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Exploring the effect of implementing affordable socially assistive pet robots in eight care homes before and during the COVID-19 pandemic: a stratified cluster randomised controlled trial and mixed-method study.

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Data sharing

The data sets generated during and analysed during the current study are available from the corresponding author on reasonable request.

Acronyms

JfA – Joy for All

RCT – Randomised controlled trial

EPIC – eHealth Productivity and Innovation in Cornwall and the Isle of Scilly

NPI – Neuropsychiatric inventory

ITT – Intention to treat

Keywords: Social robots, companion robots, wellbeing, older adults, dementia, robot pets

Compliance with Ethical Standards

The authors declare that they have no conflict of interest.

Abstract

Background

Robot pets may assist towards challenges of supporting an aging population with growing dementia prevalence. Prior work focused on impacts of robot seal Paro on older adult wellbeing, but recent studies suggest good acceptability and implementation feasibility of more affordable devices (Joy for All (JfA) cats and dogs), yet effectiveness research was limited.

Methods

We conducted an eight-month, stratified, cluster randomised controlled trial, in eight care homes in Cornwall, UK. Over four months, four care homes each received two JfA devices (one cat and dog), and four homes received care as usual (intervention and control group). Psychometrics were collected pre and post intervention, to compare change from baseline to follow-up in the intervention vs control group. In the final four months, all eight care homes had devices, but only qualitative data was collected, due to Covid-19 and reduced capacity. The primary outcome was neuropsychiatric symptoms (Neuropsychiatric Inventory – Nursing Home version (NPI)). Care provider burden was a secondary outcome (occupational disruptiveness NPI subscale), alongside the Challenging Behaviour scale, Holden Communication scale, Campaign to End Loneliness questionnaire and medication use. Qualitative data was collected through care staff observation calendars and end-of-study interviews to understand use, experience and impact. We also collected demographic data and assessed dementia severity. In total, 253 residents had robot interaction opportunities, and 83 were consented for direct data collection. This trial was pre-registered on Clinicaltrials.gov (<https://clinicaltrials.gov/ct2/show/NCT04168463>), and is reported following the CONSORT 2010 statement: extension to cluster randomised trials.

Results

There was a significant difference in total change from baseline to follow-up for NPI ($p=.000$) and occupational disruptiveness ($p=.031$) scores between the intervention and control group.

Neuropsychiatric symptoms increased in the control group, while decreasing in the intervention group. No significant difference was seen for communication issues or challenging behaviour. On NPI sub-domains, there was a significant difference from baseline to follow-up for delusions ($p=.034$), depression ($p=.010$), anxiety ($p=.001$), elation ($p=.023$) and apathy ($p=.009$), all of which decreased in the intervention group and increased slightly in the control group. The summative impact results suggested most residents who interacted with robots received a positive impact (85%, 46/54). Those who interacted had significantly higher dementia severity scores ($p=.001$) than those who did not interact. The qualitative results suggested good adoption and acceptability, suitability for subjectively lonely individuals, lack of novelty effect through sustained use and demonstrated 'reasons for use' of robots were entertainment, anxiety and agitation.

Conclusion

Affordable robot pets hold potential in improving wellbeing for care home residents and people with dementia, including reduced neuropsychiatric symptoms and occupational disruptiveness. This work suggests no novelty effect, and contributes towards understanding robot pet suitability, finding interactions were more common among residents with more moderate/severe dementia and potentially those subjectively lonely.

Introduction

Robot pets may offer a psychosocial method of improving wellbeing for older adults and people with dementia. The most well researched robot pet is Paro, the robot seal [1, 2]. The use of Paro for individuals in care homes, or with dementia suggests benefits of reduced agitation and depression [3], more adaptive stress response [4], reduced loneliness [5], reduced care-provider burden [4, 6] and reduced psychoactive and analgesic medication use [7]. However, Paro is expensive at

approximately GBP 5000 per robot, and this limits the number of people able to benefit from interactions [8]. The impact of this cost is evident in the limited number of real-world implementations of Paro. Additionally, robot pet alternatives to Paro have received much less research interest, creating further requirement for work such as this.

The Joy for All (JfA) cat and dog seem to be preferred by older people in the UK to Paro, are more affordable [9-12] and are now widely used [13] although there is relatively little formal research on their benefits. A longitudinal, 6-month staff diary study suggested that JfA devices had potential benefits of reduced agitation, increased communication, positive experiences and de-escalated situations [14]. Other studies of JfA suggested possible positive impacts [15], including for communication, with conversations being facilitated [16, 17], and providing companionship [18, 19], improving loneliness, mental wellbeing and purpose [20]. However, there were also some incidences of negative response such as jealousy and over-attachment [14], or dislike and rejection [16]. Much of the prior work with JfA devices has been conducted with community-dwelling older adults [16-18, 20] and is mainly qualitative, with small samples [17, 18].

Wexler et al. [21] conducted a randomised controlled trial (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. Participants with the JfA robot pet experienced less delirium, loneliness and fewer falls. There was no significant effect found for cognition or depression. However, the study was conducted within a hospital rather than care home and participants received a robot each which would be costly for care homes, even at the more affordable price. The study also did not measure impacts on symptoms such as agitation or anxiety, commonly reported outcomes for robot pets [2, 14]. 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.

Marsilio et al. [19], conducted the most relevant study, and provided a JfA cat to 11 care home residents for 6 weeks, the authors measured agitation, oxygen saturation, heartrate and medication use at baseline and following intervention. Qualitative weekly reflections were also maintained. They observed a decrease in agitation and increase in oxygen saturation. However, the study had a small sample, was over a short timeframe, and had no control group. They provide limited detail on device implementation, such as quantity, intervention dose, intervention schedule or method of use (e.g. facilitated/un-facilitated interactions, individual/group sessions).

Aims

We aimed to address the lack of longer-term, real-world research, with a large sample of care home residents, exploring effectiveness of affordable robot pets. In particular we:

- Explored if affordable robot pets led to improved wellbeing for the intervention group in comparison to control group ,
- Aimed to provide an indication on if robots are robust and engaging over 8 months,
- Identified under what circumstances and for which care home residents the robot pets were 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 registered on clinicaltrials.gov (19/11/2019,

reference NCT04168463), and is reported following the CONSORT 2010 statement: extension to cluster randomised trials.

