need to return the device, however the responsibility of maintaining usability of the device would lie with your home. One device could be shared, and would be less costly than investing in multiple devices, however multiple devices could be easier to share among residents and could help avoid jealousies. This option would involve only one initial outlay of cost.

Scenario 2: The decision is made to lease one or more devices on a 'pay as you go' basis. Your care home does not own the devices and will need to return them if your contract is ended, however responsibility for usability of the devices lies with a company you are renting

them from, for example, as part of your lease, the company may provide insurance, repairs, replacements, maintenance or cleaning. You could lease one device to be shared, or lease a number of devices as part of the package. This option would involve continued payments over a contract period (e.g. monthly for 12 or 24 months).

If you were asked to contribute towards this decision for your care home, which option would you be most likely to take?

If Scenario 1, purchase:

6a) Why have you chosen this procurement method? (What reasons? What are the benefits of this method over the alternative?)

6b) What price would you purchase at? (For context, Paro the Robot seal is £5000, and the Joy for All cat is £100).

6c) How many devices would you purchase, and why?

6d) Where is the funding likely to come from? (e.g. care home funds, charitable donations, resident relatives)

If Scenario 2, lease:

6a) Why have you chosen this procurement method? (What reasons? What are the benefits of this method over the alternative?)

6b) How many devices would you want included in your lease package? Why?

6c) What kinds of robot pets would you want included in this lease? Sophisticated and expensive devices such as Paro the robot seal, or more affordable devices such as the Joy for All cat and dog?

6d) What ongoing services would you like included? (e.g. repairs, replacement, cleaning)

6e) What cost would you be happy to pay for a package including the number of devices and services you mentioned above? (What monthly expense would you pay?)

6f) Where is the funding likely to come from? (e.g. care home funds, charitable donations, resident relatives)

Physiological response research (Chapter 7.1)

In this section, ideas are provided for the design of a future research study assessing impact of robot pets on older adults blood pressure, as a physiological response.

- Future research aim:
- Assess impact on blood pressure of interaction with either i) Paro, ii) Joy for All dog, ii) Joy for All cat iii) inert plush toy, and/or) just researcher visit.
- Assess impact on heart rate of interaction with either i) Paro, ii) Joy for All dog, ii) Joy for All cat iii) inert plush toy, and/or) just researcher visit.

Proposed methods for future study:

Participants will be care home residents. The residents will all have capacity to consent.

Residents will be approached by a member of the care team to explain the study in full, read through the participant information sheet and provide informed consent. Researchers will collect the following information about consented residents:

- Age
- Gender
- Blood pressure medication or relevant illnesses (such as Cushing's disease).

Once consented, participants will undergo the study procedure as follows, based on the previous pilot by Robinson et al. (2015):

- Participants will be asked to make themselves comfortable in their room when they are happy to do so, the researcher will be present. The participants will be asked to rest for 5 minutes, then blood pressure and heart rate measures will be taken. The

purpose of this initial reading is to allow residents to become accustomed to having their blood pressure taken by the research team.

- Researchers will then re-visit the following day, and repeat the above step. This reading will provide the blood pressure and heart rate reading for 'before' interacting with robots.
- Participants will then be offered one of the robots/toys. Choice of robot will be cycled from Paro, to Joy for All cat, Joy for All dog, plush toy or control (researcher only).
- Following interaction for 10 minutes, blood pressure and heart rate measures will be repeated. Researchers will observe quietly during the interaction. Ten minutes has been shown as adequate time in the previous research with Paro (Robinson et al., 2015).
- The researcher will then remove the robot/toy, and observe while the resident rests for another five minutes before a final reading of blood pressure and heart rate is taken.

Appendix G: MICRO checklist for Study 7a

MICRO Checklist

The following are checklist responses to the MICRO checklist, found at doi:10.1186/s12916-019-1301-1

Item Number: Response:

- | | |
|----|-----------------------------------------------------------------------------------|
| 1 | Types of specimen detailed within manuscript (pg 10) |
| 2 | Sampling period included (pg 10) |
| 3 | Sampling strategy described (pg 12, 13) |
| 4 | Described, environmental testing for bacterial load and identification (pg 9, 10) |
| 5 | Geographical setting described (pg 10) |
| 6 | Clinical setting described (pg 9) |
| 7 | N/A |
| 8 | Identification method described (pg 14, 15) |
| 9 | N/A no susceptibility testing for this study |
| 10 | N/A |
| 11 | N/A no antimicrobial testing |
| 12 | Included in manuscript (pg 9) |

13	Included (pg 9)
14	N/A, study aim was overall bacterial load
15	Population included (pg 9)
16	N/A
17	N/A
18	N/A
19	N/A
20	N/A

Appendix H: Tables of further example evidence for Study 8

Supplementary File: Participant likes and dislikes, and further example evidence

Participants device preferences and reasons (Q1)

Device	N	Reason
Paro	26	“Reacted to my movements”
		“Pretty eyes, soft”
Pleo	12	“Needy”
		“Interactive and responsive”
Joy for All Dog	20	“Favourite animal”
		“Almost like a real dog”
Joy for All Cat	16	“Fluffiest”
		“Most familiar”

Participant dislikes summary (Q2)

Reason	N	Example
Texture	10	<p>“Fur could be softer”</p> <p>“Don’t feel real”</p> <p>“Too synthetic”</p> <p>“Unrealistic”</p>
Internal feel	5	<p>“Hard parts in bodies”</p> <p>“Feel plastic under fur”</p> <p>“The hard feeling through their fur”</p> <p>“Bumpy robot feeling”</p>
Movements	5	<p>“Too still”</p> <p>“Random movements, not in response to me”</p> <p>“Maybe movements are a little too robotic”</p>
		<p>“Too mechanical”</p>
Size/shape	1	<p>“Cat and dog awkward to hold”</p>
Fear	3	<p>“Creepy”</p> <p>“Cat scary”</p>
Cost	1	<p>“Price of seal”</p>
Noises	3	<p>“Dinosaurs noises are annoying”</p> <p>“Some noises irritating”</p> <p>“Sounds could be better, more sounds”</p>
Ethical concern	1	<p>“I don't really know if they can be used to alleviate loneliness, and whether robots can replace humans in the aspect of intimacy”</p>
Appearance	1	<p>“Dog is one colour, not realistic”</p>
Practical/Maintenance	1	<p>“They can get dirty”</p>

Further evidence of participant responses to open question on general feelings towards companion robots for older people (Q4) – Main text Table 2

Response	%	Example Evidence
Positive	65.76	<p>“It could help them feel more responsible and useful”</p> <p>“I really like the idea, it can re-create the feeling of a pet, even if they couldn’t look after one”</p> <p>“I think anything that could help is a great idea”</p> <p>“It is good if it helps them an I know people with dementia can get stressed”</p> <p>“Great, why not”</p> <p>“Anything that reduces stress is important and beneficial”</p> <p>“They are a fun companion to have around and demand very little care”</p> <p>“I feel it would be great for them to have some comfort from”</p> <p>“I think it would be very therapeutic for them”</p> <p>“Great for people who can’t have animals”</p> <p>“I think it would be very successful providing comfort to my relative with dementia, particularly the dog, for nostalgic purposes”</p> <p>“My neighbour has dementia and misses her cat I would love to give her one for comfort”</p> <p>“Great idea for people who are alone every day”</p>
Mixed	14.93	<p>“In one way I think it’s good as its great that it gives everyone an opportunity to touch but on the other hand I think its sad cause it means that there is no real human contact around them to touch them”</p> <p>“conflicted”</p> <p>“I struggle with the concept of replacing care with robotics but in neurodegenerative diseases such as AZ dementia it can be harder on family members sometimes and if it stimulates/soothes them then maybe”</p> <p>“I wouldn’t want people to use it as an excuse not to visit their relatives or look after them but think it’s a useful thing as someone can’t be with them”</p> <p>“I think it is better to have humans nearby, but if the robots are sufficient to alleviate dementia, I think it is a good idea”</p> <p>“A good idea, the problem would be making the robot responsive enough without it being too expensive”</p> <p>“Maybe it can seem strange, but I think that’s a good thing to fight loneliness”</p> <p>“Its sweet and sad, anything that calms them had to be good”</p> <p>“Good concept but I don’t know how the old people would react to it”</p> <p>“Good idea, need to lower prices”</p>
Negative	7.46	<p>“Might be more efficient for kids”</p> <p>“I think a real animal would be better”</p> <p>“I would have the thought that it was a bit ridiculous”</p> <p>“I would be slightly worried of infantilising the person, the person may get upset or see it as a trick”</p>
No Response	11.94	

Further evidence of unprompted ethical concerns raised (Q5) – Main text Table 3

Area of Concern	Frequency	Example Evidence
Batteries	2	“There may be emotional distress if the batteries ran out”
Malfunction	1	“What happens if they malfunction?”
Human Contact	7	“I worry about the idea behind it [sic] social care [sic] is about compassion, if we turn that responsibility over to robotics what sort of society will emerge?” “Might encourage people to be distant from the elderly” “People would rely on them too much and not visit” “I may question [sic] the elderly [sic] deserve interactions with real people” “I hope they would never be used to fill an emotional need that a human would give”
Robustness	1	“Toughness, can they withstand a fall?”
Deception	4	“It may confuse them” “In cases of bad dementia, they could become confused as to whether the robot was real or not” “if the person with dementia thought it was real and found out it wasn’t they may be upset.” “Could become agitated during lucid moments if they feel they were lied to.”
Privacy	1	“Should not be connected to net (privacy)”
Danger	2	“Electrical fault if liquid spilt on them” “Tripping/falling”
Dignity	2	“They may try to feed or walk them, potential embarrassment” “I would hate if they felt patronised or like these were used as a substitute for family”
Infantilisation	1	“May feel patronised belittled with a fluffy toy”

Appendix I: Study 9 in full (as accepted) Morphology of socially assistive robots for health and social care: A reflection on 24 months of research with anthropomorphic, zoomorphic and mechanomorphic devices

Published RO-MAN 2021 – copyright IEEE 978-1-5386-5541-2/18/\$31.00 ©2018 IEEE

Publication Title: 2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN)

eCF Paper Id: ras.ROMAN21.14.e116c434

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Please note, Study 9 refers to ‘Studies 1, 2, 3 and 4,’ but in the context of the paper rather than the thesis;

- Study 1 refers to Study 3 of this thesis,
- Study 2 refers to Study 2 of this thesis,
- Study 3 refers to Study 6 in this thesis,
- Study 4 refers to Study 4 in the thesis.

