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Service Innovation Using Social Robot to Reduce Social Vulnerability among Older People in Residential Care Facilities

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ABSTRACT

This paper aims to explore the main factors of social vulnerability among older people and the improvements in social life after engaging with social robots. This paper also examines the influence of these factors on each other. Study 1 helped develop a conceptual model and research hypotheses by interviewing 17 specialists in both aged care and social robotics, using grounded theory methodology (GTM). To validate the conceptual model in general and its constructs and hypotheses in particular, Study 2 employed a confirmatory factor analysis (CFA) based on the survey distributed among 335 aged care specialists in Australia. The results of study 2 support the indirect effects of social robot enablement and robot mediation on reduction of social vulnerability (socioeconomic accessibility and community ties) through aged care service innovation. It also supports direct impact of robot mediation on augmentation of community ties among older people. Both qualitative and quantitative results measuring the research constructs and hypotheses provide valuable information to managers of aged care facilities and social robotics scholars to improve the quality of life for older people. The implementation of meaningful advances in merging people oriented robotic technology and social vulnerability in older people has demonstrated effective initiatives, including bridging the gap by synthesizing multi-disciplinary interventions to ease social vulnerability.

1. Introduction

The increasing prevalence of social vulnerability in aging societies is incontrovertible. In the context of aging, social vulnerability results from the defenselessness of aging community to social and economic changes in older people' life styles. The impacts on individual's physical and mental capabilities such as mobility and daily decisions often require massive aged care (Andrew et al., 2008; Depietri et al., 2013; Gronlund et al., 2015; Kimhi et al., 2012). Compared to frailty which only describes physical incapability such as low physical movement (Fried et al., 2001; Romero-Ortuno and Kenny, 2012), social vulnerability limits daily life and decision-making in a wider group of older people who are likely to have a loss of mental and physical functions (Kimhi et al., 2012; Nelson et al., 2015). Social vulnerability may even lead to isolation with loss of social engagement for older people in social context (Golden et al., 2009; Prince et al., 1997; Wenger, 1997). Such conditions have been a burning issue in most developed countries (Lloyd-Sherlock, 2000). For instance, the Australian Bureau of Statistics (2014) has forecasted approximately twice and triple increase of vulnerable older people in 2031 and 2061 respectively.

While some research on improving quality of life has mentioned to reduce social vulnerability among older people (Berkman et al., 2000; de Leon et al., 2003; Zunzunegui et al., 2004), it's still under debate in relation to how to keep an aged person engaged and connected with others (Andrew et al., 2008; Martinson and Minkler, 2006; Zunzunegui et al., 2003). Furthermore, despite the development of various studies on assistive technologies addressed social vulnerability (Bemelmans et al., 2012; Frennert and Östlund, 2014; Hindriks et al., 2012; Libin and Cohen-Mansfield, 2004; Louie et al., 2014; Saldien et al., 2010; Shibata and Wada, 2011), very few studies were found very useful regarding how advanced technologies such as assistive technologies actively engage with older people to resolve social issues. There is a need to understand if social changes happen in aging population depends on the technological changes. For example, while the use of assistive technologies in aged care facilities has a long history (Bemelmans et al., 2012; Compagna and Kohlbacher, 2015; Saborowski and Kollak, 2015), studies do not seem to locate older people as ongoing members of a community that are interested to use these technologies. As a result, the need to design and operate a new generation of assistive

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technologies such as social robots that enable older people to be independent and augment their mental and physical activities is required.

With innovation in aged care service in mind, studies might examine how a social robot is designed and operated to assist older people to provide innovative social services such as accessibility, adaptability, rehabilitation and therapy (Mordoch et al., 2013; Moyle et al., 2013; Saborowski and Kollak, 2015). Assuming that social robots facilitate the service-providing to older people, several studies implicitly highlight the need that social robots might enable caregivers to respond better to a wider range of health issues (Huschilt and Clune, 2012; Mordoch et al., 2013; Scassellati, 2007; Vallor, 2011; Wada et al., 2008). Such issues may include holistic care, disease diagnosis, and prevention of isolation and depression. These health issues motivate social robots to provide entertainment, interactive activities, or engaging games and daily communications. In this context, several social robots which are human-or-pet-like robots such as NAO, Paro, KASPAR, PaPeRo, AIBO and iCat aim to provide social support, engagement and independence for people with especial needs (Kramer et al., 2009; Moyle et al., 2013; Peca et al., 2014; Šabanović et al., 2015; Wu et al., 2012). There is also a rising demand for human-like social robots which can really provide human partner interaction and communication compared to pet-like social robots. Most of these previous studies have investigated the implementation of social robots in aged care without paying attention to the social needs of older people. In other words, service innovation in aged care needs to be reviewed to facilitate the use of social robots in aged care facilities (Khaksar et al., 2016a). It requires more qualitative and quantitative studies on both theoretical and empirical aspects of social robots. A realistic goal of these studies should focus on how to reduce social vulnerability in older people.

The purpose of this paper is to explore the main factors leading to reduction of social vulnerability among older people and the socioeconomic benefits that social robots can affect in aged care services from the lens of caregivers and robot developers. This paper also examines the logical influence of some of these factors on each other from the lens of caregivers. This is important because social robots are new to aged care industry and this paper intends to highlight the socioeconomic changes that social robots can offer to reduce vulnerability among older people. Consequently, this paper examines the following two questions: (1) What factors enable a social robot to provide service innovation to vulnerable older people? (2) How does a social robot mediate between aged care services and socially vulnerable older people? And finally, how does a social robot help reduce social vulnerability among these people?

This paper is structured as follows: First, it reviews literature on social vulnerability issues around older people. The role of social robots, as service innovators, is then reviewed, especially in the context of providing social services to vulnerable older people living in aged care facilities. Second, from a methodological point of view, a sequential mixed methods research is presented. The research design combines a qualitative and quantitative approach, to explore and assess the factors that enable social robots for innovative service-providing and mediate between the robot services and service innovation to finally seek factors that can lead to reduction of vulnerability among older people. More specifically, GTM (Ground Theory Methodology) was used to analyse qualitative data from in-depth interviews with 17 specialists in social robotics and aged care. Five constructs have been established and examined, namely robot service enablement (aged care service reliability, costs and safety), robot mediation (personalised service delivery, entertainment, social connectivity), aged care service innovation (social interaction and self-care and social companionship), socioeconomic accessibility (personalised capacity awareness, affordability and decision power), and the strength of community ties among older people (sense of community, social support and sense of place and time), as the main factors that reduce social vulnerability. Following this section, the role of these constructs is theoretically reviewed to develop the possible hypotheses. The confirmatory factor analysis (CFA) is then used to examine the model developed and its hypotheses based on the survey distributed among 335 aged care practitioners in Australia. The paper then draws discussion and conclusions and provides recommendations and implications.

2. Literature Review

In light of emerging prevalence of assistive technologies and their novelty in the market, especially for people with especial needs such as older people, a social robot can significantly improve the quality of social services by assisting caregivers (Huschilt and Clune, 2012; Mordoch et al., 2013; Scassellati, 2007; Vallor, 2011; Wada et al., 2008). A social robot is an accumulating body of applications suited for social interaction and physical presence (Bemelmans et al., 2012; Louie et al., 2014; Wu et al., 2012). Social robots such as Paro, Hobbit and PaPeRo are used in aged care facilities to evaluate social effects among older people and improve their quality of lives in terms of loneliness, isolation and depression (Frennert and Östlund, 2014; Robinson et al., 2013; Šabanović et al., 2015; Wu et al., 2012; Yan et al., 2014). However, most of these robots are not specifically designed to boost the engagement in an aged care facility rather than a pet-like companion or machine-like advanced computer. Along with technology advancement, social robots in aged care are expected to play a facilitating role among older people to motivate them to communicate with others (Kim et al., 2013; Riether et al., 2012). Another demand from social robots is to improve the capacity of caregivers in doing daily activities (Arkin et al., 2014; Pfadenhauer and Dukat, 2015; Salichs et al., 2015). The innovative services to residents in aged care facilities are also preferred to support these routines and habits (Rabbitt et al., 2015). Therefore, the emergence of social robots in aged care raises questions as to whether or not the use of robots in daily activities will be accepted by residents in aged care facilities and whether or not they can promote the quality of life by providing innovative services, as older people include a large part of the socially vulnerable in developed countries such as Australia. In the next section, social vulnerability among older people is reviewed in regard to the role of social robots as assistive technologies in aged care.

2.1. Older People's Social Vulnerability

Since the 1980s, social vulnerability has become a common topic of interest among researchers in robotics. Social vulnerability derives from social circumstances of daily activities that negatively influence quality and security of social welfare. The social and economic circumstances that contribute to social vulnerability include a lack of social engagement, social companionship, social support and poor socioeconomic status (Andrew et al., 2012; Andrew and Rockwood, 2010; Bath and Deeg, 2005; Dupuis-Blanchard et al., 2009; Gleibs et al., 2011). Social vulnerability is also associated with uncertainty increased due to social changes (Eakin and Luers, 2006). These changes may result from technological developments and modernization in advanced societies and generate new risks for people that co-exist with existing risks (Cutler, 2006; Millar and Lockett, 2014).