Research Design

This study was planned as a stepped-wedge, stratified, cluster randomised controlled trial (RCT) [22]. The clusters were eight care homes. However, the trial commenced in January 2020 and the COVID pandemic, resultant care home lock downs, staff workloads and resident deaths, meant that we were unable to carry out the RCT as originally planned. This variation on the planned RCT is described in Appendix 1. The study as conducted (Figure 1) comprised a four month, parallel, stratified, cluster RCT with four care homes in each arm. This was followed by a qualitative study over an additional four months where all eight care homes received robots ending with staff telephone interviews and a summative impact question. The summative impact question was a simple tool designed by the authors, where staff were asked for each resident what impact the robots had; No impact, positive, negative, no interaction.

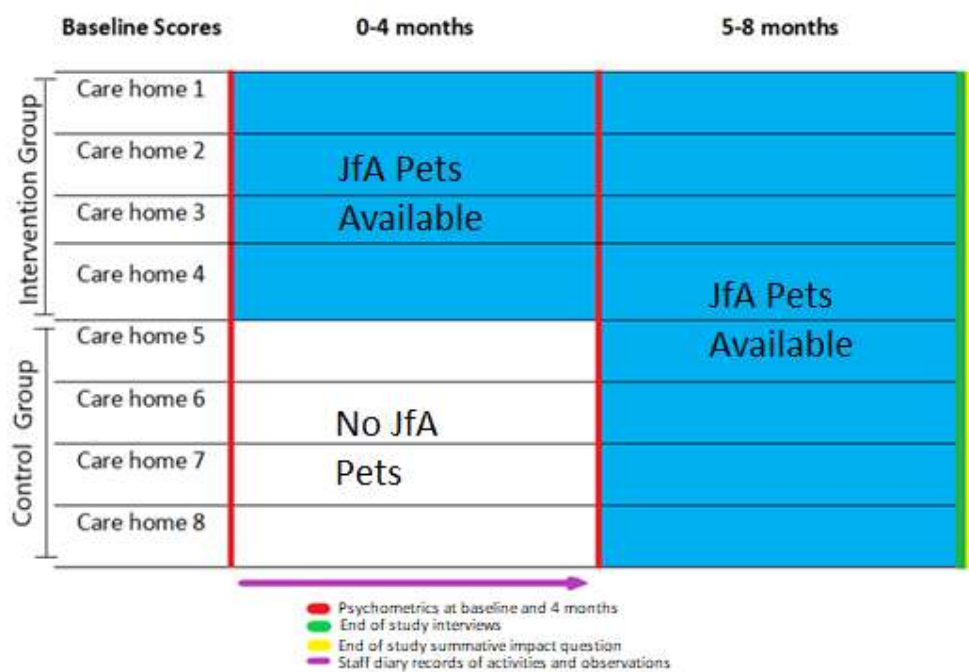


Figure 1. Research design and data collection

As demonstrated in Figure 1, 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 impact question.

Collaborating sites

Eight residential care facilities sited in rural towns in Cornwall, comprising four care homes with nursing care and four residential only care homes, with a total resident population of 253, had agreed to collaborate before the start of the project. Sixteen care staff became collaborators for the purpose of completing scales and recording observations of residents (Table 1). Homes were eligible

for participation if they provided residential care or nursing to older adults, and were situated in Cornwall, UK, allowing for regular researcher visits.

Recruitment of residents for collection of individual data

In November 2019 researchers and care staff talked to residents or residents' relatives to gauge interest in participation. Prior to randomisation, 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 distress if they did not like the robots. The 83 care home residents recruited for directly collected data comprised 61 females and 22 males and represented 33% (83/253) of all residents who had access to the robot pets. To allow stratified randomisation staff assessed consenting residents using the Dementia Severity Rating Scale [23]. This provides a score 0–54, with 0-18 being mild, 19-36 being moderate and 37-54 being severe dementia.

Randomisation

The eight care homes were stratified into four pairs based on number of consented residents, average age and average dementia severity (as key factors likely to influence behaviour) using randomly permuted blocks of size 2 by HB. 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 (KE) using a random number generator to the intervention or control arm in the ratio 1:1 (homes 1-4 and homes 5-8, Table 1).

Data Collection

Individual participant data: We aimed to collect pre/post data on five scales for 83 residents who had consented. The primary outcome was neuropsychiatric symptoms, measured with the Neuropsychiatric Inventory (NPI) completed by staff [24] with higher scores indicating higher symptom prevalence. Secondary outcomes were measured with the Challenging Behaviour Scale [25], Holden Communication Scale [26], and the NPI occupational disruptiveness sub-domain scale, all collected by staff. Residents were assisted in completing directly the three-item Campaign to End Loneliness [27] questionnaire. The five scales were completed at baseline (December 2019) and at four months (May, 2020). Finally, staff indicated, through a summative impact question, whether each resident had i) no interaction with robots, ii) robots had a negative impact, iii) robots had no impact or iv) robots had a positive impact for all participants 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 collection tools for individual outcomes at baselines and four months:

Primary outcome:

- Neuropsychiatric Inventory (NPI) Nursing Home version [24], with the total score scored 0-120, with higher scores indicating higher symptom prevalence.

Secondary outcomes:

- Challenging Behaviour Scale [25], scored 0-400, with higher scores indicating most challenging behaviour,
- Holden Communication Scale [26], scored 0-48, with higher scores indicating greater communication challenges,
- Campaign to End Loneliness Measurement Tool (3-item) [27], scored 0-12, with higher scores indicating greater loneliness,
- NPI subdomain scales [24], scored 0-12, and the NPI occupational disruptiveness scale, scored 0-50, with higher scores indicating more disruptiveness.

Cluster (care home) level data at eight months: Moyle et al. [28] 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. Collaborating care staff in all homes were encouraged to record observations on their calendars using an experience sampling method [29]. Based upon our previous use of diaries [14] we created wall-hung calendars for data entry (Figure 2).