Abstract

This paper reflects on four studies completed over the last 24 months, including focus groups, surveys, interviews and interactions with social robots including Pepper, Paro, Joy for All cats and dogs, Miro, Pleo, Padbot and cheaper toys. In total, up to 364 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.

KEYWORDS

Social robots, morphology, design, health and social care

Introduction

One research area in Human Robotics Interaction is how best to support health and social care (H&SC) (Study 1). The H&SC sector is experiencing increasing pressure worldwide (Moyle et al., 2019), with greater requirement for services (Broadbent et al., 2009) exacerbated by declining H&SC workforce numbers (Abdi et al., 2018). The use of assistive

robotics as a supporting strategy has thus gathered particular interest (Broadbent et al., 2009). In this paper, we are specifically interested in application of socially assistive robots (SAR) (Broekens et al., 2009), robots designed to meet social and psychological needs (Hung et al., 2019), which have demonstrated promising health and wellbeing benefits (Broekens et al., 2009). 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 (Fink, 2012; Klamer & Allouch, 2010; Heerink et al., 2010). As noted by Fong et al. (2003), 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 (Daas, 2014). Such devices might, for example, have potential in evoking emotional and empathetic human responses (Daas, 2014). Specifically, anthropomorphism is the attribution of human-like qualities and form to non-human objects (Bartneck et al., 2009), including physical appearance, movements, behaviours and speech (Salem et al., 2013). Similarly, biomorphic devices may have features of biological origin, such as animal ears or noses (Klamer & Allouch, 2010), while zoomorphic devices may be completely identifiable as a known animal (Moyle et al., 2019). While unrealistic animal devices have been referred to as zoomorphic previously (Klamer & Allouch, 2010), 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 (Wilson, 1984), which posits an innate inclination to affiliate with nature and living things (Grinde & Patil, 2009). Familiar cues may assist social robots in their

specific purpose, creating social interaction, as humans are social agents attuned to interaction (Dalibard et al., 2012). This may be particularly relevant in eldercare, as older people may feel anxious in the presence of a machine (Ben-Ari et al., 2018). However, these designs face challenges such as an “Uncanny Valley” response (Mori et al., 2012), capability expectations (Bartneck et al., 2009), and ethical concerns, for example, on deception (Sparrow, 2002). Mechanomorphism, meanwhile, is design congruent with mechanical, machine qualities (Klamer & Allouch, 2010).

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. (2013) 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 (Mori et al., 2012), 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 (Bartneck et al., 2009). This therefore identifies a potential 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 task capabilities (Bartneck et al., 2009). It is possible zoomorphism as an alternative avoids this issue, lowering expectations as human-animal relationships are less complex than human-human relationships (Fong et al., 2003). 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 (Fink et al., 2012; Klamer & Allouch, 2010; Heerink et al., 2010); yet perceived requirement for support can vary across H&SC stakeholder groups (Klamer & Allouch, 2010). Understanding reasons for acceptance and rejection from a range of relevant stakeholders (Broadbent et al., 2009) would thus allow better informed robot design. Previous research has explored aesthetics with relevant H&SC stakeholders; for example Pino et al. (2015) 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 (Jung et al., 2017). The results of Heerink et al. (2013), somewhat contrast Pino et al. (2015), 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 (Pino et al., 2015).

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 (Sparrow, 2002). This is particularly relevant for social robots aimed at those with dementia (Sharkey & Sharkey, 2012). 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 (Bartneck et al., 2009). 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 (Study 3 and 4), 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 (Yoshida & Yonezawa, 2016).

Overall, thus, although embodiment, morphology and anthropomorphic design have been extensively studied (Fink, 2012), 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.

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 (for publication, not within the thesis). 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.

Robots

Our studies included devices with varying degrees of anthropomorphic, zoomorphic, mechanomorphic features, human speech, life-simulation and animacy (Bartneck et al., 2009) (Figure 37, Table 29).

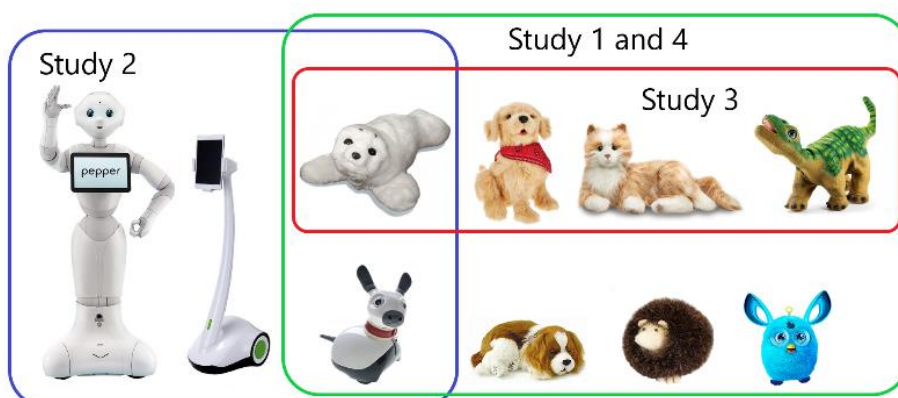


Figure 37: From left; Pepper, Padbot, (top row) Paro seal, Joy for All dog, Joy for All cat, Pleo rb dinosaur, (bottom row) Miro, Perfect Petzzz breathing dog, Knitted Hedgehog, Furby

Table 29: Robot features relevant to morphology and anthropomorphism

	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 29 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.

Studies Included

Study 1: Comparison of companion robot design preferences between older people and roboticists (Thesis Study 3). Older people and roboticists separately interacted in groups of between two and four with eight companion devices with varying degrees of biomorphism. Robots were displays 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. Participants subsequently shared design perceptions in focus groups. Participants: 17 older people (5 male, 12 female, aged 60-99), 18 roboticists (10 male, 8 female, aged 24-37).

Study 2: Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions. Content analysis of free interactions between 223 H&SC stakeholders and two zoomorphic robots, one humanoid and one mechanomorphic telepresence robot. Acceptability was assessed through mapping of themes onto Almere Model constructs, full results were mined for data relevant for morphological design. 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.

Study 3: Ethical perceptions towards real-world use of companion robots with older people and people with dementia: Survey opinions among family members (Thesis Study 8). Stakeholders interacted with four robot animals with biomorphic features, before completing a survey of ethical concerns. 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. 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).

Study 4: Care home management, staff and resident relative interviews. 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 on design. Interviews were transcribed and analysed using deductive thematic analysis. Participants: 29 care home staff, 10 resident relatives.

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 (Study 3). 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 (Heerink et al., 2013) 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.

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 occurred 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 [...] 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 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 could not 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.

Discussion

Biomorphic design is preferred over a mechanomorphic one. The reported perceptions of up to 364 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 (Ben-Ari et al., 2018). 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 (Chwen-Chi et al., 2015). 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 (2002) 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.

Speech is well received even when limited. The anthropomorphic feature of speech received some support across the studies. Although some responses were mixed, the majority of negative opinions seemed to be held by staff. 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. (2013), 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 (Fink, 2012; Salem et al., 2013; Dalibard et al., 2012), the anthropomorphic form appears occasionally to cue negative schemas of sci-fi humanoids. A further issue with anthropomorphic design previously cited is increased expectations (Bartneck et al., 2009). 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 (Bartneck et al., 2009), 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. (2017). Further previous research also found discomfort of robot use for social tasks (Arras & Cerqui, 2005). While some participants in our studies noted robots should not replace humans entirely, a concern highlighted in previous research (Hebesberger et al., 2017), 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. A further limitation of this work is the lack of full-android devices considered, meaning we cannot

contribute towards the Uncanny Valley debate (Dalibard et al., 2012), 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.

Conclusion

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.

Appendix J: Full table of themes and example evidence for Study 10

Theme	Initial Codes	Interpretation	Evidence
Positive Outcomes	Entertainment, pleasure, reminiscence, communication, emotions	Positive outcomes resulting from interaction, reflects positive effects attributed by staff to interaction with devices. Suggests a real-world impact on	<p>"Everyone was happy to interact"</p> <p>"They certainly put smiles on everyone's faces"</p> <p>"Especially enjoyed by those with dementia and learning disabilities"</p> <p>"The dog was passed around and enjoyed by many"</p> <p>"The cat and the dog were enjoyed on laps"</p> <p>"They make people smile"</p> <p>"Enjoyed and passed around"</p> <p>"Responses are always positivity and smiles"</p> <p>"They appreciated how happy it made others"</p> <p>"When you take the animals in immediately you get a response, they're excited and they're looking forward to it and it's fun"</p>

		emotions and communication.	<p>"They bring back lovely memories and emotions"</p> <p>"She would talk to and stroke [the cat] and become a lot more verbal when she has the cat"</p> <p>"Having the dog encouraged three people to talk about pets they had previously owned"</p> <p>"Making people laugh"</p> <p>"She enjoyed stroking and talking to it"</p> <p>"They talked to them and really enjoyed interacting with them"</p> <p>"Quite enjoyable"</p> <p>"It's better in the communal area, rather than one each, that way people come down and mix more"</p> <p>"They thought the cat technology was very positive"</p> <p>"Participant was also very interested in the cat"</p> <p>"The group were very interested in the cat and wanted to hold and pet it"</p> <p>"Most people felt the cat would be very useful for people who lived alone and couldn't have a pet for any reason"</p> <p>"Overall, people were very curious about the cat"</p> <p>"Having the cat there generated a lot of conversations"</p> <p>"Enjoyable petting it"</p> <p>"This group [...] initially strangers have become very connected and I did wonder, the fact that they now all chatter"</p> <p>"Again this session got a lot of conversations about people's own pets and about the positive value of living with an animal"</p> <p>"How useful the cats would be [...] particularly if they are elderly and people with dementia"</p> <p>"People were curious about the cat and wanted to look at it and pet it for a short while"</p> <p>"when I gave her the cat I could see that she was quite emotional and she held it and spoke to it with such tenderness it was really very moving"</p> <p>"The group has some new members, one lady has been asking me about the robot and [...] the cat"</p> <p>"Cute"</p> <p>"Excellent"</p> <p>"Adorable"</p> <p>"Thought it was real"</p> <p>"Couldn't help but pet it and talk to it"</p>
Acceptability	Acceptance, requesting animals, ownership, facilitator bonding	Devices demonstrated good real-world acceptability by staff and clients	<p>"They were excited to see the cat and have their turn to hold it"</p> <p>"Was asked for by a service user"</p> <p>"She very much enjoys the cat, she talks to it and strokes it"</p> <p>"[Names] requested the animals, they want to hold them"</p> <p>"They talk about loving them"</p> <p>"Spent the whole morning with the cat"</p> <p>"Sat for hours petting the cat"</p> <p>"everyone is very lovely to the toys and all like to have a turn"</p> <p>"The cat was requested"</p> <p>"People are very gentle with them and talk to them"</p> <p>"They helped themselves, it was on her lap all morning"</p> <p>"Spoke to it exactly the same way that people speak to living animals or babies"</p> <p>"Stroked as they would a cat or dog"</p> <p>"An estimated 80% of clients loved the cat"</p> <p>"The cat is a good companion"</p> <p>"Just really love it, could spend all day stroking it"</p> <p>"I could spend hours playing with this"</p> <p>"Maybe half a dozen formed a strong bond and attachment"</p> <p>"She would talk to it as if it was her own"</p>

