Robotic technologies and well-being for older adults living at home

Abstract

The purpose of this study is to investigate the benefits for aged care providers to add affordable robotic technology in their services packages to enhance the well-being of older adults from culturally and linguistically diverse (CALD) backgrounds who choose to live at home. This study, adopting a Transformative service research lens, was performed with a group of Australian older adults from CALD backgrounds aged on average 70 years old. In total, the study conducted four rounds of home trials with three different, commercially available robotic technologies from January to November 2020, each trial lasted seven days.

The findings reveal that older adults from CALD backgrounds are open to learning about new technologies and can successfully interact independently with multiple robotic technologies in their own homes. Further, our results indicate that robot technology has the potential to increase the well-being of these older people. The results show that technology can enhance a sense of belonging, independence, and quality of life while living at home. Research limitations/implications - This study shows a promising future involving the use of available technology to assist older people from CALD backgrounds to lead a better life at home. Aging at home can be central to a person’s sense of identity and independence; this study is a big step towards a new aged care system that is sorely needed in a society that experiences a rapidly aging population.

Keywords:

Community health, technology innovation, diffusion of innovation.

Introduction

The rise of the service industry has become important to economic growth in many countries. According to the data from World Bank, services' value-added accounted for about 65% of the world's GDP in 2019, and the figure is even higher at 70% for high-income countries (World Bank National Accounts Data). Services related to older age are becoming one of the fast-growing services for nations because older adults spend extensively on services such as health, well-being, and general care (Kuppelwieser and Klaus, 2020).

The aging population is regarded as one of the most significant social transformation forces in recent years, having implications for the service sectors (Bianchi, 2021; He et al., 2016). Over the next three decades, the number of older adults worldwide is projected to more than double, reaching over 1.5 billion in 2050, and the share of the population aged 65 years or over is expected to increase from 9.3 percent in 2020 to around 16.0 percent in 2050 (World Population Ageing 2020 report). The Australian population is also aging quickly. According to the Australian Bureau of Statistics (ABS), there will be 8.8 million older adults in Australia (22% of the population) by 2057, and 12.8 million people (about 25%) will be aged 65 or over (Australian Institute of Health and Welfare (AIHW) 2018). A rapidly aging population will require an adequate workforce, not only in numbers but also in terms of skill sets, to meet the increased demand and diverse needs. However, the shortage of appropriately skilled workers is expected to be an increasing challenge in the aged care sector (AIHW 2014).

According to the World Health Organization (WTO, 2021), healthy aging is "the process of developing and maintaining the functional ability that enables well-being in older age" (pp. 2). In Australia, most older adults prefer to live in their own homes, rather than moving to residential aged care, and the outbreaks of COVID-19 have further reinforced people's preference to age at home (Australian Aging Agenda, 2020). An older person's broad sense of well-being is often associated with happiness and life satisfaction (George, 2010). Living at home provides independence, as it allows people to be themselves and do what they enjoy doing - which represent crucial aspects of well-being (Millennium Ecosystem Assessment Report, 2005). However, living at home at an older age can also be lonely and cumbersome as people age. In addition, older adults often wait too long to receive access to any type of care and assistance at home under the current aged care system (Royal Commission into Aged Care Quality and Safety (RCACQS) 2021).

In addition to an increase in the number of older adults in general, Australia faces unprecedented growth in the proportion of older adults from culturally and linguistically diverse (CALD) backgrounds. According to a recent study, Wilson et al (2021) projected the share of Asia-born among the elderly people aged 65 and above would increase from 8.3% in 2016 to 22.2% by 2056 in Australia. Older adults with CALD backgrounds in Australia are not a homogenous group, and the situation and needs of individuals may vary greatly (AIHW 2018). In addition, older adults with CALD backgrounds tend to stay living in their own homes more than other older adults as in residential aged care staff are often poorly trained in culturally safe practices, with little understanding of the additional needs of people from diverse backgrounds (RCACQS 2021).There is an increasing call to improve the well-being especially of older adults from CALD backgrounds in the aged care service sector, through the adoption of Internet services (Bianchi, 2021) and technology (Charmarkeh and Lagacé, 2017).

Technology indeed provides a promising solution to this growing nationwide problem generally and for older adults in particular by providing immediate and supplementary solutions to daily home care needs for these vulnerable members of our society. Several studies have conducted experiments to test whether, and how, robotic technology can help older adults with their daily lives, both physically and emotionally (Baisch et al. 2017;

Flandorfer 2012; Orejana et al. 2015). However, the vast majority of the research studies were conducted in aged care facilities and other formal care settings (Baisch et al. 2017; Chu et al, 2017; Khaksar et al. 2016; Khosla et al. 2013; Khosla et al. 2017).

Our study aims at increasing our understanding of how interactions between customers of older age and service consumed transform the customer's well-being (Anderson, 2010; Anderson et al., 2013). The study identifies specific, commercially available robotic technologies that show the potential to enhance the well-being of older adults from CALD backgrounds so they can remain in their own homes and delay, or avoid altogether, the need to move to an aged care facility. We use a transformative services research (TSR) lens to examine the benefits of these technologies on their well-being in a home setting where the participants live with the robots in their own homes. Investigating the impact of these transformative services on their well-being outcomes is a critical element from the transformative service research perspective (Schuster et al., 2015). Most importantly, it is crucial to examine the extent of impact on consumers' well-being to these emerging technology-based transformative services as well-being benefits cannot be accrued without their adoption. The study' key contribution is to show that there are commercially available, scalable, and affordable robotic technologies that can be a real solution to the well-being of older adults who would like to stay living at home by increasing their sense of belonging, independence, well-being, and quality of life.

Literature review

Transformative service research paradigm

TSR aims to understand how interactions between the consumers and the service consumed transform the customer's well-being (Anderson, 2010; Anderson et al., 2013). From a consumer's perspective, TSR explores how and why services can positively impact and alter consumers' behaviors and ultimately improve their lives (Anderson et al., 2013). Blocker and Barrios (2015, p. 265) define the concept of 'transformative value' within the domain of TSR as a "social dimension of value creation that illuminates uplifting changes among individuals and collectives in the marketplace". From a provider perspective, to reach transformative changes, organizations are asked to increasingly offer "service model innovation", which "alter the norms of traditional service encounters" (Abney et al., 2017, p. 314).

