

Review Article

Combatting social isolation and increasing social participation of older adults through the use of technology: A systematic review of existing evidence

Steven Baker 

Microsoft Research Centre for Social Natural User Interfaces, School of Computing and Information Systems, University of Melbourne, Melbourne, Victoria, Australia

Jeni Warburton

John Richards Initiative, College of Science, Health and Engineering, La Trobe University, Wodonga, Victoria, Australia

Jenny Waycott

School of Computing and Information Systems, University of Melbourne, Melbourne, Victoria, Australia

Frances Batchelor

National Ageing Research Institute, Melbourne, Victoria, Australia

Thuong Hoang

Microsoft Research Centre for Social Natural User Interfaces, School of Computing and Information Systems, University of Melbourne; and School of Information Technology, Deakin University, Melbourne, Victoria, Australia

Briony Dow

National Ageing Research Institute, Melbourne, Victoria, Australia

Elizabeth Ozanne

Department of Social Work, School of Health Sciences, Faculty of Medicine, University of Melbourne, Melbourne, Victoria, Australia

Frank Vetere

Microsoft Research Centre for Social Natural User Interfaces, School of Computing and Information Systems, University of Melbourne, Melbourne, Victoria, Australia

Objectives: *There are growing concerns that social isolation presents risks to older people's health and well-being. Thus, the objective of the review was to explore how technology is currently being utilised to combat social isolation and increase social participation, hence improving social outcomes for older people.*

Methods: *A systematic review of the literature was conducted across the social science and human-computer interaction databases.*

Results: *A total of 36 papers met the inclusion criteria and were analysed using a four-step process. Findings were threefold, suggesting that: (i) technologies principally utilised social network services and touch-screen*

technologies; (ii) social outcomes are often ill-defined or not defined at all; and (iii) methodologies used to evaluate interventions were often limited and small-scale.

Conclusion: *Results suggest a need for studies that examine new and innovative forms of technology, evaluated with rigorous methodologies, and drawing on clear definitions about how these technologies address social isolation/participation.*

Policy Impact: This systematic review explores how technology is currently being utilised to combat social isolation and increase social participation for older people. A unique aspect of this review is that it incorporates smaller design studies and prototypes. These insights will benefit those considering the potential for information and communication technologies to contribute to older adults' health and well-being.

Practice Impact: This systematic review explores how technology is currently being utilised to combat social isolation and increase social participation for older people. Insights from the review will benefit practitioners seeking to understand the broad range of technologies that are being applied to these issues, and the common benefits and challenges associated with each approach.

Key words: *social isolation, social participation, technology.*

Introduction

Two of the most disruptive transformations facing developed countries in recent history have been the social and economic challenges related to a rapidly ageing population, and the advancements in information and communication technologies (ICTs) [1–3]. The combined impacts of these transformations have led to increasing interest in investigating how ICTs might support older adults and improve their health status by reducing the negative impacts of social isolation and loneliness, while promoting social participation.

There is a growing body of international evidence indicating that older people are particularly vulnerable to social isolation and loneliness and that it has a negative impact on their lives [4–7]. This literature highlights the associated risk factors for poor physical and mental health, serious

Correspondence to: Dr Steven Baker, Microsoft Research Centre for Social Natural User Interfaces, School of Computing and Information Systems, University of Melbourne.
Email: steven.baker@unimelb.edu.au

illness and increased mortality [4–7]. The evidence highlights the strong association between social networks, participation and health status [7].

At the same time, however, there is an identified absence of a clear and consistent definition of social isolation in the empirical literature [8–10]. For example, social isolation and loneliness are often used interchangeably, but are actually separate although related social concepts [11]. Social isolation can be seen as a more objective state, whereas loneliness relates to how people perceive and experience the lack of interaction and is thus more difficult to measure [11]. There is also ongoing debate as to how best to define the concept of social participation, with terms such as participation, social participation, social involvement and social needs being used interchangeably in the literature [12–14]. However, despite all these conceptual slippages, clear connections can be drawn between the lack of opportunities to participate in social activities and deleterious impacts due to social isolation and loneliness [4,14]. Thus, in this review, we will focus specifically on technological responses to addressing social isolation and building social participation of older people.