			<p>“She talked to it, stroked it, treated it as her own”</p> <p>“Actively sought out the dog, played with it for an hour”</p> <p>“Some people were quite attached to them”</p> <p>“Attached”</p> <p>“I was surprised how protective I felt towards the cat”</p> <p>“She wanted to have the cat again as soon as she saw it, and after spending some time with it herself did encourage other people to interact with the cat and took it to others in the group to hold”</p> <p>“She kept the cat with her for the rest of the session”</p> <p>“She wanted one for herself”</p> <p>“She really warmed to it and was reluctant to pass it on”</p> <p>“Most clients were very interested”</p> <p>“As soon as [she] saw I had it with me, she immediately wanted to hold it and it sat on her lap for the majority of the session”</p> <p>“[She] requested I bring the cat as she was attending”</p> <p>“Those who had seen the cat before were keen to hold it and also keen to show it to others”</p> <p>“Those who hadn’t seen it before were very interested and were asking about how to get one”</p> <p>“Although they did take turns and shared [...] there was a sense that people were eager for it to be their turn”</p> <p>“She became very insistent that she wanted one”</p> <p>“Overall people were very positive about the cat”</p> <p>“There was a lot of interest in it”</p> <p>“Older adults were very enthusiastic to interact with the cat”</p> <p>“[...] wanted to hold it repeatedly”</p> <p>“[...] was very taken with the cat”</p> <p>“Most interested and keen to hold and pet it”</p> <p>“Two individuals most interested were in wheelchairs”</p> <p>“The group were very keen to hold and pet the cat and encourage everyone to take a turn”</p> <p>“The cat is currently in my possession at home and after taking it to a session, I bring it home and use wet wipes on its fur and gently put it back in the box and put the box on top of a chest where it will be safe. I initially reasoned with myself that it is a piece of equipment so it doesn’t need to be out of the box, but I have that same conversation with myself each time it goes in the box. When I was asked to ‘drop it into the office’ I was initially reluctant and did think about either ‘accidentally’ forgetting to bring it in or changing my work schedule so that I could be at the event as well to ensure that it was looked after. When I did bring it in, I gave a lot of instructions about storing it and using it and I did feel a huge measure of relief when I got it back.”</p> <p>“As soon as I put it on the table they wanted to hold it”</p>
Wellbeing Use	Easing anxiety, distraction, alleviating moods	Apparent wellbeing outcomes attributed to interaction	<p>“Sometimes [...] becomes anxious [...] the cat is a good distraction, Helped her forget time and anxiety eases”</p> <p>“Anxiety eased”</p> <p>“Raise moods”</p> <p>“Reason used was anxiety”</p> <p>“Takes her mind off anxiety”</p> <p>“Brought to [...] as a distraction when it was getting close”</p> <p>“Can see the benefit for helping with anxiety and loneliness”</p> <p>“A real comfort to tenants who are isolated or have [...] dementia”</p> <p>“The cat calms you down, ladies even when older have maternal instincts, and when people lose pets it’s difficult”</p> <p>“It relaxes people with additional needs”</p> <p>“It’s really good for people who have mental health problems”</p> <p>“Very therapeutic and calming”</p>

			<p>"It gives comfort if you're stressed, very calming"</p> <p>"It's very therapeutic"</p> <p>"Just sitting with it is really relaxing"</p> <p>"We have used the cats to de-escalate an emotional situation"</p> <p>"It really seemed to calm her down"</p> <p>"It has a really calming effect"</p> <p>"She was crying, shouting, swearing [...]. Immediately her body language changed, she was relaxed, smiling, literally within seconds, she was laughing"</p> <p>"Deescalated the whole situation and worked really, really well"</p> <p>"Totally calmed down"</p> <p>"They brought comfort and joy"</p> <p>"One resident [...] talks non-stop, was silent for the whole time he was holding the cat [...] as soon as the cat was given to him you saw his whole body visibly relax."</p> <p>"Felt that it was very calming"</p> <p>"It was clear that petting the cat had a really calming but also uplifting effect on the group, they were very gentle with it"</p> <p>"The cat had the most calming effect"</p>
Change in Use	Change in use	No novelty effect, staff report increased use over study-duration from structured 1-2 hour sessions to being continually present and in-use.	<p>"1-2 group session"</p> <p>"2 hour session"</p> <p>"2 hours"</p> <p>9.30-3.00</p> <p>"Present all day"</p> <p>"Very much part of the service"</p> <p>"Part of the home"</p> <p>"As normal pets would be"</p> <p>"Have just become part of the norm"</p> <p>"people helped themselves"</p> <p>"Sitting on laps as normal pets world"</p> <p>"All day"</p>
Negative Responses	Negative response, unnecessary distraction, gender difference, jealousy	Some negative responses, minority of records	<p>"It's creepy"</p> <p>"He began to say his cat would attack it and rip it up"</p> <p>"He was agitated and repeated his cat would attack this one and that it would rip it apart and tear it's inside out and that he personally would encourage his cat to do so and that he himself would wring its neck and tear its head off"</p> <p>"It's quite scary, I'm used to my real cat"</p> <p>"It would just be a time waster"</p> <p>"I would be fussing it all day, so wouldn't get any housework done"</p> <p>"Not very enthusiastic, personally I thought it was quite creepy"</p> <p>"Very reluctant to allow others to take the cat"</p> <p>"Everyone wants them at the same time"</p> <p>"They were initially reluctant"</p> <p>"They were afraid to break it"</p> <p>"She really warmed to it and was reluctant to pass it on"</p> <p>"Although they did take turns and shared [...] there was a sense that people were eager for it to be their turn"</p> <p>"It seemed like a slightly unwelcome distraction from their conversations"</p> <p>"People discussed it in an abstract way, something to benefit other people rather than [...] personally"</p> <p>"One man initially got very excited about the cat, and then became very tearful and scared about it but the rest of the group encouraged him to stroke the cat again until he felt ok"</p> <p>"Repeatedly saying she would love one but that it would just be a time waster"</p> <p>"One man made several comments about that horrible thing, and how he would like to smash it up and it was</p>

			horrible and creepy and he wanted to break it and put it in the bin like all cats should be”
Practicalities	Cost, robustness	Price seemed too high for older people themselves to consider buying, devices appeared robust	“Disappointed in the price” “The cats are looking a little bit loved, but the dog is still looking perky” “Unfortunately the price was too high for her” “She had immediately fallen in love with the cat and wanted to know how much it cost, when I told her [...] she became very insistent that she wanted one [...] and really could afford it” “she was very disappointed because she said she couldn’t afford it” “They are doing well, but I could imagine they could get dirty quite quickly”

Appendix K: Full summary of scale selection for Study 11 during pilot with collaborators

Collaborators reported measures should focus on outcomes expected to be interesting based on results of studies to date, specifically; agitation, behavioural challenges, anxiety and depression. Therefore, the measures suggested in the pilot were; objective medication use, Challenging Behaviour Scale, NeuroPsychiatric Inventory for Nursing Homes (NPI-NH), Brief Agitation Rating Scale (BARS) (as used by Jøranson et al., 2015), Cornell Depression Scale (Jøranson et al., 2015; Petersen, 2017), Rating of Anxiety in Dementia Scale (RAID) (Moyle et al., 2013; Petersen, 2017), De Jong Gierveld Loneliness Scale, Care Provider Burden Scale and a demographic questionnaire. Data collection with these scales was trialled for some of the residents in the pilot home. Care staff and researchers read and discussed the proposed measures, completed them for a small number of residents to explore participation burden, and then reflected to select scales for Study 11.

The scales discussed in the pilot covered many key aspects of wellbeing, and Behavioural and Psychological Symptoms of Dementia (BPSD). Upon reflection with collaborators however, the participation burden would have been too great had all scales been included in Study 11, with a considerable sample for whom scales would need completing. Therefore, the specific agitation, anxiety and depression scales were dropped, as these outcomes are all included as subscales within the Neuropsychiatric Inventory which became be the

primary outcome of Study 11, and was originally suggested by the dementia liaison team and clinical psychologists. The NPI-NH includes subscales of; delusions, disinhibition, hallucinations, irritability/lability, agitation/aggression, aberrant motor behaviour, depression/dysphoria, anxiety, sleep and night-time behaviour disorders, elation/euphoria, appetite and eating disorders and apathy/indifference.