Like most services, aged care-related services require a close interaction between the customer and the service provider as service production and consumption coincide. More so, similarly to health care, aged care services are both labor and skill intensive, contributing to considerable variability in perceived performance across individuals due to differences in perceived service style, communication skills, and technical skills (Bendapudi and Leone 2002). Therefore, successful service interactions are difficult to achieve, especially in a sector like aged care, where the needs of older adults vary extensively, and consumers tend to be more vulnerable. Compared to service providers, because of their lack of experience, service consumers are often at a disadvantage, especially when service interactions are complex. Also, providers must co-create services with customers due to their experiential nature (Prahalad and Ramaswamy 2004). The more complex the service interaction, the larger is the potential for co-creation and ultimately the potential for positive outcomes for both the service provider and consumer. The service encounters can, however, affect consumers' emotional and physical well-being. As a result, service providers can have a considerable impact on consumers' well-being and thus share some responsibility for their welfare (Anderson, Ostrom, & Bitner, 2011).

Despite the progressive aging of the population in most developed countries, the field of services marketing only provides limited empirical studies on older consumers' well-being, especially on the impact of these consumers' interactions with services and service providers (Feng et al., 2019; Prakitsuwan and Moschis, 2021; Sheng et al., 2016). Service research on older adults mainly focuses on their general characteristics (e.g. age, gender, lifestyle) that affect responses to specific types of services such as financial, healthcare, and travel (Kennett et al., 1995; Moschis and Friend, 2008; Moschis and Unal, 2008), rather than how services and their attributes can affect aspects of older adults' well-being (Prakitsuwan and Moschis, 2021). In the field of services marking, there is an increasing call for studying the well-being of older adults (Prakitsuwan and Moschis, 2021).

The well-being of older adults

The concept of well-being has been examined from different perspectives, some focus on subjective feelings of pleasure and enjoyment (Diener, 2000), while others emphasize the self-realizing aspects of fulfilling one's potential (Ryan and Deci, 2001). Therefore, it is important to recognize that well-being is not a one-dimensional concept, instead it comprises multiple elements, domains, or dimensions (Prakitsuwan and Moschis, 2021).

Ryff (1989) established a multidimensional model of well-being that considers six key dimensions. They are autonomy (independence and self-sufficiency), environmental mastery (ability to create and control environments suitable to one's needs), positive relations with others (relationship with family and friends; capacity for love), self-acceptance (self-respect), life purpose (a sense of meaning in life) and personal growth (achieving personal potential). Understanding the multidimensional nature of well-being leads to a broad view of promoting well-being in older adults and moving away from the "one size fits all" approach when designing aged care services (Prakitsuwan and Moschis, 2021).

The 2005 Millennium Ecosystem Assessment report states that "well-being is experiential, what people value being and doing." (Millennium Ecosystem Assessment

Report, 2005, p.73). Furthermore, the Report emphasized people's freedom of choice and action, that is the opportunity to be able to achieve what individual values doing and being is invaluable to a person's well-being. This is a precious right that is often taken away in residential aged care.

Our study is about well-being at home. This includes how technology enhances what customers value in terms of their being and doing. It is a combination of feeling good and functioning effectively. Being, feeling good, involves having positive feelings of life satisfaction, happiness, contentment, engagement, confidence, and affection (George, 2020). Doing, functioning effectively, involves the development of one's potential, having a sense of purpose, and having control over one's life (Hutson et al., 2011).

Robotic technologies in aged care

It is predicted that robots will have a profound impact on the service sector (Lu et al., 2020). Service robots are referred to as technology "providing customized services by performing physical as well as nonphysical tasks with a high degree of autonomy" (Jörling et al., 2019). These service robots vary in designs, such as humanoid vs nonhumanoid (for instance, Pepper vs Roomba). And these robots may have a physical or virtual presence (for instance Sophia vs Alexa). In terms of functions, there are two main categories: (1) assistive robots, which have the physical assistive function, such as Moebot as a mower robot; and (2) social robots having communicative functions. Social robots are further classified as companion robots, like Paro, and socially assistive robots, which combine assistive functions with social interaction (Vandemeulebroucke et al., 2018). It is obvious that each of these robots was built for different purposes, and none of them could, or should, meet all the needs of an older adult.

In recent years, the use of robots in aged care has attracted lots of research attention (Khaksar et al., 2017; Vandemeulebroucke et al., 2021). The aged care in these previous studies is often referred to residential care, and the major focus is on the acceptance of robotic technologies by the care facilities (Mordoch et al., 2013). What is missing in our understanding is the voice of the older adults themselves, especially those who choose to live at their own homes as they age. What is lacking is how older adults experience the use of multiple robotic technologies at their own home and how the use of robots helps enhance their well-being.

In sum, technology presents a promising solution, however how interactions between the customer and technology-enabled services transform the customer's well-being is not known and is the core of this study. Drawing on the TSR framework (Anderson et al., 2013; Bianchi, 2021) and the dimensions of well-being (Ryff, 1989; Millennium Ecosystem Assessment Report, 2005), this study aims to explore a service model innovation by enhancing/elevating/altering traditional service encounters through robotic technologies for older adults living at home. Ultimately, the service encounters are aimed to transform how these consumers feel and what they do at home. We will answer the following research question in this study:

Research Question: How can different robotic technologies help enhance the well-being of older adults who are living at home?

Methodology

Research Design

This study aims to understand how different service robots can help enhance the well-being of older adults living at home. Due to the complexity of the study, multiple robots, and different living conditions of participants, a comprehensive user-centered approach was adopted in this study. In selecting the robots for this study, the research team considered the following factors, (1) they have to be affordable and commercially available so that they can be considered being adopted by age care providers; (2) they have to address three specific needs of older adults living at home that are related to general wellbeing, namely cleaning assistance, communication and connectedness with family, friends and the community, and companionship at home; (3) they have to be easy to understand and use and safe to handle for older adults. Based on these factors, the research team used three different types of robots in the study, i.e. Paro (a companion robot), Temi (communication robot), and Roomba (a vacuum cleaning robot). Inspired by the benefits of animal therapy, Paro, using with sensors and AI algorithms, is designed to give emotional assistance to older adults. Temi is a telepresence robot which has a combination of functions, including video calls, internet services and remote control etc. Roomba is one of the most commercially successful autonomous robotic vacuum cleaners in the market.