There have been a broad range of social programs designed to address the prevalence of social isolation among older people, with technological interventions proposed as one way to provide an effective response [1,11]. Chief among the advantages of ICT in combatting the challenges facing older adult populations is its ability to connect and reconnect people across large geographic distances and its support of both synchronous and asynchronous forms of communication [15]. Due to the rapidity of technological advances, it is important to explore how specific ICTs are being leveraged to address social isolation, to identify gaps in the literature and to strengthen the quality of research in this rapidly evolving area. It is also vital that those considering research in the field are well appraised of cutting-edge technologies and design approaches that offer new potential to address the challenges faced by older adults. The intent of this article is to address these issues.

Thus, the aim of this systematic review was to investigate how technology is being used to combat social isolation and increase social participation for older adults. While a number of recent reviews have explored interventions designed to address social isolation, including technological interventions [4,5,10], a unique aspect of this review is that our inclusion criteria incorporate smaller design studies and prototype evaluations from the field of human-computer interaction (HCI), a body of literature often neglected in systematic reviews. This allows us to consider the latest techniques and technologies being applied in the field and recognises the pace at which cutting-edge technologies develop. These insights will benefit all those considering new research exploring the ways in which ICTs can contribute to the well-being of older adults.

Methods

Search strategy

A systematic search strategy was designed to address the key aim of the review which was to explore how technology was being used to combat social isolation and increase social participation for older adults. The search of the literature was undertaken in August 2016 utilising PRISMA guidelines [16]. Relevant peer-reviewed literature was obtained by searching five electronic search engines: (i) Scopus; (ii) Compendex; (iii) Inspec; (iv) Association for Computing Machinery; and (v) Web of Science.

Inclusion criteria

All included articles were peer-reviewed and published in English between January 2000 and August 2016. Inclusion criteria, including the three key search terms, were as identified in Table 1. Technology referred to ICTs and could include devices (hardware), applications (software) and websites. The term older people was as used as in the literature, although generally identified as aged over 65 years. Both social isolation and social participation were included within the relevant key search term. Thus, papers included use of any technology targeted at older people and aimed at supporting social participation and/or reducing social isolation. Search exclusions are described in Table 2. Search exclusions were identified in conjunction with a research librarian while reviewing the initial search results. As the focus of the review is an applied one, in other words how technology can be utilised using interventions, only empirical research is included in the review, and both theoretical and descriptive studies were excluded.

Study selection

Analysis was conducted in a four-step process given the large number of articles that emerged at step one. First, article titles and abstracts were screened electronically for search terms and exclusions. Second, duplicates were both removed automatically and manually screened by title and abstract independently by a review author (SB) to identify studies that broadly met the inclusion criteria. Third, articles were assessed by review authors (SB, JW and FV).

Table 1: Search strategy Boolean operators and modifiers

Key search terms – Technology (Boolean Operators OR, AND)	Key search terms – Older Adult (Boolean Operator OR, AND)	Key search term – Social isolation/social participation
'Information and Communication Technology' OR ICT OR 'Information Systems' OR 'Human-Computer Interaction' OR HCI AND	Seniors OR Elderly OR 'Older Adult' OR 'Older People' AND	Social*

Table 2: Excluded search terms

Excluded search terms (Boolean Operator AND NOT)

'Organisation and Management' OR
 'Medical Information Systems' OR
 Adolescents OR
 Telemedicine OR
 'Young Adults' OR
 Robot* OR
 'Geographic Information System*' OR
 GIS OR
 'Information Management'

Fourth, full-text articles were retrieved for these, and data extraction was undertaken using a customised template by review authors (SB, JRW, FB, BD, EO, JW and TH). For each study, data extraction and collation included the following: (i) the type of technology being used; (ii) how authors defined social isolation or social participation; (iii) the methodology used; number of participants; (iv) brief summary of outcomes; and (v) any additional observations. Any disagreements were resolved through further review and team discussion.