The studies in this thesis suggest robot pets can benefit individuals differently, improving agitation for some, or relieving sadness for others (Study 4 and 10). It therefore seemed inappropriate to select one specific primary outcome (e.g. agitation), justifying choice of the NPI-NH to provide an overall score of neuropsychiatric symptoms including many wellbeing and BPSD domains. Dementia is heterogeneous, with diverse behavioural profiles (Lai, 2014), and variation in mood disturbances, with dementia not progressing uniformly (Cohen-Mansfield, 2000), thus not all individuals experience the same behavioural or wellbeing issues. The original NPI (not nursing home version) has been used in social robot research previously (Soler et al., 2015), and has good reported interrater reliability, good test-retest reliability and good face validity based on the Delphi process (Lai, 2014). The NPI also demonstrated superiority over the Empirical Behavioural Rating Scale (E-BEHAVE-AD) and Neurobehavioural Rating Scale for detecting improvements in agitation. The scale has been used in drug-trials and reported to be sensitive to drug-induced behaviour changes (Lai, 2014). There is also research suggesting neurobiological correlates with NPI subscales, including agitation, dysphoria/depression, psychosis and aggression, through methods including autopsy, imaging, electroencephalography, biochemical and genetic studies (Frisoni et al., 1999).

The NPI authors suggested screening questions had a false negative of less than 5% (Cummings et al., 1994). The NPI-NH differs only from the original in the re-wording of

family disruptiveness to occupational disruptiveness, which thus aided in understanding any impact for the care team without reliance on the care provider burden scale.

Limitations of the scale include the multiplicative scoring metric, and expected issues in normality of scores (Lai, 2014). Some researchers have cautioned against parametric methods of analysis (Perrault et al., 2000), and indeed normality histograms and Levine's tests indicated non-parametric tests to be most appropriate in Study 11. Recall bias may also pose a problem, but this is prevalent for all scales considered. Based on strengths, weaknesses, feasibility, participation burden and heterogeneity of dementia symptoms, the NPI-NH was felt appropriate, and was agreed upon by collaborators within the care homes and relevant healthcare teams (including Clinical Psychologist and Dementia Liaison Lead).

Collaborators requested addition of a communication scale for Study 11, feeling this outcome was missed during the pilot. For this reason, the Holden Communication Scale was selected. The Assessment of Communication and Interaction Scale (ACIS) is an alternative used in SAR research previously (Sung et al., 2015), but appears more relevant to occupational contexts.

During the pilot, collaborators displayed reluctance to complete the care provider burden scale (perhaps due to social desirability bias, and not wishing to imply their job was burdensome), which was then removed for Study 11. The 6-item De Jong Gierveld loneliness scale was also reported as unfeasible during the pilot, due to reliance on resident responses, sometimes not possible with more advanced dementia, and due to discomfort asking some of the negatively worded questions. The UCLA loneliness scale is an alternative used in previous SAR research (Banks et al., 2008), as is the original 11-item De Jong Gierveld Scale, however as all require resident responses, shorter length was prioritised for feasibility and positive wording was expected to encourage more responses than the De Jong Gierveld

scale, therefore it was replaced by the 3-item Campaign to End Loneliness Measurement Tool.

Appendix L: Full table of themes and example evidence for Study 11

Theme	Codes (n in interviews) [n in diaries]	Example Evidence
Adoption	Love (11)[13]	<p>“he loved it. It was it was almost emotional watching her, react, and respond to it” (Interview_home4),</p> <p>“It’s how soft it is, the long, the long fur on the cat. How pretty the faces. It’s just. Yeah, she loves it.” (Interview_home5),</p> <p>“[Name] loved the cat” (Interview_home2),</p> <p>“She loves him sooo much and wants him all the time” (Calendar_home2)</p> <p>“[Resident] loved the cat today, was smiling” (Calendar_home3)</p> <p>“[Resident] as always, loved the dog, kept the cat in her room last night” (Calendar_home2)</p> <p>“[Resident] was chatting and stroking the dog, she loved the dog as if it was her own” (Calendar_home4)</p> <p>“[Resident] loves it and goes to bed with it” (Calendar_home2)</p>
	Ownership (18)[6]	<p>“Some thought they were actually their real pet. claim to take possession of them, that they were theirs and we had to sneak them away.” (Interview_home1),</p> <p>“[Name] loved that cat, it was her cat, she would look after it” (Interview_home2)</p> <p>“It’s very much ‘his’ really. He’s really, we couldn’t really part him from it. It’s offered him a lot of comfort.” (Interview_home8)</p> <p>“completely and utterly adopted by we had two pets and they were adopted by two residents and throughout so, one of my favourite things is when one of the residents goes to her room, and the cat goes with her and it’s just sort of gives her a focus.” (Interview_home5)</p>
	Individual use (9)[14]	<p>“If you’ve got a pet, it’s yours. Ownership seemed, you know, one of the points of it” (Interview_home5)</p>

		<p>“Seeing [...] nonplussed reaction of other [residents] is like, well, we don't need to circulate it around. It's useful for certain people, so it's no good sort of having it as a house pet” (Interview_home5)</p> <p>“mostly individual To be honest, they mostly went round individually, to begin with there was a few group sessions to introduce them and everything. But most of the people who benefited most were the ones that were in their rooms all the time. Or weren't particularly having conversations with other residents or anything, with dementia, and were past the group stage and are better on a one to one.” (Interview_home1),</p> <p>“Individual, it's like having, if you've got your own pets. So you like having sort of one to one with the pets. Talk to them” (Interview_home2)</p> <p>“better if they're in their rooms with people individually, easier to manage because nobody else can see them” (Interview_home6)</p> <p>“Had down in own room for whole day, enjoyed cuddles” (Calendar_home1)</p> <p>“[Resident] keeps it in her bag and gets it out when upset” (Calendar_home3)</p>
	High level of usage [12]	<p>“[Resident] has kept the dog all day” (Calendar_home1)</p> <p>“[Resident] still has the dog, all day” (Calendar_home1)</p> <p>“[Resident] really loved the dog, left her with it because she didn't want to let it go” (Calendar_home2)</p> <p>“[Resident] loves it and goes to bed with it” (Calendar_home2)</p>
	Jealousies or possessiveness (6)[6]	<p>“She doesn't like to give it back really. She doesn't know that it's not a real cat. However, we can't really let her, we can let her have it for an hour or so. But we have to get it back off. Can be quite challenging, she does love it though” (Interview_home7),</p> <p>“Yeah, some people get sort of quite attached to them. [...] they won't leave them go” (Interview_home6)</p> <p>“I think he would probably a bit angry if we moved and get, gave it to someone else.” (Interview_home8)</p> <p>“[Resident] seems to dominate the cat if not careful” (Calendar_home2)</p> <p>“[Resident] chatted to cat, become unsettled when cat was taken away for tea</p>

		<p>time and is reporting us for animal cruelty” (Calendar_home4)</p> <p>“[Resident] chatted to the cat but wouldn’t share” (Calendar_home4)</p> <p>“[Resident] loves the dog and will not let anyone else interact with it” (Calendar_home3)</p> <p>“[Resident] has his own dog, but likes to round them all up often” (Calendar_home2)</p> <p>“a brief moment of oh I wish I could have it on my lap, but oh no don’t bother.” (Interview_home5)</p>
	<p>No novelty (9)</p>	<p>“This morning she stroked the cat like it was, you know, like she's done and loved it from day one.” (Interview_home5),</p> <p>“Yeah, the cat, she looks at it. You can see the love in her eyes, every day. When she stroked it this morning, there's no change in how much he adores it. It's so lovely to see.” (Interview_home5)</p> <p>“I think it’s only changed in the sense that it's been adopted. Yeah. So the ones that we've had I don't think people have got bored of them.” (Interview_home8)</p> <p>“It's a continuous type type of thing. Yeah. Yeah. And, realistically, if people would get bored of it, if you put it away for two weeks bring back out, most people might not remember.” (Interview_home8)</p> <p>“No no I don't think they're less, I don't think they're bored with them, They're just as useful and I think, residents are just as interested now from where to start, I don't think much change in my opinion. I don't think that's changed. You know, we've certainly with my use when I get them out.” (Interview_home7)</p> <p>“I would say it hasn't change, they're just as interested in them as they ever were” (Interview_home7)</p>
	<p>Naming (7)</p>	<p>“One gentleman basically adopted the cat, and named him” (Interview_home8)</p> <p>“She's she sees him from the hallway, which is what, [...] 10 meters away, she can see him and she's gone oh hello jack. Oh, there he is. And she knows he's there and is meant to be there. And she likes it when he is there.” (Interview_home5)</p> <p>“The dog was called Ben by this lady, and had to come to the hairdressers with her [...] He's Ben isn't he and so he shall be forevermore unless somebody else decides</p>

		<p>to name something else.” (Interview_home2) “We did have a little sort of competition about what to call him, but actually as times gone on and people have come and gone. They just made him a dog that they had right.” (Interview_home6)</p>
	Group sessions [5]	<p>“Enjoyed cuddles in group session” (Calendar_home1) “Cat was enjoyed by all residents in the group, it brought a smile to their faces and all engaged in stroking its fur” (Calendar_home2)</p>
	Personalising (1)	<p>“It’s ended up with a little pink bow in his hair. It went into her room without one and when it came out with his pink bow on and everyone loves it and it’s just stayed on there. She strokes it and tickles it under the chin. She smiles at it. It is wonderful.” (Interview_home5),</p>
Wellbeing effects, particularly mood	Calming (10)[20]	<p>“it does calm him down, he has made an attachment to it, and he’s named it. And that continued, even with his dementia.” (Interview_home8) “The best way to describe it is a lot more emotional. Yeah. A more emotional connection. I mean, that that was quite generally with most people that used it. Yeah. And it definitely had a calming effect.” (Interview_home8) “She would respond really well. She would almost think that they're real and really, really calming effect on her, for that instance, is really, really, really effective.” (Interview_home4) “Family [...] they realized how much he aided her and how much it calmed her down.” (Interview_home1) “he's able to just to just sort of calm calm himself really, just through stroking the dog, and he'll talk to it, you know, he'll sit at the window with it, on the table, he's got a table for him, we'll put it on the table for him and, he'll sit looking at the garden and stroke the dog, and it really does have a positive calming effect on him. On his mood. So we can use we can use them for the escalation. And residents that are anxious and it might actually prevent them from from getting any, any worse, Yeah, it will calm them down and help distract them from having a bit of a meltdown, for want of a better word” (Interview_home7)</p>