Working with various cultural communities and an industry partner who has a long history of service in aged care for older adults from CALD backgrounds, the research team recruited participants aged 65years or older with a Japanese cultural background, who reside in their own homes on the Gold Coast, Australia. This coastal setting was selected because the Australian Bureau of Statistics (ABS) population projections show that older people will continue to be concentrated in areas along the Australian coastline (Department of Health, 2008). The reason for only selecting participants from one CALD background for this study was to obtain a culturally homogenous sample.

The first stage of data collection was an information session, which was all held at the venue provided by a local, multicultural community centre. All participants were familiar with this venue, as MCCGC runs regular community activities for older adults from CALD backgrounds. The purpose of this session was to explain the project, introduce the robots to the participants, gain the participants' initial thoughts on the robots and create a group interaction environment among the participants.

In total, there were 44 participants in the study. Of these, 26 were initially identified by the research team based according to their age (they were 65 years or older) and CALD background (Japanese). A total of 18 family members lived with the initially identified participants in their respective homes. As they also experienced and interacted with the robots and represented, they were asked to join the project.

Among all 44 participants, there were 24 males and 20 females. For the initially selected participants, the mean age for the male and female groups was 74 years. The family members' mean age was 63.5 years old, with over 60% of these being at least 61 years or older. Table 1 lists the characteristics of all participants.

(Insert Table 1 about here)

At the point of delivery of the three robots to the participants' homes, the research team did a short survey with the participants on demographic information (including age, English level, and time in Australia). It revealed that the vast majority of the initially selected participants had immigrated to Australia more than 20 years ago. The earliest to immigrate came to Australia 46 years ago at the age of 20. Although they had all lived in Australia for many years, almost half of these participants thought their English level was average or poor. About half the participants had pets in their households. Interestingly, the vast majority of participants lived in stand-alone houses rather than apartments or townhouses. Almost 75% of all initially selected participants had children and most also had grandchildren. A quarter of the participants with children had their children live with them. Some 65% of the initially selected participants were not currently on any home care package provided by the government.

In total, we conducted four home trials from January to November 2020. Each of the trials consists of a 7-day home trial in order to explore the benefits of the robots on the participants' wellbeing in their own homes. The seven-day home trials followed shortly after an initial information session with all groups at the local community centre. Temi, Paro, and Roomba were delivered to each participant's home by one research assistant and a Japanese-speaking, qualified home care support worker from the project's industry partner.

Meanwhile, the other member of the research team set up the robots to ensure they were programmed to function properly according to the needs of each household. After that, the research team explained every robot once more in detail to the participant, including operating procedure of each robot, safety-related matters and the contact information of the research team. The research team also left a detailed instruction manual in each household for the participants' later reference and assistance during the home trial.

Before the members of the research team left, they once more explained the home trial diary, which was to be filled out by all participants on day 1, day 4, and day 7 during the robots' stay in their homes. During the 7 days, the research team checked in regularly with all participants to assist where technical issues were experienced. The research team reminded the participants on the respective days to fill out their diaries. This diary asked the participants about their perceptions and interactions with the robots during the home trial. Specifically, the diary asked the same set of questions about each robot on the respective days. The initial part of the diary asked the participants about their interaction frequency with the robots. The main part of the diary had a number of open-ended questions, which asked about the participants' engagement with each of the robots; their positive experiences with the robots; their negative experiences with the robots; what and in which way the robots surprised them; and whether they experienced any technical issues with the robots, and if so what these were. Participants were given the option to answer the questions in English or Japanese. On day 7, the robots were picked up by the research team, and all diaries were checked to ensure they were completed.

Analyses and Findings

As a third of the participants completed the diaries in Japanese, they were transcribed by two bi-lingual research assistants. All open-ended questions were transformed into themed sentences next in order to establish common patterns across the participants' responses. Next, the two chief investigators of the research team created the five-point Likert scales that each captured the range of experiences the participants expressed in the diaries. For example, for the positive experience question, "no positive experience" is coded as "1" and "very positive experience" is coded as "5. Another example, for the question on "What surprised you about the robot today", "very negatively surprised" is coded as "1", "not surprised" is coded as "3" and "very positively surprised" is coded as "5". Next, the research assistant coded all responses along the Likert-scales created. For example, one participant wrote "I am satisfied that Roomba does clean almost all over the house" when taking about the positive experience of using Roomba in Day 1, which was coded as "5" for positive experience. When answering the question about the negative experience about Paro, a participant wrote, "movement is a bit mechanical and not smooth", which was coded as "3", as the respondent indicated some negative experience. In order to minimise potential bias, the coded scales and items for all responses were cross-checked separately again by the two chief investigators. Any discrepancy was solved by an iterative process of going back to the original diary entry and checking the preliminary coding by the research assistant, and discussion between the two principal investigators. The final data was coded into an SPSS software.

Statistics such as ANOVA were conducted to analyse all data during the three entry points the diaries were filled out for each robot respectively (day 1, day 4, day 7). However, we also embed the qualitative findings of the diary entries to enhance the understanding of the quantitative results.

In the following sections, we analyse the collected data and report on the main findings within and across the trials of the project. First, we report the collective findings according to all participants' experiences with the three respective robots during the trials.

Overall Engagement experience with the robots

The findings of our paired-sample t-tests reveal several interesting differences of participants' experiences on the first day of engaging with the three robots: Participants were asked on a six-point Likert scale as to how often and intensively they engaged with each robot. Our findings reveal that they generally engaged significantly more with Paro compared to Temi (paired sample t-test = 0.05 significance) and Roomba (paired sample t-test = 0.037 significance) on the first day (the mean scores from 6-point Likert scale of 1= 'no engagement with the robot at all' to 6 = 'more than once a day long and short sessions': Paro mean score 4.12, Roomba mean score 3.38, Temi mean score 3). Albeit still playing with Temi, the participants engaged with Temi the least on day1 of the trials. The physical attractiveness of Paro could be one reason for this higher engagement according to the qualitative comments provided in the diary. Also, the ease of engaging with Paro by sound and touch may have contributed to a higher degree of engagement compared to the other robots. Female participants engaged significantly more with both Paro and Temi compared to Roomba on the first day.