Data collection and synthesis

Articles were not restricted by study design or outcome measures. Articles thus include both qualitative and quantitative data and hence are not reported based on statistical data. They also include a range of outcomes measures. Primary outcomes from the study relate to the use of technologies to support social participation and/or reduce social isolation for older people. Secondary outcomes may also relate to subsequent improvement in health and/or well-being among participants.

Results

The initial search of information sources at step one yielded an initial scan of 3123 articles from the databases, with the breakdown of results from each database presented in Table 3.

Figure 1 shows results from the four-step process. At step two, duplicate articles were eliminated, and abstracts were manually reviewed and evaluated according to inclusion criteria. The result was 890 articles, which were then reduced to 73 articles at step three. These were excluded

on a number of grounds. First, some articles were not sufficiently related to the topic; for example, the search term 'seniors' included results relating to high school seniors. Second, as noted earlier, articles were excluded on methodological grounds, with some descriptive or theoretical studies and not empirical research. Some also contained insufficient methodological detail, including short articles or extended abstracts. This reduced the numbers resulting at each step. At step four, the full texts of these 73 articles were read by members of the review team using the customised template described above. Here, a further 37 articles were removed as, on closer examination, they did not meet the inclusion criteria. At the completion of this stage, 36 articles were identified for inclusion in the review process.

Table 4 provides a summary of key aspects of the 36 papers included in the review. Due to the number of relevant studies, the findings are combined in terms of common themes. Specific articles are identified by reference number. In this table, both the aims and key outcomes are also reported, as well as what social concepts are utilised as outcome measures. In Table 5, the methods utilised by each study are described.

Findings are thus presented in terms of three key themes: (i) the types of technologies that are used in extant studies (Table 4); (ii) the social concepts that are utilised to discuss outcomes (Table 4); and (iii) the methods incorporated in this body of empirical research (Table 5). These findings enable us both to provide a critique of existing literature and to identify gaps in the evidence that merits further exploration.

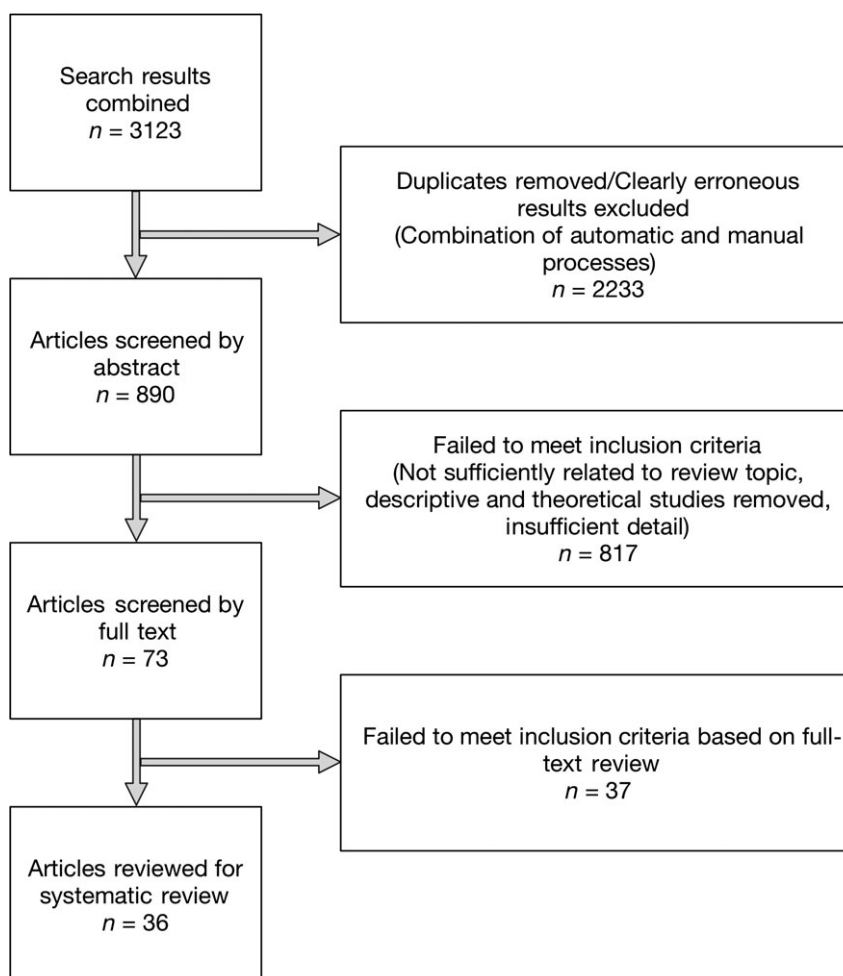
The focus of technologies utilised in review studies