	<p>“Enjoyed sitting and cuddling the dog, calmed down” (Calendar_home1)</p> <p>“Calmed her down in a moment of need” (Calendar_home1)</p>
Enjoyment (1)[19]	<p>“Yes it’s been brilliant, brilliant. A lot of them are really really keen on them. Really enjoyed having them, some thinking they were real, some realizing they weren't but enjoyed petting them.” (Interview_home1)</p> <p>“[Resident] enjoys the cats company” (Calendar_home4)</p> <p>“[Resident] enjoyed the cat, spoke to it” (Calendar_home3)</p> <p>“[Resident] enjoyed looking after the cat” (Calendar_home2)</p>
Anxiety reduced (3)[13]	<p>“She passed on bless her. We had one particular lady that it worked for every single time, it lowered her anxiety. ” (Interview_home4)</p> <p>“[Resident] enjoys the dog and helps reduce anxiety and agitation” (Calendar_home4)</p> <p>“[Resident] missing own dog, loved the cuddle, less stressed” (Calendar_home1)</p> <p>“[Resident] became unsettled with another resident, sat with her dog and fell asleep” (Calendar_home4)</p> <p>“[Resident] appeared to really relax and de-escalate anxiety” (Calendar_home4)</p> <p>“Helped to reduce agitation and anxiety” (Calendar_home2)</p>
Companionship (7)[6]	<p>“They love the companionship, they you know, they thought it was beneficial as a human talking to them.” (Interview_home1),</p> <p>“New resident was unsettles, she has spent the afternoon with the cat, she said she knows it’s not real but enjoys it’s company” (Calendar_home1)</p> <p>“[Resident] enjoys cats company” (Calendar_home4)</p> <p>“[Resident] enjoys company of both to distract him” (Calendar_home4)</p>
Smiles and happiness (1)[9]	<p>“She smiles at it. It is wonderful.” (Interview_home7)</p> <p>“[Resident] was very happy to see dog and talking and petting it” (Calendar_home1)</p> <p>“[Resident] smiled stroking the cat, “you’re lovely” (Calendar_home4)</p> <p>“[Resident] talked to the dog, lots of smiles” (Calendar_home4)</p>
Engaging resident (10)	<p>“Yeah, both, have a good old chat, try feeding them, urm. They do interact with</p>

		<p>them as though. Especially the cat again. A though It was a real cat. Yeah. They get told they're naughty boys (laughs)" (Interview_home8)</p> <p>"Yeah. And I think it's quite handy when, they're sat in the room, because then they're turning on itself, is again, that's another activity which you can instantly engage with. And then look for it and go oh what's that noise, blah bah blah, It's not just the case of sitting down and stroking it. There are other ways it can be used" (Interview_home8)</p> <p>"I've actually got a cat in my office that sat on my shelf here, and I have residents that come in, to come in and talk to the cat. They always come and say hello" (Interview_home4)</p> <p>"The one in my office now, although it's out of action it's not going out to anybody, they'll come in and just talk to it" (Interview_home4)</p> <p>"But more interactive. Not falling asleep or whatever, instead she was interacting with the dog and with other people about the dog." (Interview_home2)</p> <p>"perhaps that's where the cat goes wrong. It doesn't it does. Most things like the rolling the meowing and the purring and you know, like, like a cat would. But with a dog. I think it's a little bit more engaging, you know, a bit more. Like it's looking at you like, like it's understanding you. Yeah." (Interview_home2)</p>
	Relaxing or settling [7]	<p>"Enjoyed sitting with the cat, helped relax him" (Calendar_home4)</p> <p>"[Resident] relaxed and enjoyed" (Calendar_home1)</p> <p>"Relaxed for a while, calmed down" (Calendar_home1)</p>
	Mood improved (7)	<p>"Because of COVID, obviously, we're not we're not able to do that. So their residents, and we do have to recognize that they are missing out on having their own pets. I feel it's been a God send really having them. Especially to be able to de-escalate, for certain residents, it's been very helpful having them, really" (Interview_home7)</p> <p>"Mood, definitely the moods. Yeah, it lifted quite a few of their moods." (Interview_home6)</p> <p>"They certainly lift spirits, that's for sure." (Interview_home6)</p>

	Provides a focus (5)	"One of the residents goes to her room, and the cat goes with her and it's just sort of gives her a focus." (Interview_home5)
	Distraction (3)[2]	<p>"You can use it as a distraction. Okay, so it kind of takes away from that feeling. Yeah, yeah. You can use it as a distraction. You can engage in him in a different way to kind of totally avoiding the anger building up." (Interview_home8)</p> <p>"The ones who have dementia that tend to get some the mood swings. Yeah, we've got one now who can have a lot of mood swings, as she knows they're not real. And she will take it which is more of a distraction. And it will distract her for a while." (Interview_home1)</p> <p>"Yeah, it will calm them down and help distract them from having a bit of a meltdown, for want of a better word" (Interview_home7)</p>
	Agitation reduced [5]	<p>"Seemed to ease [Resident's] agitation" (Calendar_home2)</p> <p>"[Resident] was feeling very agitated, sat with the dog in lounge and it really calmed her down" (Calendar_home4)</p> <p>"[Resident] really enjoys dog and reduced agitation" (Calendar_home2)</p>
	Entertainment and laughter (1)[3]	<p>"I think the dog would probably be more entertainment, because you're kind of trying to get people to use it more, but the cat was definitely along the lines of the interaction?" (Interview_home8)</p> <p>"[Resident] laughed at the dog because she said something and dog barked as it's response" (Calendar_home4)</p>
	Therapeutic (3)	<p>"Because of the covid the chairs are spread apart. And because of whatever reason, a slightly bigger table was put between the owner and her friend. And the cat just lies between, you know, almost sort of elbow to hand like a long the arm of the chair. It is always there and if is pushed back a bit I bring it forward because she's stroking it everyday regularly. Yeah. So that's nice, isn't it? That's one of the therapeutic things about pets, it the touch when you're stroking it." (Interview_home5)</p>
	Reassurance (3)	<p>"Yeah. I would say the majority. Yes. They [staff] have found a tool for giving comfort, reassurance. That kind of interaction, and starting interaction as well. Using it as a topic." (Interview_home8)</p>

		<p>"I think it's [heartbeat] reassuring. Okay. That that was like sort of thud thud thud, that you get with it with a heart. I think that would be quite reassuring. I mean, they did like, yeah, they did like the purring with the cat. Yeah. As well. And that was louder, but the trouble with the cat, his bodies hard." (Interview_home2)</p>
	Sundowner, (2)	<p>"She was a Sundowner as well as a particular time of day where she would become more anxious. And we would know actually, if we get our cat or dog then she would instantly calm, really, really effective for that particular person." (Interview_home4)</p>
	Reduced boredom (1)[1]	<p>"But it's there if they want it, need it, yeah. They're upset, they're bored, give them the dog." (Interview_home2)</p>
	Enabled eating [1]	<p>"Calms her down and makes her eat by sharing with the dog" (Calendar_home3)</p>
Effects on Communication	Communication with pet [25]	<p>"[Resident] loves to chat to cat" (Calendar_home4) "[Resident] sat stroking the cat and talking to it, wrapped it up in a blanket" (Calendar_home2) "[Resident] very fond of cat, chatted, unsettled now content" (Calendar_home4)</p>
	Communication with others, and speech (19) [2]	<p>"You know, I like to walk into it. It responds when it moves. It also gives the staff and other residents a reason to talk to them. It's almost like bringing a bit more interaction between them and the residents. Like as they're talking about the dog. You go for a walk in the park, you don't talk to people who are walking you talk to people who have got dogs don't you, you talk to them about their dogs." (Interview_home5) "You know, it must be it must really focus them. And they because we do have several residents with speech, they are able to talk very well, but it's completely jumbled. And it's really difficult to make sense on time, what they're saying. However, when you put the animal in front of them, and another lady that has had greyhounds, and she loves dogs, and you know, when you give them the pet, then they come out with several very, very clear sentences. So that's quite critical. Really." (Interview_home7) "Yeah. I would say the majority. Yes. They have found a tool for giving comfort, reassurance. That kind of interaction, and</p>

		<p>starting interaction as well. Using it as a topic.” (Interview_home8)</p> <p>“Yeah. Gives you something to discuss. As well, which sometimes can be quite difficult. For some staff I think” (Interview_home8)</p> <p>“Now we had group sessions on our planner, we have a planner every week. So I could plan for a week it was it was planned to have pet therapy, and it engaged conversations and that about pets that they used to have or what they remember about, there's not just engagement with the animals, it's also reminiscing about the past events as well, which is quite good and a group activity” (Interview_home4)</p> <p>“the positive effects. Sometimes her speech is really quite muddled. However, when you put the cat in front of her, as you can see on this little video, her speech becomes very clear as she talks to it” (Interview_home7)</p> <p>“But certainly, the staff, will take one of the pets, take one out and spend time, you know, so they're interacting, they don't know, they're interacting more. They might it might spark conversation about about the residents pet or just generally their own the staff members own pet.” (Interview_home7)</p> <p>“It would appear to me that one of our ladies who has quite severe expressive aphasia, when engaging solely with the dog shows no signs of this and communicates clearly with it, I wonder if this is because, similar to music it comes from the emotional part of the brain. ” (Interview_home3)</p> <p>“I have also sent a photo of two ladies who usually spend their day in conflict with each other. The picture I think speaks for itself. [picture shows two older ladies sat on the same armchair, smiling/laughing and looking at the dog]. The response has even surprised an old cynic like me.” (Interview_home3)</p> <p>“[Resident] adores the dog, vocal conversation point” (Calendar_home4)</p> <p>“Group interaction, [Resident] initiated conversation” (Calendar_home2)</p> <p>“I gave her the robot cat to stroke and left her with it, she was then cuddling it and interacting with another resident and their family” (Calendar_home1)</p>
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	Reminiscence (5)[1]	<p>“It is, it is very much so. And then you can get talking about their dog. Or the other dogs, and all that sort of thing. Yeah, it is very much reminiscence because that's what they see as their dog. This is them, this is my dog” (Interview_home2)</p> <p>“it engaged conversations and that about pets that they used to have or what they remember about, there's not just engagement with the animals, it's also reminiscing about the past events as well, which is quite good and a group activity” (Interview_home4)</p> <p>“That gets them to talk about something that's joyful if you know something that they remember with joy rather than. Yeah, hopefully they wouldn't remember that it died. Yeah.” (Interview_home2)</p> <p>“[Resident] talked about his own pets, reminiscence of dog” (Calendar_home4)</p>
	Interaction (4)	<p>“Ben [dog] enjoyed it for hairdressers because it's lots of noise going on, so he kept turning his head, even the staff like him!” (Interview_home2)</p> <p>“Talk to them and the fact that the dog will turn as well. I don't know, does it respond to voices or is that just my imagination?” (Interview_home2)</p> <p>“Because it will look at you when you're talking if someone if someone comes along and talk then it'll move, and that appears to be good, and that's obviously what it was” (Interview_home2)</p>
Isolation and Covid	Covid use (15)	<p>“it's gone fantastically. And I'm really glad we have them especially at this ridiculous time. Yeah. I couldn't have thought of a better time for us to have them.” (Interview_home5)</p> <p>“I find that since we've had the covid situation, we're not actually allowed to have any real animals in the nursing home, we have, we do have two pet cats here. But since we're not allowed to have real life dogs in, they've come in really, really useful. Really useful thing to have. ” (Interview_home7)</p> <p>“Yeah, I think because obviously with covid, it was offering comfort. That little bit of social interaction to get, referring to the gentleman adopted, he doesn't really interact very well with other residents. And he can become quite angry. Okay. So yeah,</p>