In relation to an aging society, social vulnerability is related to older people's capacity to respond to hazards (Andrew, 2005; Cutter et al., 2003). It requires considering multidimensional sources such as social intimidations, social interactions, affordability and individual characteristics (Mendes et al., 2003; Schröder-Butterfill and Marianti, 2006). Hence, it has been difficult to provide a comprehensive definition for social factors that influence social vulnerability among older people (Cloutier-Fisher, 2005). However, some scholars in their definitions have tried to provide an understanding of causes and effects of social vulnerability. For instance, Grundy (2006) defined a vulnerable older person as a person whose accumulation social capabilities fall below the threshold required to manage actively their daily challenges.

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According to this definition, older people require social capabilities include social support and self-efficacy. Kreager (2006) contended that a vulnerable older person has less involvement in social activities because s/he does not have a strong social network with relatives or friends. Therefore, it is possible to argue that social connectivity with others mediates social interaction between the aged person and his family and friends.

Kreager (2006) concluded that technology can facilitate social connectivity among older people and the lack of social activates among older people arises from constraints such as unaffordability of technology. Van Eeuwijk (2006) believed that social vulnerability in developed countries arises from inappropriate aged care, resulting from limited financial support, individualism and weak social ties among people. It is clear that these causes limit older people in return to society. Unlike Kreager (2006), however, Van Eeuwijk (2006) contended that inadequate aged care and support for older people results also from a limited capacity of caregivers and community. Therefore, it is important to provide flexible aged care services that empower older people to have easily access to the services. This flexibility can in turn personalise service delivery in which older people would be able to afford the customised services. For example, new generation social robots are able to not only entertain an older person, but also diagnose the rate of depression in the person while providing services. Despite that these robots might be very interesting, some older people may not be able to afford high prices of social robots and/or only need primary care such as reminders for taking medicine, entertaining or playing games or music. The same issue can be also seen in residential aged care facilities in where performance of a social robot might vary in service delivery. For example, the needs of older people with severe dementia completely differ from other people. Therefore, a social robot that intends to provide services for severe dementia might have higher price and/or require more maintenance.

Other studies, such as Krug et al. (2002), highlighted hazards and causes of social vulnerability resulting from the weakness of trust in relationships. This weakness has often been intensified by modernity and entry of technological devices such as smartphones and tablets that typically do not engage people in social activities. Tate (2012) contended that uncertainties in modern life distances older people from society, as older people feel that they have fallen behind others. Unlike traditional communities, social vulnerability among older people in modern life arises from the way that people adapt to technological changes in a social context. Andrew et al. (2008) identified social factors that influence social circumstance for a vulnerable person (e.g. social support, social engagement, socially oriented activities of daily living, sense of mastery and empowerment). They designed a study with self-reported variables relating to these social factors and which aimed to measure social vulnerability to evaluate older people's health (Andrew et al., 2008). Andrew et al. (2008) concluded that social vulnerability can be reduced by increasing social ties among older people and participation in social activities and groups, leading to more support and care for older people.

The use of assistive technologies seems to answer questions on the negative consequences of social vulnerability in aged care particularly when we consider older people living in residential aged care facilities (Bemelmans et al., 2012; Frennert and Östlund, 2014; Hindriks et al., 2012; Louie et al., 2014; Shibata and Wada, 2011). Everyday living conditions of older people in modern life directly and indirectly influences the quality of their life. Although assistive technologies such as smartphones and tablets improve the quality of and innovation of services in society, older people can rarely adapt to either the technological or social changes (Abdulrazak et al., 2013; Arab et al., 2013) because they cannot easily learn how to apply such technologies to daily life. These issues are worse when we consider older people living in residential aged care facilities, who require different types of care.

The literature on modelling social vulnerability and validating its main factors is still under debate, as less attention has been paid to socio-technological changes emerging from modernization in advanced societies. For example, in the model proposed by Cutter et al. (2003), socioeconomic status, commercial and industrial development, residential property, infrastructure and lifelines, education, family structure, social dependence and medical services are highlighted. While the model points at technological devices as resources that can reduce social vulnerability, the model does not clearly present the impacts of socio-technological changes on quality of life. Similarly, the model proposed by Dwyer et al. (2004) pays attention to improving older people lifestyles through facilitating the access to services or social ties. However, the model does not mention the facilitating role of assistive technologies in aligning social changes with technological changes. Table 1 summarises the literature on social vulnerability models and determines the importance of using assistive technologies to mediate social changes with technological changes and enable vulnerable older people to better engage with their community.

As shown in Table 1, the social vulnerability models have mostly focused on factors relating to social vulnerability and less attention has been paid to the facilitating role of assistive technologies in social vulnerability. Thus, there is a serious demand for developing models that address social vulnerability based on alignment between social and technological changes.

2.2. Social Robots as Service Innovators

In the mid-2000s, the emergence of social robots began to end debates on the achievement or failure of assistive technologies in aging societies as well as reduce the complexity of social factors such as social interaction, social networks and social engagement (Bemelmans et al., 2012; Frennert and Östlund, 2014). Social robots can be referred to as robots that provide social service and support users by developing dyadic ties among people and themselves (Bemelmans et al., 2012; Frennert and Östlund, 2014; Pfadenhauer and Dukat, 2015; Riether et al., 2012; Shibata and Wada, 2011). Studies on social robots in healthcare focus on assistive robots supporting older people to work independently on basic activities and mobility such as household maintenance and provide safety for the aged person and decrease stress on the family or caregivers (Alonso-Martín and Salichs, 2011; Arkin et al., 2014; Moyle et al., 2013; Pfadenhauer and Dukat, 2015; Pineau et al., 2003). These robots, as the first generation, provide the physical services in which dyadic ties in social context were previously ignored such as in the case of CERO (Huttenrauch and Severinson Eklundh, 2002).

The second generation of social robots are associated with the companion robots that played an animal-like role such as Paro, AIBO, NeCoRo and iCat (Kramer et al., 2009; Moyle et al., 2013; Peca et al., 2014; Wu et al., 2012). The aim of designing such robots was to co-create an entertaining environment for and with older people to socially support older people community in aged care facilities. While plenty of scholars have tested the capabilities of pet social robots, compared with real pets, the third generation of social robots such Nao, Hobbit and PaPeRo, have emerged (Chu et al., in press; Dautenhahn et al., 2009; De Graaf and Allouch, 2013; Fischinger et al., 2014). The third generation focuses on the well-being of older people in a therapeutic and educational context. These social robots can diagnose and even prevent some aging disasters such as isolation, depression and, dementia. Hobbit, for example, is able to support daily life for older people in place and to postpone the need for care by others by supporting multimodal communication for variable impairment levels (Fischinger et al., 2014).

Despite the impact of third generation robots in various social contexts being unknown, the achievement of aged care social robots is projected to psychologically and physiologically improve cognitive impairment among older people and others (Moyle et al., 2013; Wu et al., 2014). It also enables older people themselves to become more independent (Bemelmans et al., 2012; Fischinger et al., 2014; Libin

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Table 1
Social vulnerability models in the literature.

Author(s), Year	Description	Factors relating to Social Vulnerability	Attention to aligning social and technological changes
Cutter et al. (2003)	Social vulnerability results from risk of hazardous events which reduces older people resiliency to recover from the hazards.	socioeconomic status, commercial and industrial development, residential property, infrastructure and lifelines, education, family structure, social dependence and medical services; age, gender, race, and socioeconomic status	Technological resources such as smart devices can improve social ties among vulnerable communities.
Dwyer et al. (2004)	The ability of an older person as a member of a family to deal with unknown consequences of social hazard.	Individual within household, community, institutional and geographical factors.	Not provided.
Langer et al. (2008)	This model focuses on relatively stability of social vulnerability among couples.	Personality traits, chronic stress, physical aggression	Not provided.
Shi et al. (2008)	How social vulnerability influences older people health outcomes.	Individual and community risk, access to and quality of care, individual and community health outcomes	Not provided
Tate (2012)	A systematic evaluation of social vulnerability indices to understand natural hazards risks and develop effective capabilities	Special needs, material resources, housing, health, social dependence, demographic structure and differential access to resources	Not provided
Lawal and Arokoyu (2015)	Development of a model of social vulnerability to improve the decision making process	Socioeconomic status, household composition and disability, minority status and language, housing and transportation	Not provided
Segrin et al. (2016)	Role of social engagement in reduction of social vulnerability	Social skills, social support, psychological distress	Not provided

and Libin, 2005). To meet these demands, social robot developers require new service offerings which might even change the concept of service. For example, initial depression symptoms are now clear to healthcare scientists. By coding these symptoms in a social robot, caregivers can identify daily activities of older people and help them to become more sociable (Fischinger et al., 2014; Moyle et al., 2013).