Activities Weekly Calendar					WEEK COMMENCING FEBRUARY 3 RD 2020
STAFF MEMBER NAME/ROLE	NUMBER OF RESIDENTS INTERACTING TODAY AND INITIALS (E.G. Z - 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 21: Example calendar for recording of activities, showing Monday and Tuesday rows (full page includes all days of the week)

Staff were asked to record notes on the calendar each time they observed resident-robot interactions, where possible. We also conducted qualitative semi-structured interviews with care staff at eight months, with open questions aiming to understand the robots use, engagement, impact and the experience of staff and residents, as below.

Semi-structured interview guide, text in brackets was not spoken but provided as notes for the researchers, additionally questions on benefits were only asked if benefits were mentioned

- Tell me about your experience with the robot pets here at (name of home)?
- How were the robot pets used?
- Was there any impact? (positive or negative impact – follow up with please explain, if benefits are mentioned, how many residents benefitted, how?)
- (If benefits were mentioned above) Which residents benefitted? Would you say there were residents the pets were more or less suited to based on your first-hand experience?
- Were there any particular features of the pets you perceived positively based on their use here with residents?
- Were there any particular features of the pets you perceived negatively based on their use here with residents?
- How did the 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?

Intervention

In mid-January 2020, homes in the intervention group were gifted a JfA cat and dog to keep indefinitely, and use or not use as they felt appropriate. The researcher provided infection control information [30], providing care homes with the cleaning protocol and informing them of products to use. This study aimed to respond to limitations of trials with highly controlled intervention doses, and explore robot pet effectiveness rather than efficacy [31]. The researcher discussed past research with care home staff, providing examples and ideas, including prior work that implemented robots with structured daily group or individual sessions [3, 28], or used robots ‘when required’ for reducing loneliness, anxiety, depression or agitation, as in previous research with Paro [32]. Decisions on robot use were then left within the professional judgement of care staff. It is likely the fourth month of the trial the pandemic 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.

Sample size

The sample size was primarily informed by feasibility and the number of residents in each home providing consent, but we calculated the minimum number required for the total sample. Based on previous work reporting on the minimal clinically important difference for the original NPI [33], we calculated using the lower value of 2.77 an estimated SD of 3.31. To detect a difference of 2.77 between groups, based on 80% power and 5% significance, a sample size of 25 per condition would be required, inflated by 20% to account for any loss to follow up, creating a total sample size of at least 70 individuals.

Data Analysis

Descriptive statistics are presented as mean (sd), median (IQR) and n (%). The change from baseline to 4 months on the primary and three secondary ordinal scales were compared between the control and intervention group using Mann Whitney U test. SPSS (IBM SPSS 25) was used for statistical analysis. A p-value of <0.05 was considered to indicate statistical significance.

Qualitative diaries and interviews were individually subject to content analysis, and then reported together due to great similarity of themes. Content analysis follows similar processes to thematic analysis, involving coding and categorising of textual information, however the frequency of occurrence is of additional importance [34].

Quantitative Scales

For the quantitative measures, we first report the primary (NPI) and secondary psychometric outcomes (Communication, Challenging Behaviour, Occupational Disruptiveness), we report 'intention to treat' (ITT) results, for all residents as randomised who survived to four month follow up (n=63). We then report NPI subdomain results, followed by 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.