		<p>it's given him that. That relationship. If that makes sense. Yeah. He's got his friend. Yeah. And, yeah, before we've obviously been conducting video calls, etc. Yeah. It has offered that comfort and I guess a little bit of a distraction as well." (Interview_home8) "That's the whole thing, I just I was overjoyed that it happened at that time. Due to that reason [no family visits]. Definitely." (Interview_home5) "Well, who knows what these two would have been like, during lockdown without them. But I feel 100% that they have improved the situation. Yeah. From the point of view of Yes. Company, yes a focus, They can see and think oh yeah and. Remembering even though dementia requires or doesn't allow you to remember, there is definitely recognition. Oh, yes. I know, I'm in the right place, because this is sat next to me." (Interview_home5) "Yes I would say so yeah. Because they're not seeing their relatives. Yeah. So especially the very beginning. But now we've got a screen up and some relatives one at a time can come in for half an hour. At the beginning. There wasn't anybody you just in maybe FaceTime or on the telephone. But yeah, so definitely useful. Yeah, very good." (Interview_home6)</p>
	<p>Cleanliness and infection control (9)</p>	<p>"Those who adopted it and then COVID came in. So it was a case of well to reduce the risk of germs spreading, that it's best that they stay with one person" (Interview_home5) "During COVID, etc, we've got to be more vigilant about cross contamination. And they are quite difficult to keep clean. And the cat. Yeah, we did have a lady that enjoyed feeding it. " (Interview_home8)</p>
	<p>Isolation (5)</p>	<p>"most of the people who benefited most were the ones that were in their rooms all the time. Or weren't particularly having conversations with other residents or anything, with dementia, and were past the group stage and are better on a one to one." (Interview_home1) "the ones who find them most beneficial, are the ones that don't really come out their room. Or don't really socially interact, integrate, they're more things that are more really useful for people that are, you</p>

		<p>know, not really interacting with anything else?" (Interview_home1)</p> <p>"But actually got, we used one when we had a lady in isolation, which is in her room now, because obviously, we're in that period, where she's kind of had that to herself for the whole week. And that's been really helpful in her isolation period as well." (Interview_home4)</p> <p>"She's not having that engagement with other residents. What do we, what can we help her to pass the time, she likes colour but you can only colour for so many hours a day, and yet we put the dog up there, and she liked the dog anyway, before isolation. So we knew it was going to be a winner." (Interview_home4)</p>
Design	Improvements (11)	<p>"I think that this sounds really awful. I know, I know what response I'm going to get from the young lady next to me. She's had lunch. It'd be quite good. If we could always take the skin off (laughs) and wash it or replace it" (Interview_home8)</p> <p>"I think because I think they could feel a little bit more weighted. Yeah. as well. Because obviously, that provides quite a lot of comfort for. People with lots of different needs. Because a few years ago, we had a baby doll. Okay. And they were much more successful if they had a realistic weight to them." (Interview_home8)</p> <p>"So basically, skin it and make it fatter" (Interview_home8)</p> <p>"Yeah I think the actions and everything are sufficient, they don't need to be too over the top. Yeah. And the dog is a bit difficult. I think if it didn't look so much like a puppy. Look, maybe like a small dog. Yeah. A small older dog, maybe? Yeah, yeah. Yes, the sizes are, like you say, wouldn't normally put a dog on the table would you" (Interview_home8)</p> <p>"We took off the scarf because it was being you know, when the dog had a little scarf, and it's a little red scarf. Yeah, we found that the owner was doing, not necessarily good things with that. So I took it away as being either a choke risk or strangulation risk or whatever. Okay. So that's been removed. But apart from that, no, I some of the realistic things on the cat like the paws are just wonderful. It's been so well made. The cat is wonderful." (Interview_home5)</p>

		<p>“Just the weight and the way it sits on their lap. Yeah. Quite. quite important. I think.” (Interview_home1)</p> <p>“Obviously, we've tried to keep them avoid using them around mealtimes and things, you know, to try to keep them clean. And they are washable. But the skin, the skin, tut, the coat doesn't actually, it's not fully removable. From that point of view, maybe, you know, that can be a little bit challenging, which are so careful with them, you know, and I think if you, if we treat them respectfully, as if they if they were real, treat them with a bit of respect, and make sure that when the residents are eating or drinking, that they're not in their hands. You know we used to have a dear lady that used to feed teddy bears. You know, but they were washable Teddy Bear, obviously, our robot pets aren't washable” (Interview_home7)</p> <p>“So I think the dog is perhaps a little bit sturdier. Because it hasn't got moving parts only, like heads and tail wags? Yeah, but it's not so many moving parts.” (Interview_home2)</p> <p>“the only thing that we found, and I spoke to you about before about, this is, the heartbeat seems very, very quiet. It's got a heartbeat but nobody can actually hear it. When you're holding it, you can't feel it.” (Interview_home2)</p> <p>“[The cat] is not squishy enough” (Interview_home2)</p>
	Realistic (9)	<p>“[The dog's] not realistic. Because we've actually got larger ones now. Yeah. And I think they've been better, okay. I mean, there's ones we've managed to pick up on or something. And the functions aren't perhaps, as good. But I think because of the size and the features, people are a lot more happy for it to just be next to them, if that makes sense. Yeah, it's probably a bit more.” (Interview_home8)</p> <p>“I mean, they bark and everything else. Make funny noises. And that, but the ones we've got here have got quite a bit of wear and tear, through their little lives. So, I'm not sure if it's like the how realistic it is. But I think it's definitely got something to do with it. Whether it's the size? I'm not sure. Because obviously the cat you're able to put it onto people's laps onto the armchair,</p>

	<p>chair or the table next to them or something. And it's kind of normal cat behaviour, isn't it? Yeah. Where as the dog? If you set that on the table? It kind of doesn't, not a dog" (Interview_home8)</p> <p>"I think the turning and moving the head was very good. It made them look, you know that they were more realistic. Yeah. The cat lifting its head up to be tickled and rolling over onto his back to be tickled like a real cat would. Yeah, there was a bit more interactive and the dog for that reason, you know and so that was good. That's why I think most took to the cat more than the dog. We have got one that adores the dog, and he feeds it." (Interview_home1)</p> <p>"I mean, the dog to me, it just looks like a soft toy. Yeah. And I mean, the poor cat has got two broken legs. Good job it's not real!" (Interview_home2)</p>
<p>Sound off (8)</p>	<p>"She puts up with it for so long and talks to it for so long and then she gets fed up with it, because every time you move, it sort of makes a noise doesn't it. Whining or barking? She's trying to sleep and it's barking!" (Interview_home1)</p> <p>"I think the cat was more favorable than the dog. But I think that's just because it's a little bit quieter. We had to turn the volume off on the dog a few times." (Interview_home4)</p> <p>"But yeah, I mean, they're just annoying sometimes because obviously there they are. sensors aren't they if you walk past it, and it's a sound somebody's lap and then it's all of a sudden, meow. Yeah. I think the cat, the cat was better than the dog." (Interview_home4)</p> <p>"We have one lady, quite poorly. And she's still really obsessed with the dog makes its way up there. They're not always wanting the noise on though so there has been that." (Interview_home1)</p> <p>"You know, maybe the cat makes a bit of noise when it's moving, to make a little bit less noise? I think that's probably unavoidable. I think they're quite realistic to be honest. The cat meowing and the dog barking isn't as realistic but I think they're pretty good really, yeah I think they're pretty good" (Interview_home7)</p> <p>"It could be irritating. Maybe. Maybe if you turned the cat off, maybe that would be</p>

		better. Or you can mute the mute button, I think.” (Interview_home2)
	Expectations (8)	<p>“Because obviously the cat you're able to put it onto people's laps onto the armchair, chair or the table next to them or something. And it's kind of normal cat behaviour, isn't it? Yeah. Where as the dog? If you set that on the table? It kind of doesn't, not a dog” (Interview_home8)</p> <p>“Exactly, yeah, and I think it's that. Maybe to do with the size again, to use it. Because you said then, 'puppy' and a puppy wouldn't normally sit still at all! And well, yeah, yeah, whereas an older dog will” (Interview_home8)</p> <p>“But especially when you compare the two dogs, together? The large one is more successful. Definitely. But again, as I said, it's probably reinforcing that realism,” (Interview_home8)</p> <p>“The dog is a bit difficult. I think if it didn't look so much like a puppy. Look, maybe like a small dog. Yeah. A small older dog, maybe? Yeah, yeah. Yes, the sizes are, like you say, wouldn't normally put a dog on the table would you” (Interview_home8)</p> <p>“Well, actually, regularly she gently puts it on the floor. Okay, she either pulls it onto her lap and hugs it or puts it on the floor, because that's where she expects a dog to be to be.” (Interview_home5)</p> <p>“Exactly. She puts it down by her ankle and then pats it on the floor. Yeah.” (Interview_home5)</p> <p>“I think what happens is the cat meows all the time. Maybe that's what it is, the dog does a few barks, but they're nice. When a cat meows, you've actually done something wrong.” (Interview_home2)</p>
	Weight and size (7)	<p>“And it's not so heavy because heavy can be a thing. A lot of them are sorta quite slim built by then. And yeah, they are annoying after a while the weight on their legs. The dogs got that disadvantage. It's heavier. Yeah. And it's not so easily sat on someone if you know because it's sat upright. More difficult. Yeah, it's more like got to sit by your side or if it's on your bed, but that doesn't quite fit. So well. As the cat.” (Interview_home1)</p>