On the fourth day of the trials, the level of engagement participants spent on the three robots was equal across the robots with no significant differences in their mean scores (Paro mean score decreased to 3, Roomba mean score 3.55, Temi mean score 3.1). Female participants engaged more with Temi than male participants but not significantly. Similarly, on day 7, there were no significant differences in the level of engagement participants spent on the three robots compared to day 4 and across female and male participants.

Overall, participants engaged with robots that they found novel, had no prior knowledge about more, and found physically attractive (i.e. Paro) on the first day of the home trial. However, this level of engagement evened out among the three robots as the days progressed and participants engaged with the robots at a similar intensity. Albeit some differences between male and female participants in their engagement levels with the robots earlier in the trial days, they generally engaged similarly with all three robots throughout the trial.

Overall 'positive' experience with the robots

On day 1, participants had a significantly more positive experience with Roomba compared to Paro (paired sample t-test = 0.027 significance) on the first day of the home trial. Participants also had a significantly more positive experience with Roomba compared to Temi (paired sample t-test = 0.015 significance) on the first day of the home trial. This means, that although they didn't engage with Roomba as much as Paro on the first day, their perceived experience with Roomba was much better (Paro mean score = 3.11, Roomba mean score 3.27, Temi mean score 2.66). The less positive experience with Temi compared to the other two robots could be due to the higher complexity and higher levels of technological knowledge needed to interact with this robot successfully. There was no difference between the positive experience with the robots across male and female participants.

On day 4, participants had a significantly more positive experience with Roomba compared to Paro (paired sample t-test = 0.015 significance) and Temi (paired sample t-test =

0.014 significance) (Paro mean score = 2.6, Roomba mean score 3.5, Temi mean score 2.3). Compared to day 1, there was no significant difference in the positive experience Temi and Paro anymore. This also means that although participants had similar levels of engagement with the robots on day 4, they had quite different experiences by day 4 with each robot.

By the last day of the home trials, participants had an equally positive experience with the 3 robots respectively. Interestingly, although Temi had the least perceived positive experience on day 1, participants may have started to learn to use Temi and familiarise themselves with the functions by day 7.

Overall 'negative' experience

Participants had a significantly more negative experience with Temi than with Paro (paired sample t-test = 0.04 significance) on the first day. An explanation for the more negative experience with Temi could be because the complexity of Temi compared to the other two robots. Roomba's performance is easy to see and instant, hence giving a more positive experience at the start of the trial. Generally, the mean scores in relation to negative experiences with each of the three robots were quite low for day 1 (Paro mean score = 2.2, Roomba mean score 2, Temi mean score 2.45). An explanation for these relatively low mean scores could be that the training provided in the information session by the research team provided sufficient knowledge to operate the robots at a satisfactory level.

By day 4, there was no significant difference between the mean scores across the negative experience participants experienced with each of the three robots (Paro mean score = 2.1, Roomba mean score 2.5, Temi mean score 2.4). This means that by day four, participants' knowledge about Temi has increased and therefore they started to understand its functions and thus did not experience additional negative experiences with this robot.

By day 7, participants had a significantly more negative experience with Temi compared to Roomba (paired sample t-test = 0.015 significance) and Paro (paired sample t-test = 0.047 significance). They also experienced significantly more negative experiences with Roomba compared to Paro (paired sample t-test = 0.045 significance), with Paro having the least negative experiences out of the three robots by the end of the trials. The most negative experience at the end of the home trial is with Temi. One reason for the finding is that Paro is the robot that requires the least technological knowledge to interact successfully with and Temi the most.

Summing up. on day 1, there was no significant difference in either positive or negative surprises across the three robots. However, on day 4, participants had a significantly more positive surprise about Roomba compared to Paro and Temi on the fourth day of the home trial. Again, it is the functionality of the vacuum cleaner that surprised participants in a positive way. Interestingly, although participants experienced most negative experiences with Temi compared to the other two robots, they still were willing to learn to engage with this robot as the week progressed.

Overall 'technical' or 'practical' problems

Participants had significantly more technical issues with Temi compared to Paro (paired sample t-test = 0.007 significance) as well as Roomba (paired sample t-test = 0.023 significance) on the first day of the home trial (Paro mean score = 1.64, Roomba mean score 1.77, Temi mean score 2.18). Participants also had significantly more technical issues with Roomba compared to Paro (paired sample t-test = 0.003 significance) on the first day of the home trial. One explanation for these findings is that most technological knowledge is needed to successfully interact with Temi (i.e. commands via voice recognition) compared to the other two robots with Paro being the easiest to interact without occurring any technical issues. This finding is consistent with the responses of our qualitative analysis of the diary responses about each robot. On day 4 and day 7, participants experienced significantly more technical issues with Roomba and Temi respectively compared to Paro. The qualitative comments centred on participants starting to realise limitations of Roomba (i.e. small dustbin, limited reach of cleaning corners) and Temi (i.e. issues with voice recognition).

In the next section, we report on the similarities and difference of the experiences with each of the three robots along all trials.

Roomba experience

Roomba engagement overall was similar across the four trials on the respective days of diary reporting. Overall, the findings show that there is a decrease in the engagement that participants had with Roomba over the 7-day trial. From the participants' qualitative comments, this decrease in engaging with Roomba was due to Roomba simply doing its job independently after being programmed on day 1, so participants enjoyed doing other things while Roomba cleaned their homes.

Similar to the engagement, the positive experience with Roomba decreased over the 7-day period. One explanation, based on the qualitative comments, is that the participants had got used to Roomba as the days progressed and risen their expectation of it. Roomba's good cleaning ability satisfied most of the users on the first day, which explains the positive on the first day with Roomba. However, as the participants got used to Roomba cleaning their homes, they started to get used to its cleaning functions and also realised Roomba's limitations, such as its limited ability to clean corners and the work involved in preparing their homes for Roomba to clean every day (i.e. lifting everything off the floor).