Results

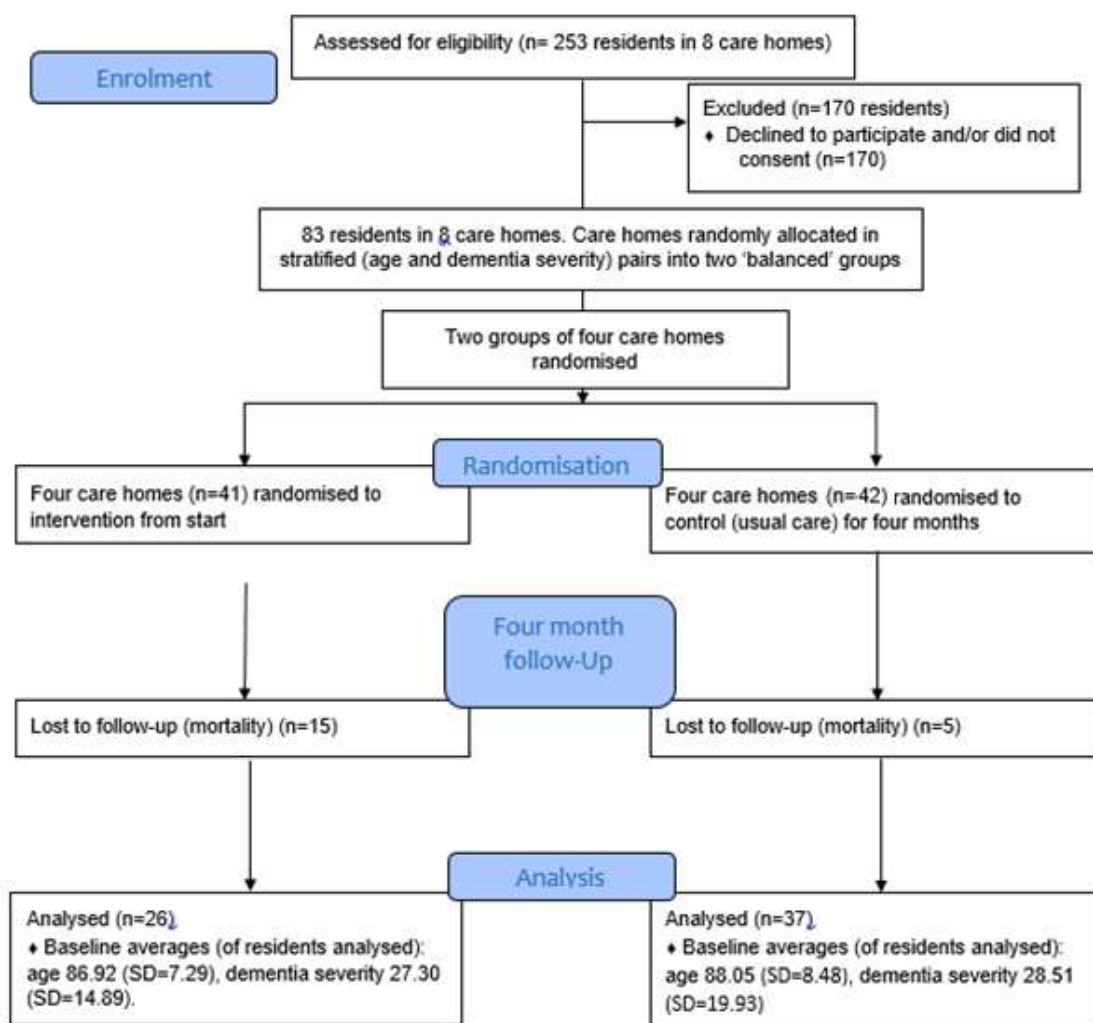


Figure 32: Consort diagram of trial recruitment, allocation and analysis of RCT data

Participants: The average age of consented participants was 87.21 (7.42), average dementia score was 32.11 (10.52) (Table 1). Twenty of the 83 residents recruited died during the study, leaving 63 participants for analysis (49 females, 14 males) (Table 1, Figure 3). There was no difference in dementia severity ($U=513$, $n=63$, $p=.650$) or age ($U=549$, $n=63$, $p=.341$) for residents included in analysis between intervention and control groups.

Figure 3 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, we carried out more detailed analysis of deaths and enquired with care home staff. Further details are given in Appendix 2.

Table 1: Demographic make-up of the participating homes and consented participants

Home	Site Type	Staff Collaborators	Total Residents	Consented Residents	Gender M – Male F – Female	Residents Included in Analysis
1	Nursing	2	33	9	3M 6F	3
2	Residential	2	16	11	1M 10F	10
3	Nursing	2	36	9	4M 5F	4
4	Residential	2	36	12	4M 8F	9
5	Nursing	2	36	7	4M 3F	4
6	Residential	2	27	13	4M 9F	12
7	Nursing	2	31	13	1M 12F	12
8	Residential	2	38	9	1M 8F	9
Totals		16	253	83	22M 61F	63

The homes with blue shading represent those in the intervention group (see Figure 1).

Table 2: Demographic make-up of the consented participants

Home	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	87.67 (6.73)	86.33 (7.37)	40.56 (9.38)	43.33 (9.71)
2	90.73 (7.85)	90.10 (7.97)	19.63 (12.82)	17.30 (10.76)
3	82.89 (2.51)	83.00 (7.39)	44.11 (8.25)	37.5 (7.59)
4	85.08 (6.33)	85.33 (6.1)	32.58 (15.77)	28.56 (15.58)
5	86.29 (10.05)	87.75 (9.60)	36.14 (10.07)	35.75 (7.58)
6	90.46 (9.53)	89.42 (9.14)	5.23 (5.93)	4.75 (5.93)
7	85.15 (8.34)	85.75 (8.41)	46.77 (6.13)	47.33 (6.03)
8	89.44 (8.00)	89.44 (8.00)	31.89 (15.84)	31.89 (15.84)
Totals	16	87.21 (7.42)	87.14 (8.00)	32.11 (10.52)

The homes with blue shading represent those in the intervention group (see Figure 1)

Psychometric analysis

Table 3: 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.

Scales (scoring)	ITT Analysis (as randomised) (n=63)							
	Baseline				Follow Up			
	Control (n=37)		Intervention (n=26)		Control (n=37)		Intervention (n=26)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Communication (0-48)	20.57 (15.13)	21.00 (29.5)	16.58 (11.85)	15.00 (20.75)	21.97 (15.12)	22.00 (30.00)	17.23 (15.33)	14.00 (29.75)
Challenging Behaviour (0-400)	54.86 (56.95)	32.00 (82.00)	43.38 (43.02)	26.00 (53.00)	48.22 (53.98)	29.00 (73.00)	31.85 (38.39)	19.50 (36.00)
Neuro-Psychiatric Inventory (0-120)	16.64 (16.41)	16.00 (13.50)	19.19 (17.08)	15.00 (22.50)	19.41 (18.72)	11.00 (26.00)	9.62 (7.83)	9.00 (10.75)
NPI Occupational Disruptiveness (0-50)	5.51 (6.37)	4.00 (8.00)	4.42 (4.86)	3.00 (7.00)	5.46 (6.26)	3.00 (8.50)	3.19 (4.54)	1.00 (3.25)

Table 4: Difference from baseline to follow up 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.

Scales (scoring)	ITT Analysis (as randomised) (n=63)		
	Mean difference baseline to follow up		Test of difference control vs intervention
	Control (n=26)	Intervention (n=20)	Mann-Whitney U test results
Communication (0-48)	1.41 (6.00)	0.65 (7.54)	$p=.181$
Challenging Behaviour (0-400)	-6.65 (25.65)	-11.54 (23.92)	$p=.345$
Neuro-Psychiatric Inventory (0-120)	2.76 (9.43)	-9.58 (14.06)	$p=.000$
NPI Occupational Disruptiveness (0-50)	-0.05 (2.47)	-1.23 (2.53)	$p=.031$