		<p>"I think the cat sits a bit more nicely on your lap if you're not mobile. Yeah, the dogs a bit heavier." (Interview_home1)</p> <p>"Yeah, just the weight and the way it sits on their lap. Yeah. Quite. quite important. I think." (Interview_home1)</p>
	Breakage (7)	<p>"We changed this battery obviously and then he just stopped working. So [manager] purchased another one and then the one we've got now has got a problem in it. So really, [...] this replacement one makes a beep just to completely random beep instead of barking or instead of I mean the cat meows and purrs I think the dog just barks, but it beeps and then it's Click, click, click, click, click. So yeah, we're in a problem period at the moment with a dog but the cat is wonderful." (Interview_home5)</p> <p>"Yeah, yeah. I mean, I mean, the dog to me, it just looks like a soft toy. Yeah. And I mean, the poor cat has got two broken legs. Good job it's not real!" (Interview_home2)</p>
	Battery life (4)	<p>"Yeah, actually, battery wise they weren't too bad actually" (Interview_home8)</p> <p>"And the batteries didn't last very long at all. We had to keep changing them, we had to buy the batteries and keep changing them. Because they were used so much." (Interview_home4)</p> <p>"the batteries were pretty substantial actually. I think we only ever changed them like once they were quite good." (Interview_home1)</p>
	Importance of movement (4)	<p>"one of the main things, I guess I appreciated when the first one went wrong, it was just turned off and left next to its owner. she interacted with it much less, so it kind of reinforced the fact the moving and the, well is just the moving as we don't we don't have it barking ever. So it's just a moving and the blinking and turning its head she talks to it because it's doing that. So that's much less and responded much less to it when it stopped moving so that's quite important, it's quite important." (Interview_home5)</p> <p>"when it broke, is that it was she sort of lost interest sort of started to ignore it almost when it didn't move, it was amazing to watch" (Interview_home5)</p>
	Purring as relaxing (2)[2]	<p>"And the purring as well. It's quite soothing, isn't it? Particularly with the lady who really</p>

		<p>benefited, she would sit and just stroke the cat and that would obviously start the cat purring and that's relaxing in itself isn't it." (Interview_home4)</p> <p>"They did like the purring with the cat" (Interview_home2)</p> <p>"Liked the purring of the cat, relaxing" (Calendar_home2)</p>
	Heartbeat enjoyable (1)[2]	<p>"That that was like sort of thud thud thud, that you get with it with a heart. I think that would be quite reassuring." (Interview_home2)</p> <p>"[Resident] loved the cat and dog and felt the heartbeat" (Calendar_home2)</p>
Suitability	Dementia severity (31)	<p>"I think realistically, the cat was, um a lot more accepted than the dog and the dog seem to be useful for people further along." (Interview_home8)</p> <p>"You know, with retaining things with retaining things, you know, with regards to their memory, they're very much in the moment you know, we try to be Stepping into that moment and being in that world, you know, in that bubble that they're in, I guess, perhaps they don't have too much of that. Memories or whatever, you know, each time that they see the pet it's quite new for them [...] and that's what's lovely, they will never grow tired of them" (Interview_home7)</p> <p>"I mean, I can say it does depend on where they are in their journey with dementia, etc. Yeah. But then they do believe the cat is real. Yeah, certainly the gentleman that's adopted. There may be moments where he thinks, oh it's not actually real, but 90% of the time when interacting, he believes it to be real." (Interview_home8)</p> <p>"I'm we, most of our residents here have a dementia. varying levels. But yeah, but yeah the more advanced dementia, residents respond better to it." (Interview_home4)</p> <p>"But most of the people who benefited most were the ones that were in their rooms all the time. Or weren't particularly having conversations with other residents or anything, with dementia, and were past the group stage and are better on a one to one." (Interview_home1)</p> <p>"the ones that haven't got dementia are still really with it, and they aren't that interested in them" (Interview_home1)</p>

		<p>“Possibly because they would just see as a toy as it is. They might say when we first had I did take it around everywhere. And a lot of people, even the staff, were saying oh it’s so lovely, it’s so lovely. They liked it, but they wouldn’t need it. You need, that sort of. How can I put it. Less inhibitions. I suppose when you’ve got dementia, isn’t it? Yeah. You know you don’t think oh, this is stupid. Because it’s a toy. Yeah. You see it as an actual animal. I mean, some people don’t they might throw it across the room. You know, that’s probably what’s happened to the cat.” (Interview_home2)</p> <p>“Yeah they found them really comforting. Yeah. Yeah. Especially more demented. Residents.” (Interview_home6)</p>
	<p>Limited interest [17]</p>	<p>“Short attention but enjoyed talking to it” (Calendar_home2)</p> <p>“Enjoyed the dog company for a while before getting bored” (Calendar_home2)</p> <p>“[Resident] not really interested” (Calendar_home2)</p> <p>“[Resident] enjoyed the feel of the dog but got fed up and threw it away” (Calendar_home2)</p> <p>“[Resident] enjoyed initially and then placed on the floor” (Calendar_home3)</p>
	<p>Think it’s real (14)</p>	<p>“One particular lady that I think like we spoke about this, but she would threaten to call the RSPCA because of a cat trying to let the cat outside except for the people that were less involved.” (Interview_home4)</p> <p>“It is quite incredible, actually how she obviously, I feel that she obviously feels it’s real. And like the other particular resident, my mom obviously thinks it’s a real cat. And then yeah, so she finds it very, very, very comforting.” (Interview_home7)</p> <p>“Residents enjoy it, and if I can send you the video of my mum and how she reacts to the cat, you know, and how gentle she is with it, and actually looking into his eyes, you know, and she’s talking to it as if it’s a real cat.” (Interview_home7)</p> <p>“There may be moments where he thinks, oh it’s not actually real, but 90% of the time when interacting, he believes it to be real.” (Interview_home8)</p> <p>“he would respond really well. She would almost think that they’re real and really, really calming effect on her, for that</p>

		instance, is really, really, really effective.” (Interview_home4)
	Dislike (2)[9]	<p>“There is also a resident that doesn't like them, not to that extent, but doesn't like them. And will ask every now and again, can you point it away from me, I don't like it” (Interview_home5)</p> <p>“[Resident] does not like cat and didn't respond well” (Calendar_home2)</p> <p>“Carried both cat and dog around and said “I'm going to kill these bloody kids”” (Calendar_home4)</p> <p>“[Resident] likes to look but not touch the dog, dislikes cat” (Calendar_home2)</p>
	Wide appeal (7)	<p>“Yes it's been brilliant, brilliant. A lot of them are really really keen on them. Really enjoyed having them, some thinking they were real, some realizing they weren't but enjoyed petting them.” (Interview_home1)</p> <p>“I'll say that they were received by everybody. Yeah. And I think I mean residents that have dementia, I can't say this, you know, for sure. But I would say that they, they feel that they're obviously the residents with dementia, I'm sure that they feel the more realistic, you know, they see them as a real animal in a way. Where the other residents perhaps don't. But I would say all in all they suit everybody, I will tell you that all in all, to everybody, everybody enjoy using them.” (Interview_home7)</p> <p>“We've only ever had 19 residents, I'd say about 15 that had at the time, you know, when we participated with them? Yeah, at some point or another?” (Interview_home1)</p> <p>“You might get a bit either love it, or disinterested. But nothing really negative like that. Nothing severe or saying anything like that at all?” (Interview_home6)</p>
	Reduced mobility (5)[1]	<p>“ay. Took something from it. Yeah. Definitely. Even people that restricted movement, etc. They take into their room if they are like, bed bound and that sort of this. And again, if it had that extra weight, yeah, it would make perhaps a bit more of a difference. Yeah. But yeah, at the end, I think everyone had pretty much positive responses. If the only people that may have been a bit more negative are those that recognize the fact that it wasn't real okay. But then they can still appreciate it for what</p>

		<p>it is, if that makes sense. It might not be used on a frequent basis. Yeah, but still topic of conversation. Yeah. Oh, isn't that clever?" (Interview_home8)</p> <p>"I think the cat sits a bit more nicely on your lap if you're not mobile. Yeah, the dogs a bit heavier." (Interview_home1)</p> <p>"We have one lady, quite poorly. And she's still really obsessed with the dog makes its way up there [to the bedroom]" (Interview_home1)</p> <p>"[Resident] loves the cat, bed bound, adorable moments" (Calendar_home4)</p>
	<p>Previous pets (3)[1]</p>	<p>"He loves that [dog], you know, probably responds to that more than the cat. And that's probably because he had a dog and he loves his dog and his dog came into the garden, you know, and he sees it. It's been really helpful to him and calming him." (Interview_home7)</p> <p>"If they've had dogs, they relate to the dog." (Interview_home2)</p> <p>"[Resident] had a dog before she was taken ill, she is a great animal lover, she kept the dog all afternoon and evening" (Calendar_home1)</p>
	<p>Infantilising (4)</p>	<p>"They're not not useful for people that just have a mild dementia because they they're just seen as toys." (Interview_home4)</p> <p>"We have a couple of negatives. Again, mild dementia a little bit anxious. But the maybe actually a toy, what you're doing, you're talking to a toy, she would make those comments as well, when people engage with the cat or dog or you would invite her over. She'd say, silly people, they're sat Talking to a toy? That kind of reaction would be We've had a few times. Yeah." (Interview_home4)</p> <p>"Yes, absolutely. Because the people who don't have dementia in the home, go, Urgh. Not just not bothered, they think it's a silly thing." (Interview_home5)</p> <p>"There's stages that this lady goes through where, like, if you go up to her and say, you know, is it okay, don't be silly, you know, they'll be they'll be at different stages during the day where she treats it differently because of how she feels. Yeah, sometimes she knows is completely a robot, it's a robot don't be silly." (Interview_home5)</p>