There was no statistically significant change in the ways that participants perceived Roomba to surprise them throughout the 7-day trial. One explanation could be that generally, the participants in our study already had at least some knowledge about a vacuum cleaning robot at the start of the trial. From the qualitative data, we know that two participants even had an older version of this type of robot. So, the surprise from the start to the end of the trial was the same towards the robot's performance.

Paro experience across trials

Participants in trial 3 and 4 engaged with Paro less towards the end of the 7-day trial than on the first day. One main explanation for the difference in pattern seems to be the pet ownership of participants in the different trials. The percentage of participants owning a pet is significantly higher in Trial 1- some even have multiple pets (refer to Table 1). Another explanation could be the novelty of the robot, which could have caused significantly more interaction on the first day. This shows a difference in the participants across the trials in relation to their engagement with this robot. Also, participants engaged more consistently with Paro in trial 1 compared to the other two trials throughout the home trial with mean scores remaining similar between day 1.

When comparing positive experiences on days 1, 4, and 7 across the three trials, there was no significant difference in the mean scores between trial 1 and 3 in relation to their positive experience with Paro. However, the mean scores when comparing trial 1 participants and trial 4 participants, had a significantly different experience with Paro on days 4 and 7 with trial 1 participants having significantly more positive experience with the robot on these days. Once again, this might be explained by the difference in pet ownership with participants in trial 1 owning significantly more pets than those in trial 4. Another explanation could be the novelty of the robot on the first day compared to consecutive trial days. Participants may have gotten used to the functions and interactions of Paro over the later days of the home trials.

Participants had generally no negative experiences with Paro (indicated by the low mean scores) and as the week progressed, the negative experiences were almost none. An explanation could be that the participants were getting used to having Paro around and were getting comfortable with the interactions and functions Paro provides.

Paro generally surprised participants across all trials significantly more at the start of the home trial compared to day 7 of the home trials. According to the participants' qualitative comments, they quickly got used to interacting with Paro and its functions and responses in relation to sound and touch and the robot became a well-accepted companion in the household. Compared to the other two robots, Paro generally had very low perceived technical issues during the 7-day home trial for participants of all trials. The low perceived technical issues became even lower throughout the 7 days. An explanation is that Paro is specifically made for the chronological age group in its functions and its artificial intelligence is well developed, making it the longest commercially available robot out of the three used in the trials.

Temi experience across trials

Trial 1 participants increasingly engaged with Temi as the week progressed. Participants in trials 3 and 4 engaged with Temi equally throughout the week. The participants across all trials perceived Temi most positively on day 1 and this perception decreased by day 4. However, interestingly the positive experience thereafter - until the end of the trial - increased again. The negative perceived experience did not change significantly over the 7-day trials despite many qualitive comments confirming that participants were frustrated with using Temi's functions, issued with Temi's voice recognition and other perceived technical issues of Temi. Similarly to Paro, Temi had the biggest perceived surprise on day 1, and significantly lower perceived surprises about the robot at the end of the 7 days. Once again, this is most likely because participants had never interacted or even seen a robot like Temi before taking part in the project but got used to interacting with the robot as the days progressed.

Finally, there are noteworthy correlations in our findings: Where participants had a positive relationship with one robot, they were also likely to have positive relationship with the other two robots. Also, participants' positive experience with Temi was highly positively correlated with their positive attitude toward technology (but not correlated with Paro or Roomba).

Discussion

The Australian population has been experiencing two major shifts. On the one hand, the population is aging fast due to the increasing life expectancy and the below-replacement fertility rate (McDonald, 2016). On the other hand, the ethnic composition is changing owning to migration (Wilson et al., 2021). The recent Royal Commission into Aged Care (RCACQS 2021) has shown that these adults from CALD backgrounds have significantly more problems accessing simple aged care services that meet their particular needs and that the existing aged care system is not well equipped to provide care that is non-discriminatory and appropriate for these vulnerable members of society.

The Royal Commission argues that Australia's aged care system is well behind other sectors in its use and application of technology and has no clear information and communications technology (ICT) strategy. This mix of factors has resulted in an aged care sector that is behind the research, innovation and technological curves (RCACQS 2021). Considering the promising innovations that exist in technology in general, and robotic technology in particular, technology may be the answer to some of the biggest problems face the aged care sector. However, there is a lack of understanding of exactly *how* technology can do this.

Moreover, a recent editorial of the Journal of Services Marketing, Rosenbaum and Russell-Bennett (2021) identified the impact of service technologies, including robotics and digital services, on human well-being as a major future research opportunity in services research. However, most of the current research investigating robotic technologies in the service sector is either conceptual or examines the adoption of the robotic technology in a laboratory setting with hypothetical scenarios. Researchers have called for more studies on the actual behaviors of service users in real-life settings (Lu et al, 2020).

Our study responds directly to the call for research and the growing national problem of ensuring the wellbeing of older adults from CALD backgrounds who want to remain living in their homes. It does this by examining how technology can provide a solution for these vulnerable members of society. We make some distinct contributions in relation to prior research. We used a TSR lens to examine how the well-being of consumers of older age can be enhanced via technology service design and delivery in their own homes (Anderson et al., 2013; Bianchi, 2021). We now discuss the empirical findings in our study:

First, in contrast with the vast majority of research studies, who examine human–robot interactions in laboratory settings and residential aged care facilities, participants in this study all lived in their own homes. Second, this project is one of the first to introduce a multi-robot study into participants' homes, with most other studies on human–robot interaction having only introduced one robot into their research settings. Third, most robotic technology studies research robot-human interactions with older adults of declining mental and physical health, participants in this study were of reasonable (or better) mental and physical health.

Several key findings emerge from this project. First, older adults from Japanese CALD backgrounds are not only willing to learn about new technologies but also successfully interacted with all three robotic technologies in their own homes. Each robot was designed for a specific need and all participants understood the specific benefits of each robot and the majority of participants genuinely enjoyed a positive experience with the robots.