For all scales, higher scores indicate greater prevalence of challenges

Table 4 demonstrates that based on 'ITT' analysis, there was 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 5: 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)	Baseline				Follow Up			
	Control (n=37)		Intervention (n=26)		Control (n=37)		Intervention (n=26)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Delusions	.76 (2.46)	.00 (.00)	1.57 (3.34)	0 (.25)	1.43 (3.18)	.00 (.50)	.19 (.80)	.00 (.00)
Hallucinations	.49 (2.04)	.00 (.00)	.73 (1.95)	.00 (0.00)	1.03 (2.69)	.00 (.00)	.27 (.87)	.00 (.00)
Agitation	4.68 (3.86)	4.00 (7.50)	3.42 (4.20)	2.5 (6.00)	3.70 (4.27)	2.00 (7.00)	1.00 (2.4)	.00 (.25)
Depression	2.43 (3.21)	2.00 (3.00)	2.08 (2.53)	.50 (4.50)	3.03 (2.94)	2.00 (5.00)	1.62 (3.03)	.00 (2.50)
Anxiety	2.30 (3.19)	1.00 (3.50)	3.31 (4.25)	.00 (8.00)	2.92 (3.55)	2.00 (6.00)	.84 (2.12)	.00 (.00)
Elation	2.30 (3.19)	.00 (.00)	1.31 (2.65)	.00 (2.00)	.84 (2.28)	.00 (.00)	.92 (2.61)	.00 (.00)
Apathy	2.24 (2.56)	2.00 (4.00)	3.58 (3.30)	4.00 (6.00)	2.76 (3.55)	2.00 (4.00)	2.38 (3.45)	.00 (4.00)
Disinhibition	.78 (2.76)	.00 (.00)	.37 (1.30)	0 (.00)	.78 (2.76)	.00 (.00)	.00 (.00)	.00 (.00)
Irritability	2.62 (3.36)	1.00 (4.00)	1.54 (3.05)	.00 (2.00)	2.59 (3.48)	.00 (6.00)	1.19 (2.83)	.00 (1.25)
Motor Behaviours	.14 (.67)	.00 (.00)	1.31 (2.69)	.00 (.75)	.32 (1.11)	.00 (.00)	1.19 (2.68)	.00 (.00)
Sleep Behaviours	1.22 (2.85)	.00 (.50)	1.38 (2.74)	.00 (2.25)	.24 (1.04)	.00 (.00)	1.27 (2.91)	.00 (.50)
Eating Behaviours	.46 (1.10)	.00 (.00)	1.81 (4.10)	.00 (.00)	.35 (.92)	.00 (.00)	.88 (2.80)	.00 (.00)

Table 6: Difference from baseline to follow up of the Neuro-psychiatric inventory for the intervention and control group

Scales (scored 0-12)	ITT Analysis (as randomised) (n=63)		
	Mean difference baseline to follow up		Test of difference control vs intervention
	Control (n=37)	Intervention (n=26)	Mann-Whitney U results
Delusions	.68 (2.85)	-1.38 (3.46)	$p=.034$
Hallucinations	.54 (1.48)	-.46 (2.21)	$p=.064$
Agitation	-.97 (2.93)	-2.42 (3.76)	$p=.216$
Depression	.56 (2.30)	-.46 (3.19)	$p=.010$
Anxiety	.62 (1.93)	-2.46 (4.37)	$p=.001$
Elation	.62 (2.00)	-.38 (2.47)	$p=.023$
Apathy	.51 (2.43)	-1.19 (3.14)	$p=.009$
Disinhibition	.00 (.00)	-.35 (1.29)	$p=.084$
Irritability	-.03 (3.47)	-.35 (3.39)	$p=.551$
Motor Behaviours	.19 (.81)	-.12 (.59)	$p=.100$
Sleep Behaviours	-.97 (2.98)	-.12 (.99)	$p=.187$
Eating Behaviours	-.11 (.66)	-.92 (3.26)	$p=.344$

When looking at the individual domains, there was 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. Appendix 3 demonstrates issues in normality of the data, justifying choice of non-parametric analysis.

Summative Impact Question

Table 7: 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. Of the residents reported to interact (54/81), 85% (46/54) were reported to have a positive experience. Table 7 demonstrates that most residents who survived the 8 months, and were included in analysis (61/81) interacted with the pets (75%, n=46/61), and that most (66%, n=40/61) had a positive impact, 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 7 suggesting nearly a quarter of residents included in analysis (n=15/61) did not interact with robots, we report a comparison of characteristics of residents who did and did not interact to comment on suitability.

Difference between interacting and non-interacting residents

Table 8: 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 Mann-Whitney U
Communication	22.22 (13.29)	11.20 (11.98)	p=.005
Challenging Behaviour	61.02 (54.73)	22.20 (26.27)	p=.003

Neuro-Psychiatric Inventory	20.28 (18.09)	11.40 (9.06)	<i>p</i> =.057
NPI Occupational Disruptiveness	6.15 (6.23)	2.27 (2.84)	<i>p</i> =.010
Dementia Severity	33.46 (15.60)	14.73 (16.03)	<i>p</i> =.001
Age	87.02 (7.68)	88.47 (9.08)	<i>p</i> =.318

Residents who subsequently went on to interact with robots had significantly higher dementia severity scores than residents who did not interact (Table 8). 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.

That many care homes restricted shared robot use from four months onwards would have influenced some residents not interacting, particularly in control homes where robots were only provided from month 5. However, homes reported 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 not pursuing interactions with residents who were disinterested, feeling they were best placed with ‘adoptees’ in any case.

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 about 25% (248/(8*120)) of care-home-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, 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 9). In control homes, typical activities including singing, manicures, reminiscence, television, garden games, hairdresser visits and quizzes.

Table 9: 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 10: Content Analysis of Qualitative Interviews and Calendar Entries