Service innovation in aged care is the first priority in designing and operating social robots for older people. Frennert and Östlund (2014) proposed a real insight into social robots and contend that a social robot evolves new offerings from the service concept. The concept of service innovation is typically used in the literature on marketing and less-applied in both social robotics and aged care (Khaksar et al., 2016b). Service innovation in aged care concentrates on improvements in living conditions of older people to reduce the risks of aging in social context. Social robots, as social assistive technologies, are the catalyst for aged care service innovation, because not only do they seek the best solutions to aging problems, but they also play a preventive role for any other problems that might happen to them in future. For example, the robot Paro can identify depression in an older person and encourage the individual to become more involved in social activities such as group games (Moyle et al., 2013). Inoue et al. (2012) tested the robot Paro in a nursing home with 5 older people. They observed that participants are more interested in communicating with Paro in the afternoons, when they have less social involvement with others. They also recognised that the services provided, have been focused more on requests that encourage older people to get together in a given location. (Tapus et al., 2009) observed that the social robot AIBO is able to improve the cognitive attention of older people with dementia. AIBO also encourages older people to get together, enjoy having conversation and playing games. After this experiment, they also recognised that older people intend to stay with each other and the robot. Wada et al. (2006) tested the performance of Paro on 14 people with dementia and calculated the frequency of similar orders and services provided. In this study, they concluded that robot therapy improves the cognitive impairment among older people. Therefore, using such a social robot is likely to be beneficial and effective in Japan, since it seems that the life expectancy of an aged person is approximately eighty years.

Due to the complexity of social factors that affect the quality of lives for older people and to break technological boundaries in aged care, researchers have become extremely interested in identifying paths that help understand social robots as assistive technologies; For example, studies by Bemelmans et al. (2012); Kim et al. (2013); Moyle et al. (2013); Fischinger et al. (2014); Pfadenhauer and Dukat (2015) argued that social robots motivate older people to become actively engaged in social activities such as playing games and puzzles. More specifically, these studies demonstrate how social robots can present a supplement to social activities in aged care facilities and improve the quality of lives for older people as therapeutic companions. Some other studies suggest that the use of social robots in aged care can provide safety and social support to residents through social interaction and companionship. Table 2 shows a number of these studies that highlight the role of social robots as service innovators in aged care.

3. Methodology

This paper conducts a sequential mixed methods research (Creswell, 2013); from a qualitative approach (Study 1) to a quantitative approach (Study 2). In an initial qualitative phase, the research team gathered primary information on social vulnerability among older people, exploring the facilitating role of social robots in aged care and innovation in services. To conduct an exploratory qualitative research (Study 1), GTM was used. CFA, as the quantitative phase (Study 2), was also then applied to validate the conceptual model proposed and examine the hypotheses (Hair et al., 2006). More specifically, Study 2 explored how social robots can be considered to provide innovative services in aged care and to reduce social vulnerability among Australian older people.

4. Study 1: Methodology and Procedure

Research on social robots in aged care service innovation is at the early stage of adoption and involves a large number of fields of science such as computer science, robotics, social science, and psychology (Dautenhahn et al., 2009; Fischinger et al., 2014). Therefore, using a qualitative method that simultaneously consists of ethnography, biography, phenomenology and case-study, is highly pertinent. This research applies GTM (Charmaz, 2014) to develop theoretical aspects of aged care service innovation to reduce social vulnerability by using social robots, seeking possible linkages between phenomenon and concepts (Charmaz, 2014), and drawing relationships (Glaser and Strauss, 2009).

GTM originated in the social sciences as a fundamentally qualitative methods technique (Glaser and Strauss, 2009). GTM helps ground the theory from in-depth interviews to explain why a phenomenon occurs and how (Charmaz, 2014). This method includes a systematic procedure of seeking the research gap, designing questions, finding the participants of interest, in-depth interviews, theoretical sampling,

Table 2
Literatures on social robots as service innovators.

Author(s), Year	Description	Findings	Social vulnerability observed	Service Innovation obtained after Qualitative Phase
Heerink et al. (2006)	11 male and 25 female older people divided into four groups of 8 and two groups of 4 responded a thirty question questionnaire	iCat: The robot improves socially communicative conditions for older people.	Less social interaction	Self-care
Kidd et al. (2006)	23 older people at two nursing homes by individual visits, over a period of 4 months.	Paro: Increase of social interactions among the older people. Increase in the presence of caregivers. Creating a welcoming atmosphere for residents.	Less social interaction	Self-care
Wada et al. (2008)	29 older people (including 11 men and 18 women, 62–90 years) with dementia in a nursing home in Japan.	Paro: Improvement of the cognitive impairment by interaction.	Isolation and depression	Social interaction
Tapus et al. (2009)	3 females in a care facility in the USA, during 8 months.	Bandit: In a group session, the robot improves or maintains the cognitive attention of older people and cognitive impairments by encouraging them.	Lack of social activities	Self-efficacy
Tanaka et al. (2012)	34 aged female volunteers, aged 66-84 at their homes during 8 weeks.	Kabochan Nodding Communication ROBOT: It was effective for the improvement of cognitive activities, especially in executive and memory functions.	Loneliness and anxiety	Social companionship
Sabanovic et al. (2013)	10 older people with dementia in a nursing home.	Paro: Improvement of social activities, in particular modalities of social Interaction, including visual, verbal, and physical interaction.	Social impairment	Social interaction
Louie et al. (2014)	46 aged participants including 37 females and 9 males, aged 62-91.	Brian 2.1: Positive applications of the robot in Social activities.	Less social interaction	Social interaction
Lammer et al. (2014)	49 participants, the age of 70 + with two conditions (reciprocal dialogue vs. control).	Hobbit: Improvement of older people's participations in daily activities. Positively interactions leading to learning.	Cognitive improvement	Self-care
Johnson et al. (2014)	6 participants aged 56-93 with mental and physical disability.	NAO: Better communications among older people.	Lack of social activities and need for assistant to live independently	Self-care and social engagement
Chu et al. (in press)	139 participants with dementia with mental and physical disability.	PaPeRo: Improvement of self-care among older people with dementia through social engagement.	Lack of social activities and need for assistant to live independently	Self-care and social engagement

trustworthiness, and coding (Glaser and Strauss, 2009). The process of coding is the main part of the GTM including open coding, axial coding and selective coding. However, Charmaz (2014) believes that researchers should be more involved with the informants (participants) to co-construct the qualitative data. Therefore, she suggests that the coding process includes open and selective (focused) coding (Charmaz, 2014).

Informants were recruited using theoretical sampling in which a theory is discovered by intentionally looking for new informants that may develop the emerging theory (Glaser and Strauss, 2009). In this research, saturation occurred at the fifteenth interview; however, two more interviews were used to ensure accurate results. Considering that research on social robots is a relatively new field in aged care and finding possible informants for in-depth interviews was difficult, we had to seek confirmation and disconfirmation of data in the existing transcripts after reaching data saturation. Informants had at least 5 years of experience in aged care and experienced working with social robots for the purpose of reducing social vulnerability among older people living in residential aged care facilities. They were divided into three groups: software and hardware developers of social robots (five

Table 3
A sample of interview questions.

Topic	Initial Questions
Reliability	How do you evaluate effectiveness of service provided by the robot?
Trust	To what extent do you trust the robot's performance?
Usefulness	What features would you identify in a useful social robot?
Social support	How do you socially support older people in aged care facilities?
Social collaboration	To what extend do you expect older people can get involved with social activities?
Social interaction	How should social robots encourage older people to engage actively with their community?
Social-technological changes	To what extent do you expect robots can change human being's life style?
Safety	How many times a day / week you can see that older person is using the robot?
Affordability	What should be changed in the robot for your liking?
Care services	What kinds of services do you think you can provide with social robots?

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and six informants respectively) and six caregivers. The informants were selected from South Korea, Italy, Japan (each country with one informant) and England and Austria (each country with two informants) and Finland and USA (each country with three informants) and Australia (four informants). The informants were found using LinkedIn Professional groups. The interviews were structured based upon a list of topics found in the existing literature. These topics included: service responsiveness, service reliability, usefulness, readiness, safety, robot appearance, and software development in social robotics and social support, aged care services, mental and physical disabilities, social collaboration, social interaction in aged care. In the initial interviews, the informants were asked questions on all topics. As the interview progressed and based on the procedures relating to grounded theory methodology, some topics were replaced with or added into the list. Table 3 shows a sample of questions asked.

Trustworthiness of the study was established to ensure rigour in the data collection and analysis (Glaser and Strauss, 2009). The research team spent at least 8 months to obtain the findings by listening to recorded interviews, reading and analysing transcripts, reviewing the literature, interpreting concepts and investigating the relationships among categories. The regular fortnight meetings with the other authors helped to review the results step by step. The research team also asked the informants to comment on their transcripts, helping co-construct meanings and concepts (Charmaz, 2014). To further establish the validity of qualitative data (Creswell, 2013), data triangulation was applied. Strength of the sample was that informants came from different countries and provided an opportunity to identify different social-cultural aspects in the field of study. This assisted researchers to identify insights from different sociocultural points of view (Charmaz, 2014). The research team also asked the informants to comments on their transcriptions for more data collection. Therefore, in this research, data triangulation was achieved by examining interpretations of interviews and memos, persistent observation and reviewing the results with some informants of the research.

To avoid the potential biasing effects of informants providing socially desirable responses, the research team applied other approaches throughout data collection and analysis. For example, the informants were told that their participation in this study was completely anonymous. They were also asked to respond to questions in a way that helps researchers to figure out what is the problem and how to solve it. Furthermore, the research team was committed to the best possible application of their response without any bias and discrimination. One of the serious concerns in this study was as how to convince informants to not think about the robots as a replacement in aged care. Some informants were concerned about the performance of social robots in aged care leading to a reduction in job opportunities in aged care, as caregivers. To reduce this concern, however, the research team pointed out that social robots are assistive technologies that facilitate the process of providing services to older people and might create more job opportunities throughout the research period.