Our participants had a younger 'cognitive age' than their 'chronological age' (Amatulli et al., 2018; Westberg et al., 2021), which became obvious in the progression of interacting with the robots at home throughout the seven days. Several participants wrote that they felt 'too young for the companionship robot' Paro on day 1, however, after interacting with the robot in their own homes for seven days, their attitudes towards this robot changed in favour of Paro. Our findings suggest that Paro, which has predominantly been developed and tested on people with cognitive impairments, is potentially also beneficial as a companion for healthy older adults in a home setting. According to our participants' qualitative comments, Paro can act as a pet replacement and several participants in our study established an emotional relationship with this robot, showing that Paro can potentially be one part of solving social isolation and increasing mental wellbeing.

The communication robot Temi in this study was used to enhance communicating to friends, family, and the community - while living at home. Interestingly, Temi was the robot that excited the participants in our study the most at the start of the trials due to its robot-like look and functions none of which participants had seen before. The home trials revealed mixed results due to the limited user-friendliness of Temi's difficult-to-understand functions. However, most surprisingly, our findings reveal that most participants across the trials understood Temi's potential to connect to family, friends and the outside world were willing to learn how to interact with Temi– despite their difficulties interacting with this robot – if they were given more time with it.

The vacuum cleaning robot Roomba was the most accepted of the three robots in the study from the start, due to its visible benefits in the home and familiarity of similar vacuum robots on the market. Our findings show that Roomba can directly assist people's wellbeing because it freed our participants from their cleaning tasks to enjoy other things. Our findings also reveal Roomba's limitations, showing that, once again, this robot is complementary rather than a substitute for a human caretaker. Overall, our findings show that Roomba is beneficial for older adults to keep their floors clean daily while allowing them to enjoy other aspects of their lives.

Overall, our findings therefore confirm that Paro has a positive impact on older adults' BEING as it provides the potential of a companion that requires no taking care off. Roomba's potentially positive impact is to free time for older adults to DO enjoyable things while Roomba cleans their home. Lastly, our findings also suggest that Temi may positively impact both BEING and DOING in that it increases connectedness and interacting with the outside world.

Implications and Conclusion

The Royal Commission into Aged Care (RCACQS 2021) considers that the new aged care system needs an information and communications system that is vastly evolved from the system that currently exists. It is recommended that systems should be designed to enable better services for older people. In specific, an increased investment is recommended in pre-certified assistive technologies and smart technology to support the care and functional needs of older people, and to help manage their safety and contribute to their quality of life (RCACQS 2021).

This project aimed at exploring whether robotic technology could assist and support older adults with CALD backgrounds to remain in their own homes and delay, or avoid altogether, the need to move to an aged care facility. Our findings show that robot technology has the potential to increase social participation and social connectedness for these older people. In particular, our findings reveal that technology can enhance a sense of belonging, independence, wellbeing and quality of life. Our study therefore has important policy implications for how to include specific and targeted technologies into personalised home care packages.

Our study has several noteworthy limitations. We only selected one CALD group in one location; it is thus possible that the same study with other culturally and linguistically diverse groups might lead to different results. Further, the trial period of seven days is short and future studies should extend this period where possible to gain richer data on the human–robot interactions. Also, the COVID-19 pandemic caused disruption to the study, resulting in unanticipated limitations, such as not being able to use the fourth robot and not being able to do focus groups for trial 2. There are many exciting future research avenues that flow from the findings of this project. Future research studies may consider extending this research to other CALD backgrounds using additional or other robot technology.

Our study shows a promising future that includes the use of technology to assist older people from CALD backgrounds to lead a better life at home. Our findings are among the first research outputs that have real potential to be turned into evidence-based best practice and continuous improvement in the use of technology that benefits the whole aged care sector. Ageing at home can be central to a person’s sense of identity and independence, and a new age care system that allows technologies to assist might be part of the answer for our nation.

References

Abney, A.K., White, A., Shanahan, K.J. and Locander, W.B. 2017. In their shoes: co-creating value from deaf/hearing perspectives, *Journal of Services Marketing*, 31: 313-325

Alvarez-Dardet, S.M., Lara, B.L. and Perez-Padilla, J. 2020. Older adults and ICT adoption: analysis of the use and attitudes toward computers in elderly Spanish people, *Computers in Human Behavior*, 110, doi: 10.1016/j.chb.2020.106377

Amatulli, C., Peluso, A.M., Guido, G. and Yoon, C. 2018. When feeling younger depends on others: the effects of social cues on older consumers, *Journal of Consumer Research*, 45: 691-709

Anderson, L., Ostrom, A.L. and Bitner, M.J. 2011. Surrounded by services: a new lens for examining the influence of services as social structures on well-being, working paper, W. P. Carey School of Business, Arizona State University

Anderson, Laurel, Amy L. Ostrom, Canan Corus, Raymond P. Fisk, Andrew S. Gallan, Mario Giraldo, Martin Mende, Mark Mulder, Steven W. Rayburn, Mark S. Rosenbaum, Kunio Shirahada, and Jerome D. Williams 2013. Transformative Service Research: An Agenda for the Future, *Journal of Business Research*, 66: 1203-1210

Anderson, Laurel 2010. Improving Well-Being through Transformative Service, in Moving Forward and Making a Difference: Research Priorities for the Science of Service, by Amy L. Ostrom, Mary Jo Bitner, Stephen W. Brown, Kevin A. Burkhard, Michael Goul, Vicki Smith-Daniels, Haluk Demirkan, and Elliott Rabinovich, *Journal of Service Research*, 13: 4-36

Australian Aging Agenda 2020. How a pandemic changed home care, https://www.australianageingagenda.com.au/covid-19/how-a-pandemic-changed-home-care/ (accessed 19 September 2021)

Australian Institute of Health and Welfare (AIHW) 2014. *Ageing and the health system: challenges, opportunities and adaptations*, https://www.aihw.gov.au/getmedia/19dbc591-b1ef-4485-80ce-029ff66d6930/6_9-health-ageing.pdf.aspx (accessed 15 February 2021)