Of the 36 papers reviewed, the largest segment (13 papers) comprised research into older adults' use of social network services (SNS) (see Table 4). Of the papers included in this review, five were examinations of older adults' use of pre-existing commercial SNS such as Facebook and LinkedIn. The remaining eight papers evaluated older adults' use of bespoke SNS. These ranged from examinations of newsgroups and web portals [17–19] through to custom-designed SNS that responded to the perceived needs of older users [20–24].

While there was a mix of studies examining either existing or custom-made approaches in relation to SNS, studies that focussed on touch-screen-based interventions – the second most prevalent technology identified in the review – skewed heavily in favour of bespoke interfaces for older users (eight of nine papers). Many of these software applications aimed to tap into and leverage the perceived advantages of the touch-screen format, such as the lack of a mouse or other pointing device, or a rigid desktop-type hierarchical file system. Much of the software incorporated social features, such

Table 3: Results from initial search of included databases

Electronic research database	Results
Scopus	749
Compendex	593
Inspec	385
ACM (full digital guide to computing literature)	1185
Web of Science	211
Total	3123

Figure 1: Selection process for systematic review.

as the ability to share photographs or initiate videoconference features to promote social interaction, with either other older adults [25–27] or family members and friends [28–30]. Three papers included here examined the experiences of the older adults using the touch-screen systems, the design implications and some of the ethical challenges involved with this type of research [31–33].

The remainder of the papers examined either novel technologies that sat outside those noted above or evaluations of the impact of ICT-based training and support on older adults' social lives. Seven papers examined the adaptation of various existing technology platforms such as videoconferencing, ambient assisted living devices or *exergames*, which aimed to engage older adults in social activities. These studies tended to examine very novel interaction techniques, for example 'Walky' – the microblogging walking frame [34] – or the 'Seasons Wholeness' immersive music and art experience [35], although this innovation often came at the expense of larger scale evaluations. The final category

of papers, those interested in interviewing older adults about their experiences using ICTs or evaluating large-scale data about Internet and ICT usage, was valuable in framing the more technology-focussed papers within broader concepts of social participation and social interaction.

Social concepts used to determine outcomes

Table 4 presents the range of social concepts utilised in the review literature. These varied considerably, with many failing to define clearly the social outcomes being addressed in their study, whether it related to redressing social isolation or increasing social participation. As outlined in Table 4, the social concepts were often poorly defined using broad terms such as 'increasing communication' or 'improving access to information'. Twelve of the thirty-six papers in the review contained no definition of what was meant by social participation or social isolation at all. Only five papers offered an explicit definition that was based on a standardised measure or included a discussion of the debates about social outcomes.

Table 4: Summary of results.