The coding process began with open coding in which the research team identified the concepts and properties from passages, memos and notes (Glaser and Strauss, 2009). In this phase, phenomenon broken down to core words was named and categorised. Similar to the axial coding process proposed by Glaser and Strauss (2009), open coding in constructivist GTM is also the process of generating initial categories in which research team links sub-categories to their concepts (Glaser and Strauss, 2009). At a higher abstract level, selective (focused) coding takes place to generate core categories and link them to each other (Glaser and Strauss, 2009). This phase determines how a particular explanation of a situation can move toward a more abstract demonstration (Glaser and Strauss, 2009).

All transcripts were read one-by-one. Core words were underlined from passages. This process occurred three times to ensure the usefulness of the data obtained. At the second stage, using NVivo10 to do a context analysis based upon a line-by-line method, an open coding procedure was applied to capture preliminary categories that represent the main phenomenon. This software supports category-generation and the relationships among categories. The line-by-line coding produced approximately 43 initial concepts. Aggregating and eliminating helped to reduce the number of initial concepts. The concepts were reduced to 15 items. In Study, items were compared to generate a conceptual model through possible relationships among five emerging core categories.

5. Study 1: Hypotheses Development

In this section, the core categories are reviewed based on the informants' comments to help generate hypotheses and possible relationships among categories. All core categories were supported by the relevant literature.

5.1. Robot Service Enablement

Informants implied that the reliability of services, cost of purchasing and maintaining a social robot, and the sense of safety in aged care services must be simultaneously considered to create value with/for older people. The emphasis on these enablers seems to facilitate human-robot interaction (HRI) in the long term. Furthermore, older people can easily accept a robot's usefulness. While the comments made by caregivers mainly concerned safety, the robot developers focused more on reliability and cost. Table 4 presents some key comments made on robot service enablement (RSE).

Some informants pointed out that social robots such as Paro and PaPeRo are able to both talk and act for older people with cognitive impairment. These robots judge whether or not older people wish to remain in this situation. In addition, some other comments were noted regarding older people's preference for a continuation of stable and consistent routines. Social robots, therefore, should be ready to provide service to an older person. Returning to the literature, the research team recognised that redundancy in service and consistency in service delivery are, respectively, two major aspects of service reliability in aged care. Social robot reliability has increased in importance with the use of social robots being used in aged care (Fischinger et al., 2014; Koike et al., 2009; Libin and Libin, 2005; Pfadenhauer and Dukat, 2015). When reliability is considered from a service innovation approach as an enabler, a social robot would be able to deliver services to the right person at the right time. Desai et al. (2012) argued that robot system reliability has been less investigated in the social robotics literature since most studies pay more attention to accuracy and repeatability of performance. Zanchettin et al. (2013) contended that robots have increasingly been operated to perform different kinds of tasks in different ways.

Considering that aged care expenses are a big issue for both older people and for caregivers (or their families), some informants commented on affordability and time-saving as two characteristics which enable social robots to be applied in aged care. The caregivers emphasise that social robots are very expensive and many older people are unable to afford these technologies. However, several scholars (Dautenhahn et al., 2009; Fischinger et al., 2014; Gouaillier et al., 2008; Moyle et al., 2013; Šabanović et al., 2015) state that a new generation of social robots are becoming more affordable. In terms of time-saving, caregivers and some scholars added that social robots can be reliable assistants and improve the capacity of caregivers to look after older people. For example, PaPeRo is able to individually recognise older people in aged care facilities and remind them to do their daily activities (Šabanović et al., 2015). Similarly, Paro can recognise any change in older people's behaviours and actions, and inform caregivers (Moyle et al., 2013). The robotics laboratories and research teams are working to design and operate social robots that can provide social services for older people that are affordable enough to be purchased

Table 4
A sample of key comments on Robot Service Enablement.

Core categories	Sub-categories	Factors of sub-categories	Context
Robot Service Enablement (RSE)	Aged Care Service Reliability (ACSR)	Service Redundancy	Multi-tasking, duplication of services, different capabilities, variety in features/ service package
		Service Consistency	On-time services, on-spot services, quality improvement of services, accuracy in services, availability
	Aged Care Cost (ACC)	Time-saving	Quicker responses to the user, quick responses to caregivers
		Affordability	Purchase, maintenance
	Aged Care Safety (ACS)	Emergency Alarm	Warning to older people, caregivers, family members, emergency services.
		Robot Safety	Safe presence, safe movement, behavioural safety, functional safety, cute face

by individual customers (Fischinger et al., 2014; Gouaillier et al., 2008). Therefore, in future, low-cost social robots are likely to be more accessible for older people.

In addition to service reliability and aged care costs, social robots should be able to provide safety for older people. Within the literature there has been frequent debate as to whether or not social robots can increase safety for older people (Bemelmans et al., 2012; Fischinger et al., 2014; Mordoch et al., 2013; Pfadenhauer and Dukat, 2015; Shibata and Wada, 2011; Wu et al., 2012). A group of caregivers and hardware developers discussed safety in interaction between a social robot and older person from different points of view. They believe that a robot's physical stature might hurt older people especially those who suffer from physical and mental disabilities. For instance, informant 17 contended that some older people with dementia might get offended or even too emotional when a social robot performs for a long time. Some other informants stressed that the role of emergency alarms would improve the quality of life for older people and reduce stress among caregivers.

Emergency alarms are a key point of the robot safety, especially for social robots, since these robots aim to prevent any critical event for older people (Fischinger et al., 2014; Moyle et al., 2013; Zsiga et al., 2013). The robot must ensure that the user is safe while providing services. In doing so, the designers of social robots must consider three aspects: safety in communication, safety in presence, and safety in behaviour (Sabanovic et al., 2013; Siciliano and Khatib, 2008; Wada et al., 2008). As social robots are programmable multifunctional social devices designed to work with a user and provide ongoing safety, social robots should not be able to violate ethics or morals. Ensuring ethical behaviour helps older people and their family members to feel comfortable and safe. The first generation of social robot were often found to perform unsafe, hazardous actions (Šabanović et al., 2015; Siciliano and Khatib, 2008). Problems often occurred when robots were planned to perform highly repetitive and unpleasant tasks. The next generation of social robots have been designing to perform in a safe way and also to provide safety to the user (Frennert and Östlund, 2014; Robinson et al., 2013; Šabanović et al., 2015; Wu et al., 2012). The robot 'Hobbit', for example, can recognise dangerous situations and report them to caregivers by anticipating the similar situations occurred before (Fischinger et al., 2014).

5.2. Robot Mediation

Following enablers that facilitate the robot services, informants agreed that a social robot plays a mediation role in aged care by delivering personalised services, entertaining and socialising older people. More specifically, the caregivers participated in this study implicitly considered social robots as entertainers in aged care. However, the robot developers, especially software developers commented on personalised service delivery and social connectivity as two mediators that reduce social vulnerability in aged care by using social robots. Table 5 presents some key comments made on robot mediation (RM).

Reviewing the first and second interview's transcripts helped the research team to differentiate entertainment from personalised service delivery, due to its importance in HRI. Almost all informants believed that responding to the user's orders makes a robot useful. From this point of view, social robots can culturally promote a sense of empathy in older people in different contexts by delivering particular social services. The qualitative findings suggest that personalised service delivering seems to be an appropriate way to improve the quality of lives for older people individually based on their demands.

Reviewing the literature, personalised service delivery relating to social robots can be defined as the capability of a social robot to communicate and interact with a user, in a context where the needs for providing social services can be considered (Lisetti et al., 2004; Severinson-Eklundh et al., 2003). Personalised service delivery is a consequence of interactions between a social robot and user. Personalised service delivery provides a framework for robot developers to design, develop, and operate a social robot in a social context (Inoue et al., 2012; Koike et al., 2009; Saborowski and Kollak, 2015; Siciliano and Khatib, 2008). This framework can be considered as a platform that includes a set of software and hardware capabilities in a social robot. For example, the robot NAO has a specific platform that helps deliver social companionship and social interaction to the user (Gouaillier et al., 2008). Some scholars also argue that social robots are technological innovators that can mediate providing social services to the user (Bemelmans et al., 2012; Dautenhahn et al., 2009; Fischinger et al., 2014; Gouaillier et al., 2008; Moyle et al., 2013) to keep older people interested in social activities. With these improvements in service delivery, the user can gain better transparency about the service and as a result trust the performance of the robot. Older

Table 5
A sample of key comments on Robot Mediation.