Australian Institute of Health and Welfare (AIHW) (2018), *Older Australia at a glance*, https://www.aihw.gov.au/getmedia/2cb104f4-c6d1-4728-9be3-a418840588de/Older-Australia-at-a-glance.pdf.aspx?inline=true (accessed 2 February 2021)

Baisch, S., Kolling, T., Schall, A., Rühl, S., Selic, S., Kim, Z., Rossberg, H., Klein, B., Pantel, J., Oswald, F. and Knopf, M. 2017. Acceptance of social robots by elder people Does psychosocial functioning matter? *Robotics*, 9: 293–307

Baghirathan, S., Cheston, R., Hui, R., Chacon, A., Shears, P., & Currie, K. 2020. A grounded theory analysis of the experiences of carers for people living with dementia from three BAME communities: Balancing the need for support against fears of being diminished. *Dementia*, 19: 1672–1691

Bianchi, C. 2021. Exploring how internet services can enhance elderly well-being, *Journal of Services Marketing*, 35: 585-603

Blocker, C.P. and Barrios, A. 2015. The transformative value of a service experience, *Journal of Service Research*, 8: 265-283

Boz, H. and Karatas, S.E. 2015. A review on internet use and quality of life of the elderly", *Cypriot Journal of Educational Sciences*, 10: 182-191

Charmarkeh, H. and Lagacé, M. 2017. Guest editorial: seniors and technology: issues of inclusion and exclusion, *Canadian Journal of Communication*, 42: 2

Chen, Y.R. and Schulz, P.J. 2016. The effect of information communication technology interventions on reducing social isolation in the elderly: a systematic review, *Journal of Medical Internet Research*, 18: 11

Chu, M.T., Khosla, R., Khaksar, S.M.S. and Nguyen, K. 2017. Service innovation through social robot engagement to improve dementia care quality. *Assistive Technology*, *29:* 8–18.

Department of Health 2008. *Trends in population ageing*, https://www1.health.gov.au/internet/publications/publishing.nsf/Content/work-res-ruraud-toc~work-res-ruraud-2~work-res-ruraud-2-5~work-res-ruraud-2-5-2 (accessed 6 March 2021)

Diener, E. 2000. Subjective well-being: the science of happiness and a proposal for a national index", *American Psychologist*, 55: 34-43

Feng, K., Altinay, L. and Olya, H. 2019. Social well-being and transformative service research: evidence from China, *Journal of Services Marketing*, 33: 735-750.

Flandorfer, P. 2012. Population ageing and socially assistive robots for elderly persons: the importance of sociodemographic factors for user acceptance. *International Journal of Population Research*

George, L.K. 2010. Still happy after all these years: research frontiers on subjective well-being in later life", *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 65B: 331-339

Hutson S., Lim S. L., Bentley P. J., Bianchi-Berthouze, N., Bowling A. 2011. Investigating the Suitability of Social Robots for the Wellbeing of the Elderly. In: D'Mello S., Graesser A., Schuller B., Martin JC. (eds) Affective Computing and Intelligent Interaction. ACII 2011. Lecture Notes in Computer Science, vol 6974. Springer, Berlin, Heidelberg

Jörling, M., Böhm, R. and Paluch, S. 2019. Service robots: drivers of perceived responsibility for service outcomes", *Journal of Service Research*, 22: 404-420

Kennett, P., Moschis, G. and Bellenger, D. 1995. Marketing financial services to mature consumers", *Journal of Services Marketing*, 9: 62-72

Khaksar, S.M.S., Khosla, R., Chu, M.T. and Shahmehr, F. S. 2016. Service innovation using social robot to reduce social vulnerability among older people in residential care facilities. *Technological Forecasting and Social Change*, 113: 438–53

Khaksar, S.M.S., Shahmehr, F.S., Khosla, R. and Chu, M.T. 2017. Dynamic capabilities in aged care service innovation: the role of social assistive technologies and consumer-directed care strategy", Journal of Services Marketing, 31: 745-759

Khalaila, R. and Vitman-Schorr, A. 2018. Internet use, social networks, loneliness, and quality of life among adults aged 50 and older: mediating and moderating effects", *Quality of Life Research*, 27: 479-489

Khosla, R., Chu, M.T. and Nguyen, K. 2013. Affective robot enabled capacity and quality improvement of nursing home aged care services in Australia. In *2013 IEEE 37th Annual Computer Software and Applications Conference Workshops*: 409-414

Khosla, R., Nguyen, K. and Chu, M.T. 2017. Human–robot engagement and acceptability in residential aged care. *International Journal of Human–Computer Interaction*, 33: 510–22

Kuppelwieser VG, Klaus P. 2021. Revisiting the Age Construct: Implications for Service Research. *Journal of Service Research*. 24: 372-389

Li, Q. and Luximon, Y. 2018. Understanding older adults' post-adoption usage behavior and perceptions of mobile technology, *International Journal of Design*, 12: 93-110

Low, L.-F., Anstey, K. J., Lackersteen, S. M. P., & Camit, M. 2011. Help-seeking and service use for dementia in Italian, Greek and Chinese Australians. *Ageing & Mental Health*, 15: 397–404

Lu, V.N., Wirtz, J., Kunz, W.H., Paluch, S., Gruber, T., Martins, A. and Patterson, P.G. 2020. Service robots, customers and service employees: what can we learn from the academic literature and where are the gaps? *Journal of Service Theory and Practice*, 30: 361-391

Mordoch, E., Osterreicher, A., Guse, L., Roger, K., & Thompson, G. 2013. Use of social commitment robots in the care of elderly people with dementia: A literature review, *Maturitas* 74: 14–20

Orejana, J.R., MacDonald, B.A., Ahn, H.S., Peri, K. and Broadbent, E. 2015. Healthcare robots in homes of rural older adults. In *International Conference on Social Robotics* (pp. 512–21). Cham: Springer

Wan He, W. Goodkind, D. and Kowal, P. 2016. An aging world: 2015, international population reports", available at: https://www.census.gov/content/dam/Census/library/publications/2016/demo/p95-16-1.pdf

Millennium Ecosystem Assessment 2005, Ecosystems and Human Well-Being: Synthesis, Island Press, Washington, DC. https://www.millenniumassessment.org/documents/document.356.aspx.pdf (accessed 19 September 2021)

McDonald, P. (2016). Ageing in Australia: Population changes and responses. In H. Kendig, P. McDonald, & J. Piggott (Eds.), Population ageing and Australia's future (pp. 65–83). ANU Press.