Theme Explanation	Codes (n in interviews) [n in diaries]	Example Evidence
Adoption <i>Evidence strongly supported good robot adoption into services, and usually by particular 'adoptee' residents</i>	Love (11)[13]	"He loved it. It was it was almost emotional watching her, react, and respond to it" (Interview_home4)
	Ownership (18)[6]	"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)
	Individual use (9)[14]	"Mostly individual [...], to begin with there was a few group sessions [...]. 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 [...], with dementia, and were past the group stage." (Interview_home1)
	High level of usage [12]	"[Resident] has kept the dog all day" (Calendar_home1)
	Jealousies or possessiveness (6)[6]	"She doesn't like to give it back really. She doesn't know that it's not a real cat. [...] But we have to get it back off. Can be quite challenging, she does love it though" (Interview_home7)
	No novelty (9)	"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)
	Naming (7)	"One gentleman basically adopted the cat, and named him" (Interview_home8)
	Group sessions [5]	"Enjoyed cuddles in group session" (Calendar_home1)
	Personalising (1)	"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 its just stayed on there." (Interview_home5)
Wellbeing effects, particularly mood <i>Evidence strongly supported wellbeing benefits</i>	Calming (10)[20]	"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 [...] getting any, any worse, Yeah, it will calm them down and help distract them from [escalation]" (Interview_home7)
	Enjoyment (1)[19]	"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)
	Anxiety reduced (3)[13]	"We had one particular lady that it worked for every single time, it lowered her anxiety." (Interview_home4)
	Companionship (7)[6]	"They love the companionship, they you know, they thought it was beneficial as a human talking to them." (Interview_home1)
	Smiles, happiness (1)[9]	"[Resident] talked to the dog, lots of smiles" (Calendar_home4)
	Engaging resident (10)	"[Residents were] more interactive. Not falling asleep or whatever, instead she was interacting with the dog and with other people about the dog." (Interview_home2)
	Relaxing or settling [7]	"Enjoyed sitting with the cat, helped relax him" (Calendar_home4)
	Mood improved (7)	"Mood, definitely the moods. Yeah, it lifted quite a few of their moods." (Interview_home6)
	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]	“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)
	Agitation reduced [5]	“[Resident] was feeling very agitated, sat with the dog in lounge and it really calmed her down” (Calendar_home4)
	Entertainment and laughter (1)[3]	“[Resident] laughed at the dog because she said something and dog barked as it’s response” (Calendar_home4)
	Therapeutic (3)	“She’s stroking it everyday regularly. Yeah. So that’s nice, isn’t it? That’s one of the therapeutic things about pets, it’s the touch when you’re stroking it.” (Interview_home5)
	Reassurance (3)	“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)
	Sundowner, (2)	“She was a Sundowner as well [...] 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.” (Interview_home4)
	Reduced boredom (1)[1]	“But it’s there if they want it, need it, yeah. They’re upset, they’re bored, give them the dog.” (Interview_home2)
	Enabled eating [1]	“Calms her down and makes her eat by sharing with the dog” (Calendar_home3)
Effects on Communication <i>Evidence supported robot impact on residents’ communication, with the pets and people, further to improving speech capabilities</i>	Communication - pet [25]	“[Resident] loves to chat to cat” (Calendar_home4)
	Communication with others, and speech (19) [2]	“Sometimes her speech is really quite muddled. However, when you put the cat in front of her [...], her speech becomes very clear as she talks to it” (Interview_home7)
	Reminiscence (5)[1]	“You can get talking about their dog [...]. Yeah, it is very much reminiscence because that’s what they see as their dog. This is them, this is my dog” (Interview_home2)
	Interaction (4)	“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)
Isolation and Covid <i>Evidence showed particular benefits of robot pets as a supporting strategy against loneliness and isolation in response to the Covid-19 pandemic</i>	Covid use (15)	“Well, who knows what these two would have been like, during lockdown without them. But I feel 100% that they have improved the situation.” (Interview_home5)
	Cleanliness and infection control (9)	“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)
	Isolation (5)	“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 know, not really interacting with anything else?” (Interview_home1)
Design <i>Staff suggesting a few possible design improvements based on their experience, and commented on positive and negative design factors.</i>	Improvements (11)	“It’d be quite good. If we could always take the skin off (laughs) and wash it or replace it” (Interview_home8)
	Realistic (9)	“I think the turning and moving the head was very good. It made them look, you know that they were more realistic.” (Interview_home1)
	Sound off (8)	“We have one lady, quite poorly. And she’s still really obsessed with the dog [...]. They’re not always wanting the noise on though so there has been that.” (Interview_home1)
	Expectations (8)	“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)

	Weight and size (7)	"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)
	Breakage (7)	"And I mean, the poor cat has got two broken legs. Good job it's not real!" (Interview_home2)
	Battery life (4)	"The batteries were pretty substantial actually. I think we only ever changed them like once they were quite good." (Interview_home1)
	Importance of movement (4)	"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)
	Purring as relaxing (2)[2]	"Liked the purring of the cat, relaxing" (Calendar_home2)
	Heartbeat enjoyable (1)[2]	"[Resident] loved the cat and dog and felt the heartbeat" (Calendar_home2)
Suitability <i>The data gave some insight into the most suitable use context for use with residents, including those with dementia and those isolated, perhaps due to mobility impairments</i>	Dementia severity (31)	"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)
	Limited interest [17]	"[Resident] enjoyed the feel of the dog but got fed up and threw it away" (Calendar_home2)
	Think it is real (14)	"One particular lady [...] she would threaten to call the RSPCA because of the cat, trying to let the cat outside, we wouldn't let it out." (Interview_home4)
	Dislike (2)[9]	"I'm going to kill these bloody kids" (Calendar_home4)
	Wide appeal (7)	"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)
	Reduced mobility (5)[1]	"[Resident] loves the cat, bed bound, adorable moments" (Calendar_home4)
	Previous pets (3)[1]	"If they've had dogs, they relate to the dog." (Interview_home2)
	Infantilising (4)	"She'd say, silly people, they're sat talking to a toy?" (Interview_home4)
	Staff dislike (1)	"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)
Nurture Evidence <i>suggested residents tended to care for robots and treat them as living animals</i>	Cuddled and fussed [29]	"Cuddled as a real one, calmed her down" (Calendar_home1)
	Feeding (8)[5]	"Yeah, we did have a lady that enjoyed feeding it. And she had a puree diet." (Interview_home8)
	Care for and nurture the pet (8)[5]	"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)

Table 10 demonstrates the themes resulting from analysis of comments made in the calendars and interviews. The full table of themes with example evidence is available in Appendix 4, further to a full narrative on the themes.

Discussion

Our results suggest affordable robot pets be able to produce important wellbeing impacts for older adult care home residents, with further potential positive impacts for staff through reduced occupational disruptiveness.

Principal Findings and Comparison to Prior Work

This study strongly supports the usefulness and benefits of implementing affordable robot pets into care homes for older adults. It contributes towards limited literature in this area, with most prior companion robot research focusing on Paro [1, 28], a device with limited acceptability among older people [9, 10] and too expensive for widespread implementation [12, 35]. Previous work considering alternative, more affordable, robots had been mainly conducted within the community [16, 20] or hospital settings [36, 37], with limited generalisability to care home residents [38], and with smaller samples and short time frames [19, 39]. Additionally, much previous work has involved highly controlled intervention doses [7, 28], thus assessing efficacy rather than potential real-world effectiveness [31], as here. This study therefore provides an important and novel contribution to companion robot literature.