Core categories	Sub-categories	Factors of sub-categories	Context
Robot Mediation (RM)	Personalised Service Delivery (PSD)	Empathy	Understanding the usefulness of robot, the robot services and , Sharing the feelings with robot
		Responsiveness	Completing a task, quality improvement of responses, appropriate reactions
	Entertainment (ENT)	Game and Music	The ability to play different types of game and music
		Dance and Sing	The ability to dance with and sing for older people, reminding them good memories
	Social Connectivity (SC)	Human-Like Communication Modality	Human-like reactions, human-like behaviour, human-like movement, gesture, talking, looking, recognising different situation
		Interaction Facilitation	Understanding group activities, network communication, robot-group interaction

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people in aged care facilities have regular entertainment programs that usually occur in groups. Informants pointed to games, puzzles, songs and dance as the main components of entertainment. For example, Informant 2 contended that an entertaining environment is really important in environments such as aged care as older people are likely to have entertainment activities every day. Scholars believe that entertaining is an important capability of social robots in providing service to older people (Bemelmans et al., 2012; Dautenhahn et al., 2009; Fischinger et al., 2014; Libin and Libin, 2005; Moyle et al., 2013). The first generation of social robots were exclusively designed to entertain users (Libin and Libin, 2005; Pineau et al., 2003; Severinson-Eklundh et al., 2003; Siciliano and Khatib, 2008). In the next generation, social robots aimed to encourage older people to remain interested in using robot services by playing games and music or dancing with the older person (Bemelmans et al., 2012; Koike et al., 2009; Shibata and Wada, 2011; Siciliano and Khatib, 2008). While previous generations of robots were designed and operated to entertain, the current generation focuses more on providing social services related to the caring industry and education services with some focus on entertaining older people. The entertainment characteristic of social robots depends on their appearances and functions (Gouaillier et al., 2008; Wu et al., 2012). For example, NAO is a full-humanoid robot that is able to dance, sing and play (Gouaillier et al., 2008). These functions increase the capability of NAO to entertain older people who have different needs. However, iCat is an animal head-like robot that is able to play puzzles with older people (Hindriks et al., 2012). A study by Wada et al. (2008), also highlights the role of Paro in treating people with dementia in a residential care facility by singing songs.

The research team also found that 'social connectivity' as a category can be considered to evaluate the facilitating role of social robots in aged care. Considering that social robots are created to improve social activities among older people, our assumption is that the different forms of social connectivity such as vision and auditory systems, can involve older people with social robots. For example, informant 3 remembered the robot PaPeRo as having a baby face and emphasised that her face was cute and interesting for older people to communicate to. Some other informants emphasised human characteristics such as face, ears and voice and the ability to learn and communicate like a human as making the robots seem more sociable. Besides, social robots seem to be more helpful in aged care. Some informants believed that social robots can play a facilitating role in aged care. For example, informant 15 who observed 'Hobbit' commented that a social robot should be understandable for older people to actively perform in a social context.

For a social robot, speech and vision recognition have been defined as the ability to interpret the data obtained from the surrounding environment (Fischinger et al., 2014; Fong et al., 2003; Wada et al., 2008). The visual system in social robots allows them to assimilate data from different information sources (Huschilt and Clune, 2012; Wu et al., 2012). The act of seeing begins with coding the different moods and behaviours of the user and creates a pattern of each single mood or behaviour, based on the pre-defined algorithms of human behaviours (Siciliano and Khatib, 2008). The act of hearing is the ability to identify sound by detecting vibrations or changes in the pressure of a surrounding medium (Wu et al., 2012). The entire process of HRI involves the socio-cognitive system of a social robot to create the computational and algorithmic levels of coded moods and behaviours (Saldien et al., 2010; Wu et al., 2012). Furthermore, social robots use social connectivity characteristic to facilitate interaction among other users (Sabanovic et al., 2013; Sehili et al., 2014). As the result, a robot needs a vision system, auditory system, expressive motor system, high level perception, behaviour and motivation system and vocalization system to follow human like communication modalities and facilitate interactions.

Table 6
A sample of key comments on Aged Care Service Innovation.

Core categories	Sub-categories	Context
Aged Care Service Innovation (ACSI)	Social Companionship (SCo)	Feeling of friendship with the robot, interest to communicate and stay with the robot
	Social Interaction (SI)	interaction with the robot, interaction with the robot while other listen to you, interaction with other while robot exists
	Self-care (SCa)	Reminding older people to take their medicine, diagnosing isolation and depression, preventing social isolation and depression and mental impairment Reviewing public and local news, becoming updated by upcoming event, reading books and checking self-mistakes in talking and writing, developing skills and qualifications

5.3. Aged Care Service Innovation

The next core category extracted from the qualitative findings was 'aged care service innovation (ACSI)'. Informants contended that social vulnerability such as aloneness, isolation, depression and social exclusion can reduce the capabilities of older people to engage actively with their communities and to continue their routines independently. Informants emphasised that it is not easy to involve older people in social activities. They noted that living in care facilities might decrease their aspirations for communication with others. As a result, the arrival of a social robot might motivate them to stay in touch with others, and to become more independent and have less involvement with caregivers. Table 6 presents some key comments made on ACSI. However, the majority of informants stated that achieving this purpose depends on the acceptance of the robot. The informants also stated that there are significant consequences for the relationship between robot service enablers and service innovation in aged-care.

This characteristic can be associated with the recent study of Moyle et al. (2014) that focus on feasibility of a remote robot, Giraff, and its communication with older people with dementia and their families. This research indicates that social robots are able to socially engage older people with others. Kanoh et al. (2011) worked on two different baby-like robots YORISOI Ifbot and concluded that the robot's performance improved the ability of learning among older people by motivating them to critically think about and generate their own understanding of what they observed.

Several studies have been focused on using the capability of communication and learning in social robots to reduce cognitive impairment in older people. This includes the study of Wada et al. (2008), which worked on software aspects of the robot 'Paro' to improve the speed of communication, and voice and visual recognition to help the robot to be more appropriate for long-term group activities especially social companionship. Similarly, Shen et al. (2015) with Kaspar2 and Sabanovic et al. (2013) with the robot 'Paro' tested the robots' capabilities in different nursing homes and came to the conclusion that older residents wanted a more interactive than moveable robot. However, some studies have investigated how social robots assist in making older people independent. (Louie et al., 2014) investigated the performance of the robot 'Brian 2.1' in a social context and found that the presence of robots can improve the capacity of caregivers or family members to get less-involved in their daily activities. This is supported by Lammer et al. (2014), which also gained the same results by testing the robot 'Hobbit'.

Therefore, on the basis of the qualitative data, as well as other research designs found in the relevant literature, the following two hypotheses are designed:

H1. *Robot service enablement influences aged care service innovation.*

H2. *Robot mediation influences aged care service innovation.*

5.4. Social Vulnerability

Social vulnerability was commonly identified by informants as characterising the aged. The terms 'social ties', 'social behaviours', 'social characteristics', 'economic status', 'access to friends and families', 'the frequency of social activities per day or week' and so on were frequently stated by informants to represent the importance of social vulnerability among older people. Throughout the interviews, the informants were asked to explain the role of communities to reduce isolation and depression among older people with the use of social robots in aged care. While some informants stated that smartphones and tablets have seen older people fall behind in daily life than for the young, some other pointed out that vulnerability among older people seems to be undeniable. Therefore, advanced societies such as Australia should find a way to control this social phenomenon.

Some informants surprisingly mentioned that the use of social robots in aged care facilities seems to be more affordable for older people, especially those who have no support by their family members. They believed that social robots can change the quality of life for vulnerable older people if they are reliable and cheap enough. Some others also highlighted that the understanding of a social robot as an assistive technology is not similar to smartphones or other technological devices, instead, it is to notify that older people would be able to promote their personalised capacity if social robots help them to get more involved with their community. Some others also reported their own observations on social robots that could improve the decision making process for older people. For example, Informant 12 pointed at Paro and stated that this robot assists older people with mental impairment to better focus on their daily activities by reminding them how to do their own jobs such as going to the toilet and saying hello to a friend. In addition, caregivers mentioned that innovative services emerging from the use of social robots in aged care, have been encouraging older people to engage actively with others and feel more comfortable when robot plays around them. For example, Informants 2 and 14 stated that sense of community among older people and social support from each single member of the community were positive consequences of deploying social robots in their aged care facilities. Caregivers greatly emphasised that the existence of social robots in residential aged care facilities reduced complains and difficulties arise from being away from family among older people (e.g. Informant 17).

Overall, while robot developers participated in this research, focused more on the socioeconomic accessibility of older people, caregivers emphasised the role of social robots to improve community ties for older people. More specifically, the socioeconomic accessibility of older people can be seen in their capabilities to buy and to maintain social robots for a better life with better decisions and capacity building. However, a common perception was that it is difficult for older people or their family members to afford a social robot. Therefore, some informants pointed out that aged care facilities can afford to purchase and maintain at least one social robot and it helps all residents to engage with the robot equality without any concerns about its price. Informants 5, 8 and 11 directly pointed at the sense of place and time among older people living in their aged care facilities in which they felt robots belong to the aged care facilities, as they do. Table 7 presents some key comments made on the construct of social vulnerability (SV).

Socioeconomic accessibility is most probably the main aspect of social vulnerability among older people (Andrew and Rockwood, 2010). Grundy and Holt (2001) stated that limited income can negatively affect health accessibility of older people as they may not have access to aged care or be able to afford the assistive technologies or appliances. Losing the ability of capacity building to the older people's capabilities such as self-awareness and attention to environment and others can also be a crucial aspect of social vulnerability in aging society. A study by Grundy and Holt (2001), for example, also indicated that the rate of awareness to diet, social behaviour and physical status of body significantly have a positive relationship to social vulnerability among older people.