Technology focus	References	Aim	Social concepts	Key outcomes
Touch-screen technology	[27]	To assess use of iPads with older adults using off-the-shelf applications	Network society, disadvantaged populations, homelessness	Facilitating interactions with support workers Reconnecting with family Reminiscing about life events
	[28] [32]	Evaluations of a bespoke touch-screen application	Interactions with family members and friends Promoting physical activity Encouraging the sharing of digital content with peers	Factors that impacted on the adoption of the devices and bespoke software Usability issues with touch-screen devices Challenges of working with older adults in a range of real-world and institutional settings Classifying older adults' communication styles Sustainability of use over time Privacy and personal identity issues Promoting self-expression
	[30]			
	[25] [26]			
	[31] [29]	Reflections on the design challenges and/or ethical implications of touch-screen-based interventions with older adults	N/A	Consider the factors behind older adults choosing to withdraw from studies using ICTs Communications styles and their impact on research. Disconnect between client needs and the needs of older users.
SNS	[33]			
	[45]	Evaluations of older adults' use of existing SNS	Explore the links between SNS use and QoL factors Assess the impact of personality types on SNS use	No relationship between loneliness and SNS use, or non-use Most effective for online communities to be designed to focus on facilitating information sharing Importance of privacy for older SNS users Ambivalence about whether Facebook provided a sense of community Older adults describe themselves more formally than younger users on SNS
	[46]			
	[47]			
	[48] [49]		Comparisons of younger and older SNS users Assessments using psychometric scales	Older women more enthusiastic about SNS use Senior newsgroups tend to be dominated by a small group of users
	[19]	Evaluations of bespoke SNS specifically tailored for older users	Compare social isolation and social engagement results What do older users value in bespoke SNS?	Older adults favour extending social contact to include other technologies (telephone, VoIP, email) in addition to SNS SNS use in an aged care facility found to increase self-esteem and self-confidence SNS use by Chinese older adults favoured formally organised leisure activities over self-organised for mobile SNS Concern over privacy prevented some older adults from using bespoke SNS
	[20]			
	[17]		SNS as a means of promoting contact with family and friends. Intergenerational interaction	
	[21]		Gaining information about local events	SNS posts with emotional content show higher social connections among members than factual posts SNS can be used more for information gathering than social interaction
	[22] [23] [24] [18]			

Table 4: Continued

Technology focus	References	Aim	Social concepts	Key outcomes
Adaptation of use of existing technology platforms	[37]	To adapt video technology	A means of addressing social disconnectedness Intergenerational interaction Social participation in the information society to improve QoL	Users reported these systems helped to create a sense of social presence. However, participants preferred physical meetings and interactions
	[50] [35]			Users reported a sense of security when using the system; however, there were concerns about privacy
	[51]	To integrate social functions into ambient assisted living technologies	Gaining information about local services and supports Promoting social connectedness	Testing various interaction methods showed a preference for touch-based interaction over speech
	[52]			Innovative technologies included 'Walky', an interactive walking frame that shares your walking data with friends Encouraging parasocial relationships between older adults and virtual agents
Use of games to encourage social participation	[34]	To assess potential benefits of exergames	Intergenerational interaction	Potential role of ICTs in encouraging reminiscence and storytelling
	[43]		Intergenerational interaction Fun and pleasure	Exergames perceived as being more rewarding for younger users than older Sharing social game elements, such as comparing scores, beneficial for engaging older users
ICT training analyses and interview studies	[53] [54] [55]	Impacts of computer training	Does computer training have a positive impact on older adults' sense of social connectedness?	Results from the studies contradicted each other with one finding no correlation with enhanced social connection [46] and the other concluding that ICT use has the potential to enhance social networks [47]
	[56]			Using the Internet may be beneficial for decreasing loneliness and increasing social contact for older adults
	[57] [58] [36]	Interviews with older adults on attitudes to technology and social participation	Impact of Internet use on perceived social isolation and loneliness Older adults' preferences concerning social support	Perceptions and use of ICTs are embedded in older adults' personal social and physical contexts

ICTs, information and communication technologies; QoL, quality of life; SNS, social network services; VoIP, voice over Internet protocol.

Table 5: Study types included in the review

Study types	Number of papers	References
Interview-based qualitative evaluation	16	[17,21,23,24,26,27,30,31,33,36,47,50,54,55,57,58]
Smaller scale design, pilot and/or prototype evaluations	8	[25,29,32,34,35,37,43,52]
Surveys of older adults' use of ICTs	2	[48,49]
Mixed-method evaluation	3	[28,45,51]
Social network analysis	2	[18,19]
Quantitative evaluation	5	[20,22,46,53,56]
Total	36	

ICTs, information and communication technologies.