	Staff dislike (1)	<p>“we’ve had barriers, challenges, one staff member is freaked out, scared of it. So in the lounge, it is a communal area, and we have the cat sitting to the right of the doorway, and the dog is in front of the doorway. And when I come in in the morning, and one of the staff members has been on, they’re both under my desk, because she has to ask them for them to be removed.” (Interview_home5)</p>
Nurture	Cuddled and fussed [29]	<p>“Cuddled as a real one, calmed her down” (Calendar_home1) “[Resident] missed her real dog and this helped fill the void, she really enjoyed cuddling and fussing the dog” (Calendar_home1)</p>
	Feeding (8)[5]	<p>“Yeah, we did have a lady that enjoyed feeding it. And she had a puree diet.” (Interview_home8) “Yeah, both, have a good old chat, try feeding them” (Interview_home8) “They were always very covered in food because they like to be fed.” (Interview_home4) “I mean, it’s been fed many chocolate biscuits, we wet wipe it regularly” (Interview_home5) “Someone did try feeding hers one day, when they’re feeding, because they do still like to play with it. She hasn’t tried to feed it ever before but this one particular day she decided it needed to be fed and was feeding it whatever she was eating. And we had to have a bit of a clean out but it was fine” (Interview_home1) “We have got one that adores the dog, and he feeds it.” (Interview_home1) “Sat with them, sort of smoothing them down. One lady wants to feed it, all the time” (Interview_home6) “Feeding the dog peaches and cream” (Calendar_home4) “Obsessed with the dog, trying to feed the dog her food” (Calendar_home4)</p>
	Care for and nurture the pet (8)[5]	<p>“we do have one lady who likes to take it into her room, to care for it, she will put it in her bed and cover it over” (Interview_home7), “And because it is something that he loves and cared for. Not always, but majority of the time. He will soften, lower his tone, start referring to the cat. Very positive for his behaviour really.” (Interview_home8)</p>

		<p>“However, having the robot pets really helped, certainly helped with residents, you know, to keep them calm and focus on on actually having a little animal there to care for and look after and comfort them you know” (Interview_home7)</p> <p>“She's, she's lovely. And she was very caring about the cat. So it seems like they bring out different things in different people.” (Interview_home2)</p> <p>“I mean, [resident] loved that cat. It was her cat. She would look after it.” (Interview_home2)</p> <p>“Well, there was an element of worry for it when it was alive and moving, do we need to do anything we need to take it out, does it the need feeding. I mean, it's been fed many chocolate biscuits, we wet wipe it regularly” (Interview_home5)</p> <p>“That decline, you know, and then she'd say what's wrong with it. I don't know what's wrong with it just because it wasn't moving, not because it wasn't there” (Interview_home5)</p> <p>“[Resident] was obsessed with the dog, trying to feed dog her food, got upset when it wasn't eating” (Calendar_home4)</p> <p>“And I'll just say to him, oh, can you just? Can you just keep an eye on the on the dog or the puppy? For me, just for five minutes and he'll sit and talk to it.” (Interview_home7)</p>
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Appendix M: Ethical approvals

Approval for Study 1 and 2

Held by Gabriel Aguiar Noury, from the Faculty of Science and Technology Ethics Committee.

Approvals for Study 3 (first for the older adults, second to extend the study with roboticists)

18 January 2018

CONFIDENTIAL
Hannah Bradwell
Marta Romeo
Faculty of Science and Engineering

Dear Hannah and Marta

Ethical Approval Application

Thank you for submitting the ethical approval form and details concerning your project.

The use of robots by older people, incorporating (i) therapeutic pet robots (ii humanoid robot

I am pleased to inform you that this has been approved subject to the following amendments:

- 3.1 Paragraph B – what measures will ensure video recording does not capture participants prior to consent (e.g. will cameras be positioned to prevent this)?
- 5.7 The information sheet should include a statement regarding photos taken by Pepper.

Kind regards



Paula Simson
Secretary to Faculty Research Ethics Committee

Cc. Prof Ray Jones
Prof Angelo Cangelosi

8 February 2018

CONFIDENTIAL
Hannah Bradwell
Faculty of Science and Engineering

Dear Hannah

Amendment to Approved Application

Application Title: The use of therapeutic pet robots

I am pleased to inform you that the Committee has granted approval to you for the amendments to the application originally approved by the Faculty on 18 January 2018.

Kind regards



Paula Simson
Secretary to Faculty Research Ethics Committee

Cc. Prof Ray Jones

Approval for Study 4

23rd January 2018

CONFIDENTIAL

Hannah Bradwell
Korner Flat
Park Bottom
Redruth
TR15 3UF

Dear Hannah,

Application for Approval by Faculty Research Ethics Committee

Reference Number: 17/18-876

Application Title: The use of therapeutic pet robots in care homes for people with dementia

I am pleased to inform you that the Committee has granted approval to you to conduct this research.

Please note that this approval is for three years, after which you will be required to seek extension of existing approval.

Please note that should any MAJOR changes to your research design occur which effect the ethics of procedures involved you must inform the Committee. Please contact Sarah Jones (email hhethics@plymouth.ac.uk).

Yours sincerely

Professor Paul H. Artes, PhD MC Optom
Professor of Eye and Vision Sciences
Co-Chair, Research Ethics Committee - |
Faculty of Health & Human Sciences and
Peninsula Schools of Medicine & Dentistry

Approval for Study 5

As above – same study as Study 4.

Approval for Study 6

20 February 2018

CONFIDENTIAL
Hannah Bradwell
School of Nursing and Midwifery

Dear Hannah

Ethical Approval Application

Thank you for submitting the ethical approval form and details concerning your project:

A comparison of commercially available companion robots and alternatives

I am pleased to inform you that this has been approved.

Kind regards



Paula Simson
Secretary to Faculty Research Ethics Committee

Cc. Prof Ray Jones
Dr Serge Thill

Approval for Study 7a

Requirement for ethics waived by Faculty of Science and Engineering Committee, as there are no human participants.

Approval for Study 8



13 November 2018

CONFIDENTIAL

Hannah Bradwell
School of Nursing and Midwifery

Dear Hannah

Ethical Approval Application

Thank you for submitting the ethical approval form and details concerning your project:

A comparison of commercially available companion robots and alternatives

I am pleased to inform you that this has been approved.

Kind regards

A handwritten signature in black ink, appearing to read "Paula Simson".

Paula Simson
Secretary to Faculty Research Ethics Committee

Cc. Prof Ray Jones
Dr Serge Thill

Approval for Study 9

Ethics not required – study is a post-reflection on previous work.

Approval for Study 10



12 July 2018

CONFIDENTIAL

Hannah Bradwell
School of Nursing and Midwifery

Dear Hannah

Ethical Approval Application

Thank you for submitting the ethical approval form and details concerning your project:

A comparison of commercially available companion robots and alternatives

I am pleased to inform you that this has been approved.

Kind regards

A handwritten signature in black ink, appearing to read "Paula Simson".

Paula Simson
Secretary to Faculty Research Ethics & Integrity Committee

Cc. Prof Ray Jones
Dr Serge Thill

Approval for Study 11 pilot

7 August 2018

CONFIDENTIAL
Hannah Bradwell
Felicity Allman
School of Nursing and Midwifery

Dear Hannah and Felicity

Ethical Approval Application

Thank you for submitting the ethical approval form and details concerning your project:

A comparison of commercially available companion robots and alternatives

I am pleased to inform you that this has been approved.

Kind regards



Paula Simson
Secretary to Faculty Research Ethics Committee

Cc. Dr Serge Thill
Prof Ray Jones

Approval for Study 11



North East - Newcastle & North Tyneside 2 Research Ethics Committee
NHS BT Blood Donor Centre
Holland Drive
Newcastle upon Tyne
Tyne and Wear
NE2 4NQ
Telephone: 0207 1048091

13 November 2019

Miss Hannah Bradwell
31 Rosevine Way
Camborne
TR14 0DY

Dear Miss Bradwell

Study title: The use of therapeutic pet robots for older people and those with dementia in the care home setting
REC reference: 19/NE/0319
IRAS project ID: 268571

Thank you for your letter of 31 October 2019, responding to the Committee's request for further information on the above research [and submitting revised documentation].

The further information has been considered on behalf of the Committee by the Chair.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a **favourable ethical opinion** for the above research on the basis described in the application form, protocol and supporting documentation [as revised], subject to the conditions specified below.

Mental Capacity Act 2005

I confirm that the committee has approved this research project for the purposes of the Mental Capacity Act 2005. The committee is satisfied that the requirements of section 31 of the Act will be met in relation to research carried out as part of this project on, or in relation to, a person who lacks capacity to consent to taking part in the project.

Conditions of the favourable opinion

Appendix N: Author contributions

Publication	Author Contributions
1	All authors contributed to study conception and design. Data collection and analysis was conducted by HB and GA. The first draft of the manuscript was written by GA. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.

2	All authors contributed to study conception and design, led by HB. Data collection and analysis was conducted by HB and KE. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
3	All authors contributed to study conception and design, led by HB. Data collection was conducted by HB. Microbial expertise and analysis was provided by CWJ and JL. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
4	All authors contributed to paper conception, led by HB. MSL provided microbial expertise. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
5	All authors contributed to study conception and design, led by HB. Data collection was conducted by HB and JR and analysis was conducted by HB. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
6, 7	All authors contributed to study conception and design, led by HB. Data collection and analysis was conducted by HB. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
8	All authors contributed to study conception and design. Data collection and analysis was conducted by HB, GA and KE. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
9	All authors contributed to paper conception, led by HB. Data was re(analysed) by HB. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
10	All authors contributed to study conception and design, led by HB. Data collection and analysis was conducted by HB, ST and RJ. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
11	All authors contributed to study conception and design, led by HB. Data collection was conducted by HB, DS and KE and analysis was conducted by HB and KE. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.

12	All authors contributed to study conception and design, led by HB. Data collection and analysis was conducted by HB, RJ and KE. The first draft of the manuscript was written by HB. All authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript. Supervision was provided by RW, ST and RJ.
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