A frequent finding in the literature is that social vulnerability among older people results from a lack of social support (Martinson and Minkler, 2006; Mendes et al., 2003; Prince et al., 1997; Wellman and Wortley, 1990) and less involvement in social daily activities (Cutter et al., 2003; de Leon et al., 2003; Golden et al., 2009; Gronlund et al., 2015; Kimhi et al., 2012). More specifically, some studies suggest that a lack of social support and sense of place and time can debilitate community ties among older people themselves and with others (Lindström et al., 2004; Marmot, 2005; Mendes et al., 2003; Romero-Ortuno and Kenny, 2012; Ziersch et al., 2005). Some others, however, contend that community ties are associated with the sense of community in social context (Berkman and Syme, 1979; Blazer, 1982; Seeman and Berkman, 1988; Tate, 2012; Thoits, 1995). Sense of community, place and time enable an older person to easily engage with different people while do not feel loneliness. In addition to social characteristics of older people, physical disabilities are also likely to reduce their enthusiasm to be back to their communities. For example, an aged person with a physical disability might be unable to normally catch up with other society members and might feel lonely (Andrew et al., 2008).

Following the assumption that social vulnerability among older people increases the need for social robots to effectively perform in aged care and that social robots can effectively mediate support and care in aged care by assisting caregivers, it seems that this performance

Table 7
A sample of key comments on Social Vulnerability.

Core categories of SV	Sub-categories	Factors of sub-categories	Context
Socioeconomic Accessibility	Personalised Capacity Awareness (PCA)	Personal capabilities	Self-confidence, self-reliance, self-knowledge, self-efficiency, personal achievement
		Social capabilities	Development of reflective practice, resilience and adaptability to the society, decision-making, conflict-resolving
	Affordability (AFF)	Purchase	Flexible prices, enough income, health insurance cover
		Maintenance	Maintenance, access to after sale services
	Decision Power (DP)	Power of choose Knowledge to choose wisely	Decisions about how to choose a game, to do an activity, to remember an activity, to learn new things
Community Ties	Sense of community (SoC)	Unification	Common social and economic aspects, common communication skills
		Social common sense	Common beliefs, culture, language and understanding
	Sense of place and time (SoPT)	Common sense about residential aged carefacility	Belonging to this environment, second house
		Common sense about their presences in residential aged care facility	Comfortable, Calm, safe, available, family
	Social Support (SS)	Emotional support	Perception of psychological needs, understanding of feelings, and reaction to the distress
		Companionship support	Interpersonal relationship, mutual understanding, social exchanges

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can encourage aged care facilities to use social robots in daily life to reduce social vulnerability among older people by engaging them actively with their community (Moyle et al., 2015; Šabanović et al., 2015; Siciliano and Khatib, 2008; Wada et al., 2008). The use of social robots in aged care facilities also is more affordable than individual purchases (Dautenhahn et al., 2009; Fischinger et al., 2014; Mordoch et al., 2013; Moyle et al., 2013). It allows the older people to use these robots in a more affordable manner. Relying on social robots can alleviate the difficulties that caregivers face when dealing with older people. For example, in many cases, a social robot can inform caregivers of emergency situations by using this robot as a companion robot (Fischinger et al., 2014; Moyle et al., 2015; Sabanovic et al., 2013). Aged care service innovation can provide comfort, care and support for older people and enhance their capabilities to afford a social robot. Therefore, on the basis of the qualitative data, as well as other research designs found in the relevant literature, the following six hypotheses are designed:

H3. *Aged care service innovation influences socioeconomic accessibility of older people.*

H4. *Aged care service innovation influences augmentation of community ties among older people.*

H5. *Robot service enablement influences socioeconomic accessibility of older people.*

H6. *Robot service enablement influences augmentation of community ties among older people.*

H7. *Robot mediation influences socioeconomic accessibility of older people.*

H8. *Robot mediation influences augmentation of community ties among older people.*

6. Study 2: Methodology and Procedure

In Study 2, the research team applied structural equation modelling (SEM) to evaluate conceptual model explored in the previous phase and test the hypotheses. SEM helps exploring the relationship between multiple constructs (Hair et al., 2010; Koufteros and Marcoulides, 2006). SEM replaces a set of homogenous observed variables (items) with a smaller set of latent constructs and estimates these latent constructs with the items (Anderson and Gerbing, 1988). In this study, all core categories and subcategories were considered as latent constructs and items respectively. **Robot service enablement (RSE)** including *the items of aged care service reliability*, *cost* and *safety* and r**obot mediation (RM)** including the items of *personalised service delivery*, *entertainment* and *social connectivity*, were the two independent constructs in the model. **Aged care service innovation (ACSI)** was known as a mediator construct in this theoretical model which includes *social interaction, social companionship* and *self-care*. **Socioeconomic accessibility (SA)** including personalised capacity awareness, power decision and affordability and the strength of **community ties (CT)** including *sense of community*, *sense of place and time and social support*) were nominated as the dependent construct.

SEM also evaluates the fitness of the conceptual model based on the value of items for each latent construct (Koufteros and Marcoulides, 2006). The research team established the measurement model using confirmatory factor analysis (CFA) (Kline, 2006). In doing so, the research team conducted a survey designed to analyse whether social vulnerability factors among older people influence aged care service innovation through RSE and RM. The respondents consisted of aged care nurse practitioners, occupational therapists, personal aged care assistants, aged care advocates and lifestyle coordinators. LinkedIn, a professional networking site, was used to identify possible participants. As social robotics is a relatively new research application for aged care, the target population of this study was limited. Survey participants included caregivers, practitioners, and occupational therapists. The research team used three means to distribute the survey: online, email, and face-to-face meetings. The items were written in a 7-point Likert Scale (Creswell, 2013) to determine the degree of agreement or disagreement with an item and its statement. Unsurprisingly, during the data screening, we found that some of the data show deviations from normality. In remedying potential violations of the expectations for CFA, Hair et al. (2010) suggest that the skewness and kurtosis levels should be considered. We found that the skewness and kurtosis levels of one dependent and one independent latent constructs are out of the limits of $\pm$ 1: RSE with the skewness and kurtosis levels of – 1.09 and 1.41 respectively; SA with the levels of – 1.43 and 1.73 respectively. To transform the non-normal to normal data, a square root and a log transform were applied using SPSS 21. Other latent constructs remained untransformed, since the level of the skewness and kurtosis for these constructs were within the interval of (−1, +1). We used the normalised data for further analysis.

According to Hair et al. (2010), when there are many indicators of constructs or latent variables, it is better to recruit 10 respondents per one indicator. However, Anderson and Gerbing (1988) recommend that researchers apply a sample size of 100 to 150 for theoretical models that determine three or more indicators per factor. Hair et al. (2006) later acknowledged this method and asserted that this method can usually be sufficient for a convergent and appropriate solution for CFA. Hair et al. (2006) add that 100 is the minimum sample size for using maximum likelihood estimation (MLE) to ensure that the model represents highly accurate estimates. In adding more participants to the sample size (sample size = 100), sensitivity in the MLE method to identify differences among the data also increases. However, Hair et al. (2006) claim that a sample size of 400 – 500 is seen to be too sensitive for model goodness-of-fit. Therefore, a total number of 335 survey responses were considered for further analyses (a number of 365 responses were received). Table 8 shows the characteristics of the sample. Less than 40% of participants were unfamiliar with the use of social robots in residential aged care facilities. Therefore, the research team decided to show at least five different videos to all participants in which the PaPeRo robot was performing for older people. It helped the participants to become familiar with robot application in residential aged care facilities. The research team also gave more information such as *how many times a day do and how does PaPeRo perform in residential aged care facilities*, if necessary.

Table 8
Characteristics of the sample.

Category	Item	Frequency	Percentage
Gender	Male	150	44.8
	Female	185	55.2
Age	20-30 years	32	9.6
	31-40 years	98	29.3
	41-50 years	124	37
	51-60 years	64	19.1
	+60 years	17	5.1
Experience	>1 year	48	16.8
	1-5 years	136	40.6
	6-10 years	69	20.6
	11-15 years	56	16.7
	+15 years	26	7.8
Familiarity with Social Robots	Attended in field trials	63	18.8
	Familiarity through Social Media	139	41.4
	Unfamiliar with social robots	133	39.7

Table 9
Factor analysis to verify convergent validity.