Moschis, G.P. and Friend, S. 2008. Segmenting the preferences and usage patterns of the mature consumer health-care market, *International Journal of Pharmaceutical and Healthcare Marketing*, 2: 7-21

Moschis, G.P. and Unal, B. 2008. Travel and leisure services preferences and patronage motives of older consumers", *Journal of Travel & Tourism Marketing*, 24: 259-269

Prakitsuwan, P. and Moschis, G. P. 2021. Well-being in later life: A life course perspective", *Journal of Services Marketing*, 35: 131-143

Ryan, R.M. and Deci, E.L. 2001. On happiness and human potentials: a review of research on hedonic and eudaimonic well-being, *Annual Review of Psychology*, 52: 141-166

Rosenbaum, M. S. and Russell-Bennett, R. 2021. Viewpoint: When service technologies and human experiences intersect, *Journal of Services Marketing*, 35: 261-264

Royal Commission into Aged Care Quality and Safety (RCACQS) 2021. *Final report*, https://agedcare.royalcommission.gov.au/publications/final-report (accessed 26 March 2021)

Ryff, C. D. 1995. Psychological Well-Being in Adult Life, *Current Directions in Psychological Science*, 4: 99-104

Schuster, L., Drennan, J. and Lings, I. 2015. Understanding consumers' decisions to adopt technology-enabled transformative services. *The Services Industries Journal*, 35: 846-864

Sheng, X., Siguaw, J. and Simpson, P. 2016. Servicescape attributes and consumer well-being, *Journal of Services Marketing*, 30: 676-685

Vandemeulebroucke, T., de Casterlé, B.D. and Gastmans, C. 2018. How do older adults experience and perceive socially assistive robots in aged care: a systematic review of qualitative evidence, *Aging and Mental Health*, 22: 149-167

Vandemeulebroucke, T., Dzi, K. and Gastmans, C. 2021. Older adults' experiences with and perceptions of the use of socially assistive robots in aged care: a systematic review of quantitative evidence, *Archives of Gerontology and Geriatrics*, 95: Article 104399

Veena, C., Kwon, W. and Juan, G. 2012. Internet use and perceived impact on quality of life among older adults: a phenomenological investigation, *The International Journal of Health, Wellness, and Society*, 2: 1-13

Westberg, K., Reid, M. and Kopanidis, F. 2021. Age identity, stereotypes and older consumers' service experiences, *Journal of Services Marketing*, 35: 54-64

Wilson, T., Temple, J., Brijnath, B., Utomo, A. and McDonald, P. 2021. The ageing of Asian migrant populations in Australia: projections and implications for aged care services, *Asian Population Studies*, Online publication: DOI: 10.1080/17441730.2021.1953689

World Health Organization (WTO) 2021. Decade of healthy aging baseline report summary, https://www.who.int/publications/i/item/9789240023307 , (accessed 20 October 2021)

World Bank National Accounts Data, 2021. https://data.worldbank.org/indicator/NV.SRV.TOTL.ZS , (accessed 19 October 2021)

World Population Ageing 2020 report, https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/undesa_pd-2020_world_population_ageing_highlights.pdf, (accessed 1 October 2021)

Table 1: Characteristics of all participants

Code	Gender	Age	Living Status	Pet	House Style
Participants					
P1	Male	67	Living with a partner and children	No	House
P2	Male	70	Living with a partner and children	Yes 3 cats	House
P3	Male	68	Living with a partner	No	Apartment
P4	Male	89	Living with a partner	Yes 2 dogs and 1 cat	House
P5	Male	65	Living with a partner	Yes 1 dog	House
P6	Female	69	Living with a partner	Yes Golden fish	House
P7	Female	77	Living with a partner	Yes 1 dog	House
P8	Female	70	Living with a partner	No	Townhouse
P9	Male	75	Living with children	No	House
P10	Male	69	Living with a partner and children	Yes 1 dog	Townhouse
P11	Male	76	Living with a partner	No	Apartment
P12	Male	76	Living with children	Yes 1 cat	House
P13	Male	70	Living with a partner	No	Townhouse
P14	Male	79	Living with a partner	No	Apartment
P15	Male	69	Living with children	Yes 1 dog	Apartment
P16	Male	76	Alone	No	House
P17	Male	66	Living with a partner	No	House
P19	Female	71	Living with a partner	Yes 1 dog	House
P20	Female	83	Alone	No	Townhouse
P21	Female	75	Alone	No	Townhouse
P22	Female	72	Living with a partner and children	No	Townhouse
P23	Male	86	Alone	No	House
P25	Male	72	Living with a partner	Yes	House
P26	Male	82	Living with a partner	Yes 1 dog	House
P27	Male	71	Living with a partner	No	House
P28	Male	72	Living with a partner	No	Apartment

Family members					
F1	Female	61	Living with a partner and children	No	House
F2	Female	49	Living with a partner and children	Yes 3 cats	House
F4	Female	78	Living with a partner	Yes 2 dogs and 1 cat	House
F6	Male	70	Living with a partner	Yes Golden fish	House
F7	Male	81	Living with a partner	Yes 1 dog	House
F8	Male	78	Living with a partner	No	Townhouse
F9	Female	47	Living with parents	No	House
F10	Male	37	Living with parents	Yes 1 dog	Townhouse
F11	Female	76	Living with a partner	No	Apartment
F12	Female	44	Living with parents	Yes 1 cat	House
F13	Female	65	Living with a partner	No	Townhouse
F15	Female	34	Living with a partner	Yes 1 dog	Apartment
F17	Female	70	Living with a partner	No	House
F19	Male	76	Living with a partner	Yes 1 dog	House
F25	Female	72	Living with a partner	Yes	House
F26	Female	61	Living with a partner	Yes 1 dog	House
F27	Female	73	Living with a partner	No	House
F28	Female	70	Living with a partner	No	Apartment