JfA robots demonstrated significant improvements 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 in the intervention group is an encouraging result suggesting important effects of affordable robot use, considering that the NPI measures key behavioural and psychological symptoms associated with dementia [24]. 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. [6] 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. However, the significant difference in occupational disruptiveness could suggest the implementation of pets aided in easing the challenges of the carer's role.

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 [3, 5-7]. The support for impact on delusions is also congruent with the work of Schulman-Marcus et al. [37], who reported on stakeholders feeling JfA devices were useful for hospital patients with delirium. The potential for these more affordable devices to produce promising therapeutic benefits is an important result, with implications for research and practice. Interestingly, we did not find a significant impact for agitation, as previous work did for Paro [3]. Similarly, in the cluster RCT conducted by Moyle et al. [28], there was no significant effect on agitation in the Paro intervention group. Moyle et al. [28] suggested chosen psychometrics can sometimes miss behavioural improvements, and suggested complementing scales with qualitative feedback.

Our 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 that affordable robot pets can produce wellbeing outcomes. Furthermore, interviews and calendar free-text observations 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 entertainment, 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 on the NPI subscale. The importance of meaningful activities for older adults in care homes cannot be overstated, impacting physical and mental wellbeing [40]. Reduced apathy and greater engagement in an activity creates an improvement to quality of life. The calendar and interview data suggest older adults cared for and nurtured robots, which perhaps provided a sense of responsibility and purpose. Although most nurturing seemed to involve cuddling and fussing the animals, there were also counts of residents feeding, dressing and grooming the pets, thus providing care.

In contrast to prior work suggesting robots could improve communication and interactions [41], our Holden communication scale results demonstrated no significant difference in communication as a result of robot implementation. However, our qualitative results suggested robots encouraged communication, mediating social connection as shown in previous work with Paro [41]. The communication scale we selected provides a measure of resident speech and conversational ability [26], a possible limitation of our work. Future research may seek to employ measures of social cohesion and quality of interactions. Interestingly, our 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.

Our experience sampling of observations through calendars [29], 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 demonstrated 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 and prescribed intervention doses [7, 28], as real-world use is likely more flexible and variable. 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, the study demonstrated no novelty effect for devices over 8 months, providing evidence against novelty as a concern for robot pet research and implementation [42]. 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 [2, 3, 5] or individual robot intervention [16, 17, 36]. 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, availability of multiple devices appears desirable, due to some issues in sharing and jealousies, evidenced here 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 [10], 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. Stakeholders felt the JfA cat had more appropriate vocalisations than the dog, 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 [9-12]. In contrast to our previous work however [14], suggesting devices were suitably robust, this study reports cases of breakages. 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 prior work and 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 [43] and our suggestions, that homes took extra precautions on shared robot use. Despite this, pets provided a highly valuable tool during the pandemic and lockdowns, 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 those 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 pandemic situations may ease the challenges of isolation. Isolation is particularly pertinent for care home residents [38], 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 [43]. 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.

Regarding general acceptability, 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 [8, 28], described as a 'therapeutic tool that's not for everybody' [44]. In contrast to the prior work with Paro however, where acceptability was reported to be 50% [44], the JfA devices seem more generally acceptable.

Regarding device suitability, 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 [43]. 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 [9], and care home residents without dementia [10]. 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 prior work [9], as despite not having dementia, the older people lived in individual flats and reported requirement for social company. In previous work with independent older adults living in the community, 4/12 robots were rejected [16], with community dwelling older people less vulnerable to isolation and loneliness [37]. Additionally, Pino et al. [45], reported on healthy older adults feeling too able to benefit from SAR support, while Tkatch et al. [20] 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.

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 [29]. A second 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 [31]. 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 [8]. One limitation of this work is the lack of participant responses to the loneliness measure, creating an inability to assess impact on loneliness quantitatively. We had also originally intended to collect medication records but due to the impact of Covid-19 this was not possible. Prior work with Paro had suggested resultant decreases in use of psychoactive and analgesic medication [7], thus this remains a topic for future research.

Secondly as a limitation, 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 [46]. A third methodological limitation results from the inability to blind collaborators to conditions. It is possible the significantly improved outcome measures in the intervention group are a consequence of the inability to blind collaborators. This challenge has been reported in prior Paro RCT's, whereby the influence of participating in the research itself raised staff awareness to improvements and contributed towards the positive findings [3]. 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 use of a cluster RCT may also be perceived as a limitation over standard RCT's [3]. 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 [3, 28]. A final 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 [28]. 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.

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. Findings also support no novelty effect for affordable robot pets, and suggest 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.