Construct	Items	FL	CR	AVE
Robot Service Enablement (RSE)			0.955	0.730
	Aged Care Service Reliability	0.82		
	Aged Care Service Cost	0.84		
	Aged Care Service Safety	0.90		
Robot Mediation (RM)			0.952	0.952
	Personalised Service Delivery	0.87		
	Entertainment	0.92		
	Social Connectivity	0.82		
Aged Care Service Innovation (ACSI)			0.915	0.654
	Social Interaction	0.76		
	Social Companionship	0.81		
	Self-Care	0.85		
Socioeconomic Accessibility (SEA)	Personalised Capability Awareness	0.83	0.948	0.688
	Affordability	0.80		
	Decision Power	0.85		
Community Ties (CT)				
	Sense of Community	0.75	0.918	0.683
	Social Support	0.78		
	Sense of Place and Time	0.94		

6.1. Reliability and Validity

Over completing and analysing the preliminary data in Study 2, minor modifications such as reduction simplification in the number of questions and avoiding vagueness and repetition were made to improve the reliability of the scale. Reliability of the scale was satisfactorily evaluated for internal consistency for all constructs, determining an acceptable range of Cronbach's Alpha values (see Appendix 1), above the recommended value 0.70 (Creswell, 2013). The content validity was conducted by asking specialists and colleagues to respond to questions carefully and comment on each question, if necessary. In addition, the design of the survey was based upon the results obtained from the Qualitative Phase (the GTM) and the relevant literature review on social robots in aged care. According to Sekaran (2006), extracting quantitative items from the both qualitative phase and literature review can improve content validity. A CFA verified both convergent and discriminant validity tests using Amos 21. As evident in Table 9, standardized factor loadings were (FL > 0.5), construct reliability (CR > 0.7) and average variance extracted (AVE > 0.5) (Brown, 2015; Hair et al., 2010). Fortunately, all constructs and their variables met these standards. Table 10 illustrates discriminant validity by comparing the square roots of AVE each construct's correlation coefficients (Fornell and Larcker, 1981). According to Fornell and Larcker (1981) all latent constructs' correlation coefficients should be less than the square root of AVE values to verify the discriminant validity.

Table 10
Means, standard deviation and correlations to verify discriminant validity.

Construct	Mean	Std. Deviation	1	2	3	4	5
1. RSE	4.46	1.33	**.85**				
2. RM	5.10	1.19	.122	**.88**			
3. ACSI	4.66	1.38	.346	.248	**.81**		
4. SEA	4.19	1.49	.144	.116	.221	**.83**	
5. CT	4.51	1.29	.081	.309	.269	.171	**.82**

All Correlation is significant at the 0.01 level (2-tailed). The bolded section: square root of AVE values.

6.2. Common Method Variance

Re-establishing the CFA model in which all items were loaded on a common factor (Podsakoff et al., 2003), this study applied the common method variance (CMV). It was found that CMV accounted for less than 4% of the variance ($\mathcal{X}^2/df = 1.7 < 3.00$, $P < 0.05$). Therefore, this result suggests that the CMV in this study may not be a serious issue.

6.3. Measurement Model and Hypotheses

Maximum likelihood estimation in CFA was used to assess the measurement model. The same standards were applied to assess convergent validity. The final model yielded significant measures for model fitting. Chi-square X^2; p = 0.000 < 0.05), Chi-square/degree of freedom ($\mathcal{X}^2/df = 1.73 < 3.00$), comparative fir index (CFI = 0.979 > 0.90), normed fit index (NFI = 0.951 > 0.90), goodness of fit index (GFI = 0.947 > 0.90), adjusted goodness of fit index (AGFI = 0.923 > 0.90), root mean residual (RMR = 0.026 < 0.10), and root mean square error of approximation (RMSEA = 0.047 < 0.050) verified the validity of measurement model. This process was significantly tested and verified, and the hypotheses were assessed based upon the final model (Fig. 1).

As presented in Table 11, H1 shows a significant positive influence of robot service enablement on aged care service innovation. H2 shows a positive influence of robot mediation on aged care service innovation and H3 and H4 represent positive influences of aged care service innovation on socioeconomic accessibility of and community ties among older people respectively. Along with the mediating effect of aged care service innovation, four more hypotheses including H5-H8 were also provided to test the direct impacts of robot service enablement and robot mediation on socioeconomic accessibility and community ties.

More specifically, in H5 and H6, insignificant direct relationships were found between robot service enablement and socioeconomic accessibility (estimate = 0.07; C.R. = 1.11 that is in of (-1.96 + 1.96) and P-value = 267> 0.05) and community ties (estimate = -0.02; C.R. = -0.365 that is in of (-1.96 + 1.96) and P-value = 0.715 > 0.05). Similarly, H7 that shows the direct relationship between robot mediation and socioeconomic accessibility, was not also supported (estimate = 0.06; C.R. = 1.04 that is in of (-1.96 + 1.96) and P-value = 298> 0.05). Thus, to enhance the quality of the lives of vulnerable older people using social robots, we need to consider the mediating effect of aged care service innovation. However, the direct relationship between robot mediation and community ties was significantly supported. Table 11 shows the results of supported hypotheses in Study 2.

7. Discussion and Conclusion

This paper conducted a mixed methods research to develop a conceptual model and eight research hypotheses using GTM and to test these hypotheses using CFA.

First, the results of Study 1 helped build up new constructs in the literature on social robotics, service innovation in aged care and social vulnerability. As a result, five constructs were drawn through in-depth interviews with specialists in both social robotics and aged care, leading to providing eight research hypotheses that logically were supported in the relevant literature. Study 2 used CFA to evaluate the significance of the proposed hypotheses. The main findings were that: (1) robot service enablement and robot mediation can positively improve aged care service innovation; (2) aged care service innovation can positively reduce social vulnerability by improving socioeconomic accessibility of and community ties among older people. Of all direct relationships between two independent and two dependent latent constructs, only robot mediation has a positive impact on community ties. These relationships were scarcely examined in the prevalent literature.

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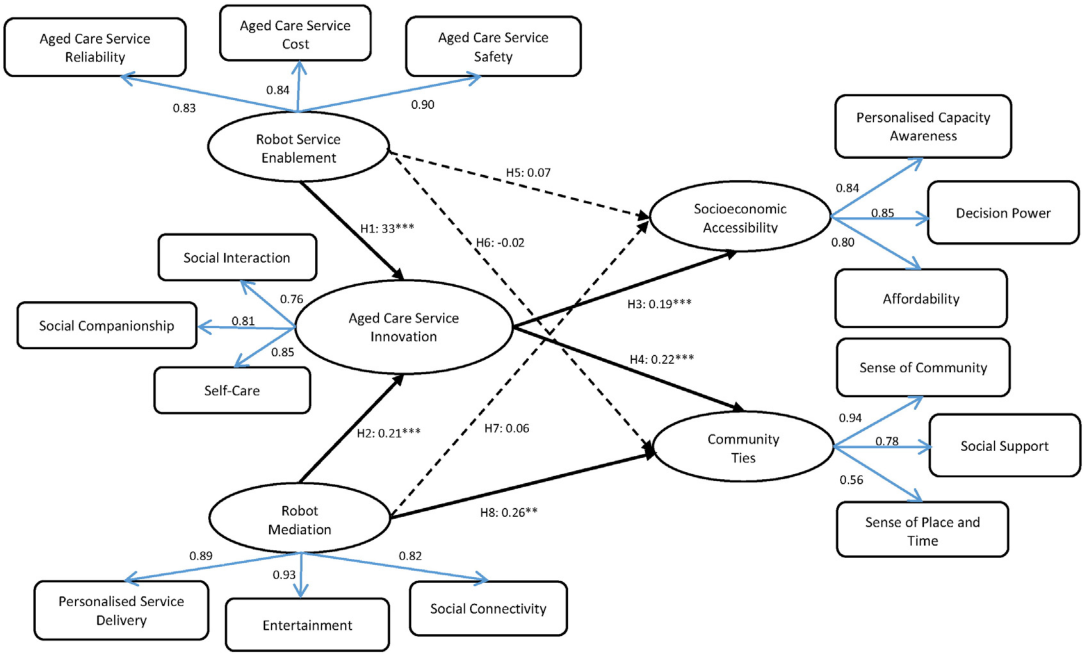

Note: Path estimates are standardized coefficient. ***p < .001; **p < .01 (two-tailed set). → Supported Hypotheses ---> Not Supported Hypotheses

Fig. 1. Structural model of aged care service innovation by using social robots. Note: Path estimates are standardized coefficient. ***p < .001; **p < .01 (two-tailed set). → Supported Hypotheses —> Not Supported Hypotheses.

More specifically, all the indirect effects (H 1-4) were significant. First, the relationship between robot service embalmment and aged care service innovation was positively supported. This shows that robot service enablers including reliability, affordability and safety in robot services can facilitate providing innovative services in aged care facilities. Second, the relationship between robot mediation and aged care service innovation was positively supported. This is likely to be because of the facilitating factors of robot services including personalised service delivery to each single older person, entertainment and social connectivity that aim to create value for and with older people and their caregivers in an innovation manner. For example, the game bingo which is very popular in the Australian aged care facilities can be played with social robots such as PaPeRo. This robot can recognise the primary cognitive impairments among older people during the game and continue it as long as the game is interesting to the participants. PaPeRo is also able to look after those how might fall behind and let them get back to the game. In addition, caregivers that formerly used to call numbers in this game, feel comfortable while the robot plays game. During this time, they can also allocate their time to better monitor older people performances.

Study 2 also supported the impacts of aged care service innovation on both constructs relating to reduction of social vulnerability among older people (socioeconomic accessibility and community ties). More specifically, third, relationship between aged care service innovation and socioeconomic accessibility was positively supported. Innovative services created by using social robots in aged care can increase access to and equality in aged services for all older people in aged care facilities. This is because social robots can be equipped based on the needs available in aged care facilities. For example, social robots that are only designed to give accompany to and entertain older people, are more affordable than those that are developed to diagnose isolation and depression in older people with dementia. In addition, social robots can notify older people of their capacity to engage with their community. For example, if an older person is too emotional and cannot burden listening to sad music, the robot may warn this situation to the person or caregiver. As a result, the robot can help older person better decide in his/her daily life without any serious concern about doing something that may put the person at risk.