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Appendices

Appendix 1: Variation from planned stepped-wedge trial due to Covid-19 pandemic

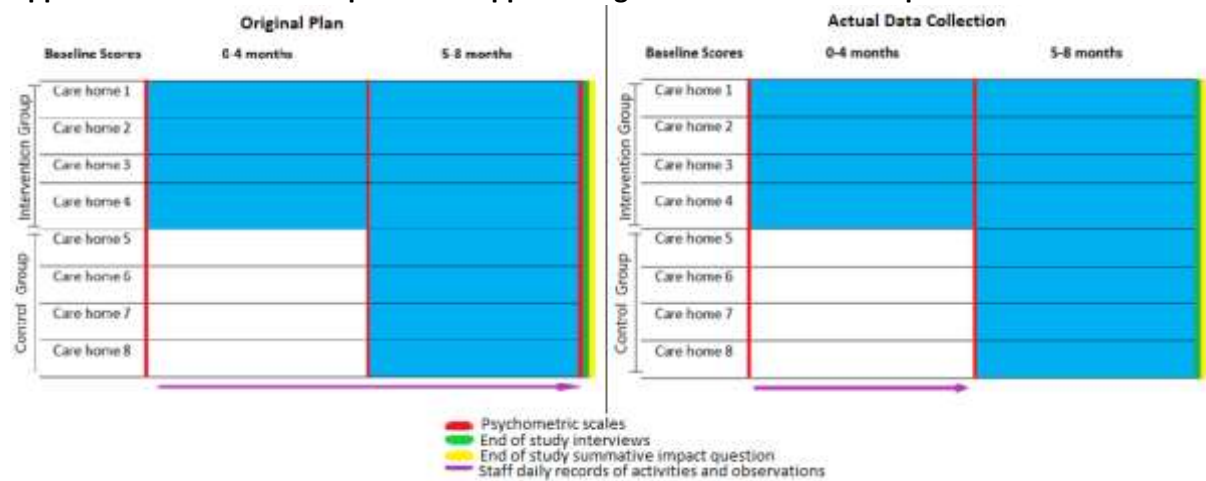


Figure 1: Stepped wedge study design as originally planned (left), study design as carried out as a result of the pandemic, showing the removal of quantitative data collection at 8 months and the ending of staff diaries at 4 months (right).

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

Appendix 2: Further analysis on deaths during the trial and impact of Covid-19

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. For a better understanding of deaths in control and intervention homes, Table 1 displays deaths among residents in the trial homes that were not consented to the trial.

Table 1: 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	

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, 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 (Table 1).

Appendix 3: Histograms demonstrating normality issues for the primary outcome of Neuropsychiatric symptoms at baseline and four months, in both intervention and control group.

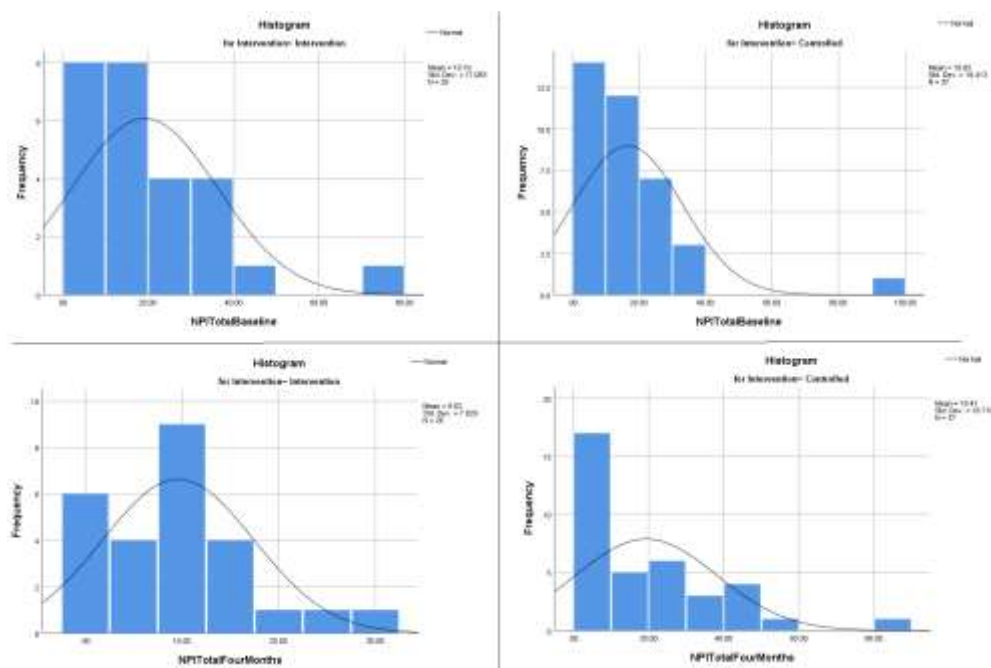


Figure 2: Normality histograms for primary outcome (NPI total) at baseline (top) and four months (bottom) for intervention (left) and control (right) groups

Appendix 4: Full table of themes and evidence

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 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>
	No novelty (9)	<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>
	Naming (7)	<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 to name something else.” (Interview_home2)</p> <p>“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)</p> <p>“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)</p> <p>“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)</p> <p>“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)</p> <p>“Family [...] they realized how much he aided her and how much it calmed her down.” (Interview_home1)</p> <p>“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</p>

		<p>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 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,</p>

		<p>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)	<p>"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>
	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)</p> <p>"[Resident] sat stroking the cat and talking to it, wrapped it up in a blanket" (Calendar_home2)</p> <p>"[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)</p> <p>"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</p>

		<p>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)</p> <p>"Yeah. I would say the majority. Yes. They 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>"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>
	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, 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)</p> <p>“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)</p> <p>“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</p>

		<p>recognition. Oh, yes. I know, I'm in the right place, because this is sat next to me." (Interview_home5)</p> <p>"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>
	Cleanliness and infection control (9)	<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)</p> <p>"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>
	Isolation (5)	<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)</p> <p>"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 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</p>

		<p>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, chair or the table next to them or something. And it's kind of normal cat behaviour, isn't it?"</p>

		<p>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 better. Or you can mute the mute button, I think." (Interview_home2)</p>
	<p>Expectations (8)</p>	<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</p>

	<p>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 stropped 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 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, urm 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>
	Limited interest [17]	<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>
	Think it’s real (14)	<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 instance, is really, really, really effective.” (Interview_home4)</p>
	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 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>
	Previous pets (3)[1]	<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>
	Infantilising (4)	<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)</p> <p>“[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)</p> <p>“Yeah, both, have a good old chat, try feeding them” (Interview_home8)</p> <p>“They were always very covered in food because they like to be fed.” (Interview_home4)</p> <p>“I mean, it's been fed many chocolate biscuits, we wet wipe it regularly” (Interview_home5)</p> <p>“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)</p> <p>“We have got one that adores the dog, and he feeds it.” (Interview_home1)</p> <p>“Sat with them, sort of smoothing them down. One lady wants to feed it, all the time” (Interview_home6)</p> <p>“Feeding the dog peaches and cream” (Calendar_home4)</p> <p>“Obsessed with the dog, trying to feed the dog her food” (Calendar_home4)</p>

	<p>Care for and nurture the pet (8)[5]</p>	<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),</p> <p>“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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