Table 11
Hypothesis testing results.

Hypothesis	Estimate	S.E.	C.R.	p	Result
H1. RSE → ACSI	.408	.33	5.34	< .001	Supported
H2. RM → ACSI	.210	.21	3.66	< .001	Supported
H3. ACSI → SEA	.162	.19	2.64	< .01	Supported
H4. ACSI → CT	.214	.22	3.24	.001	Supported
H5. RSE → SEA	.080	.07	1.111	.267	Not supported
H6. RSE → CT	-.028	-.02	-.365	.715	Not supported
H7. RM → SEA	.055	.06	1.04	.298	Not supported
H8. RM → CT	.251	.26	4.30	< .001	Supported

Note: S.E. = Standardized Regression Weights; C.R. = Critical Ratio; p = p-value (statistical significance).

Forth, the model also supported relationship between aged care service innovation and augmentation of community ties among older people. It is clear that the purpose of social robot development is to support better life for older people living in residential aged care facilities. In doing so, features of social robots such as providing social interaction, social companionship and self-care seem to encourage older people to more actively engage with their community. For example, the ability to contact older people's family or friends in aged care facility can make a social robot as a tele-social support platform that easily engage older people with their family and friends. In addition, these features might improve older people's perceptions toward aged care facilities as a right place to be. For example, group games provided by PaPeRo or Paro such as bingo are a way to get older people involved in a social activity at the same place and time. Given that social robots are introduced as service innovators in aged care facilities, the construct of aged care service innovation could appropriately mediate the robot services and factors reducing social vulnerability.

In addition to the mediating effects of aged care service innovation between the robot service drivers (robot service enablement and robot mediation) and factors relating to reduction of social vulnerability among older people, this paper tested direct effects between the drivers and factors (H 5-8). Of all hypotheses, only the relationship between robot mediation and community ties was positively supported. This supported hypothesis shows the mediating role of social robots between caregivers and older people, emphasising that social robots can improve community ties among older people through entertainment, personalised service delivery and social connectivity. Knowing that the aged care industry is looking at the benefits that social robots can create for the aged care facilities including accessibility, social and community benefits and social support, the use of social robots in aged care is not at the stage of commercialisation and the robots have yet to be in the market. As a result, the participants in our survey were somewhat unable to technically consider the role of social robots in reducing social vulnerability. This might have led to the rejection of three of direct effects. However, providing innovative services to older people is always a way to be successful in aged care industry. All specialists in aged care know that service innovation through technological advances can improve quality of life for older people living in residential aged care facilities. As a result, the mediating role of aged care service innovation was acknowledged by the survey participants.

7.1. Theoretical Implications

This mixed methods research made several contributions to the literature. The research team investigated the influences of robot service enablement and robot mediation on aged care service innovation directly and factors reducing social vulnerability indirectly, contributing to both aged care social robotics literature and aged care service innovation literature. While social robotics has been applied in several studies on aged care, however the majority of them consider social robots as talking machine or pet, without paying attention to human like engagement in aged care. In addition, this study developed a conceptual model for the use of social robots to reduce social vulnerability in aged care facilities. In aged care and social robot contests, there are many social and economic factors that impact the quality of life for older people such as affordability, income, social networks, interpersonal relationships, community ties and social support. In existing studies, very few of research surveyed these factors simultaneously. However, the conceptual model proposed in this study could appropriately address some of these factors. This conceptual model focuses on social changes that are able to align with technological changes. Overall, this study advances the theoretical approach to social robots based upon five new concepts: robot service enablement, robot mediation, aged care service innovation, socioeconomic accessibility and community ties.

7.2. Methodological Implications

Although the research methods and techniques applied in this study were not novel, the research team used a new combination of them that had not been done previously. More specifically, Study 1 used GTM to explore initial concepts of aged care social robots in a social vulnerability context and develop a conceptual model. By using CFA, Study 2 validated a conceptual model and evaluated the research hypotheses.

7.3. Practical Implications

The aging population in advanced countries such as Australia requires the establishment of service innovation in aged care to provide better services to older people with their diversity in terms of well-being and social support. It is also important that aged care services become cost effective for older people community. Social robots, as a new generation of assistive technology, are able to meet the challenges that influence the well-being of older people. This paper helps social robotics scholars, the management of aged care facilities and caregivers to improve the quality of life for older people by understanding the role of social robots in aged care.

Firstly, the results of this paper indicated that social robot services can lead to the provision of service innovation in aged care and promotion of the quality of life for older people to live socially and independently through reduction of social vulnerability. In order to meet these expectations, aged care managers are suggested to gradually reconstruct daily social activities in aged care facilities by using social robot as caregiver's assistant to improve the capacity of caregiving to older people. In doing so, the managers should consider the entertaining aspects of social robots such as gaming, singing, and dancing to allow older people to become familiar with the robot. The social robotics scholars, on the other hand, can enhance human-like communication modalities in social robots to make them more interested than just a toy or pet. In addition, they are needed to be very intelligent and quick to respond to help older people to independently live in aged care facilities. It also facilitates the process of service delivery and builds trust between the robot and older people.

Secondly, social robots are able to provide the respite for caregivers in aged care facilities. Playing and communicating with a social robot, improves the capacity of caregivers to allocate much more time on other aspects of aged care such as identifying the rate of isolation and depression in older people. Moreover, the use of social robots in aged care can help older people to actively engage with the daily programs provided by caregivers. For example, Australian older people enjoy playing bingo. This game can be performed by using a social robot. Over this time, caregivers can monitor the performance of older people in social context. Thirdly, providing social interaction and companionship for and with older people helps them to expand their connection and relationship with others. In Australian's aging community, for example, social robots can interest older people to play game and music leading to more social interaction with other people. This paper indicates that the use of social robots can reduce the concern about the socioeconomic accessibility of older people to better services in aged care facilities, as the robot is non-judgemental.

To the best of our knowledge, this study is the first to explore the socio-technological factors leading to aged care service innovation and the reduction of social vulnerability among older people, and to develop a conceptual model examining the relationships among robot mediation, aged care service innovation, socioeconomic accessibility of and community ties among older people. Australian aged care facilities were targeted in this study to help a better understanding of service innovation in aged care to reduce social vulnerability among older people using social robots.

7.4. Limitations and Further Research

This study acknowledges some limitations. First, this study was carried out only among aged care practitioners and occupational therapists in Australia. Further research is needed to approve the results with a wider group of people who are involved with aged care social robots such as older people's relatives. Second, while the results of data reliability and content validity have been successfully done, the research team relied only on the Qualitative Phase and the relevant literature to generate the hypotheses. However, it would be better if further research applies an exploratory factor analysis (EFA) to ensure the items generated are appropriately applied in their construct. Third, while the results of the model developed are successful in the context of aged care, there is no guaranty that these results would be applicable in other areas such as autism care or child care. Therefore, the research team encourages other scholars to find other aspects of social vulnerability that influence these areas.

This paper, first, recommends social robotics scholars should focus more on designing and operating aged care social robots by identifying social factors that reduce social vulnerability among older people. Understanding these socio-technological factors allows scholars to put more effort into service innovation delivery to older people living in aged care facilities and to improve the capacity of caregivers in aged care. Second, aged care facilities should focus on the use of social robots to improve aged care services and create greater opportunities for older

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people both to engage with society and independently improve the quality of their lives. Third, given that social vulnerability among older people is undeniable, understanding factors that make an aged person vulnerable is an important topic. This paper indicates that it is better to apply social robots in aged care to reduce social vulnerability by improving social interaction, independence among older people and increasing the capacity of caregivers. Knowing the factors of social vulnerability, social robotics scholars are able to design and operate appropriate social robots for older people rather than technology push.

Appendix 1. Summary of the five constructs and their Cronbach's alphas.

Construct	Item	Measurement Items	Cronbach's Alpha
Robot Service Enablement			0.89
	ACSR	Social robot should deliver service with or without connecting to the internet and other devices.	
	ACC	Social robot should be affordable for purchasing or leasing.	
	ACS	Social robot should keep the caregivers informed about critical situations that might endanger older people.	
Robot Mediation			0.91
	PSD	Social robot should provide service responding older people's needs whenever, wherever and whatever.	
	SC	Social robot should respond the needs to make the sense of comfort for older people.	
	ENT	Social robot should be able to play game/music and dance/sing to entertain older people.	
Aged Care Service Innovation			0.85
	SI	Social robot should provide service which augments social interaction among older people.	
	SCo	Social robot should provide service which augments good memories for older people.	
	SCa	The assistance of robot service should help older people to do daily activities independently.	
Socioeconomic Accessibility			0.87
	AFF	Robot personalised services can be affordable for older people with different levels of purchasing power.	
	PCA	Robot service should increase the personal awareness of older people to their capabilities.	
	DP	Social robot should improve decision-making for older people, e.g. when to go to the toilet, how to choose a song, when to play a game and so on.	
Community Ties	SoPT	Social robot should help enhance the sense of belonging among older people as residents of an aged care facility.	0.86
	SS	Social robot should provide service to make older people more resilient to their community.	
	SoC	Social robot should help older people to enhance the sense of community.	

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.techfore.2016.07.009.

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