Breadth of methodologies included

One of the defining characteristics of the systematic review was its embrace of a broad set of studies relating to older adults' use of ICT for social participation. This was done to ensure that the review captured the ways in which a broader range of techniques and technologies are being used to discover how cutting-edge technology can impact on the well-being of older adults. An overview of the range of study types included in the review is summarised in Table 5.

The majority of studies included in the review employed qualitative methods to evaluate the impact of new technologies on older adults. These studies typically involved small samples between 8 and 43 participants and employed a range of qualitative methodologies including ethnography, grounded theory and action research. One study [36] was distinguished by its larger sample size (388 participants). The relatively high number of pilot or prototype evaluations included in the review reflected our goal to include papers that incorporate insights about novel uses of cutting-edge technologies. The majority of the papers in this category comprised smaller participant numbers, often less than 10 [19,21,41,43–45], although two papers [29,37] reported on prototype design testing that involved larger participant numbers.

Discussion

This systematic review has identified 36 extant articles which have explored how technology has been used to date to combat social isolation and/or increase social participation for older adults. While this is a relatively high number, an exploration of key themes addressed in this literature suggests both some key findings and important limitations in the body of evidence. The implications of these findings will be discussed under the three main areas presented in the findings above.

First, the technologies included in the review showed the dominance of research focussed on just two categories of ICT-based interventions: touch screens and SNS. We acknowledge that both touch screen and SNS are logical foci for research in this field. A comprehensive review of

tablet and smartphone usage by the Australian Communications and Media Authority (ACMA), released in 2016, found that '67% of Australian Adults used a tablet computer at least once a day to go online' [38]. Touch-screen technology has also proven to be popular among older people, such that a 2016 ACMA report on the digital lives of older Australians notes that tablet usage by older Australians was higher than by other adults (18%, compared to 16%) [39].

Similarly, the growth in SNS use over the past decade has risen exponentially, with Facebook being the most obvious example of this trend, increasing from around 1 million monthly active users in 2004 to over 1.2 billion monthly by 2013 [40]. Population-based survey research in both Australia and the United States supports the view that while older sections of the population still lag behind other segments, social media use is increasingly becoming a part of older adults' lives [39,41].

However, these findings also suggest that there is a need to broaden the focus of research efforts beyond the two dominant areas identified in the review. We hope that our inclusion of novel smaller scale prototype studies is a small step towards encouraging this effort. Examples include the design and evaluation of 'Walky' [34], an approach to embedding communication technology into everyday objects – in this case a walking frame – so as to make vulnerable older adults' activities more visible in their local communities; and the 'Seasons Wholeness' immersive music and art experience [35]. Several papers also reported the design of ICT-based games that would engage both children and older adults in fun shared activities [42,43]. The inclusion of these studies helps to frame creative means by which ICTs can inspire older adults to engage in social activities beyond the narrow constraints of mass market consumer devices and services.

However, overall, the dominance of SNS and touch-screen techniques does highlight a gap in research that focusses on more innovative technologies. This includes emerging technologies such as virtual and augmented reality applications, or virtual assistants that make use of machine learning and artificial intelligence.

The second key theme relates to the use of social concepts in this body of evidence. As noted in Table 4, many reviewed studies fail to clearly define the social outcomes being addressed in their study, whether it relates to redressing social isolation or increasing social participation. Some make an assumption relating to improved social outcomes, while others do not discuss concepts being incorporated into their study. While we acknowledge that there is an ongoing debate in the research literature about the best definition for both social isolation and social participation, there is nonetheless a need to offer an explicit definition or acknowledge this conceptual debate in order to design an intervention with clearly definable outcomes [7]. Thus, future studies need to provide a framework for what might be considered a successful intervention, either by including standardised measures or by providing qualitative evidence of the success of an intervention in a given context.

Third, methodologies incorporated into this body of research are broad and varied. Thus, while research into SNS use spans a range of research methods, including larger scale quantitative evaluations, to date, much of the research into older adults' use of touch-screen devices is still focussed on more preliminary user testing and shorter field trials. There is thus a clear gap in the literature for larger scale studies aimed at evaluating the impact of mature touch-screen-based interventions with older users in real-world contexts over time.

Overall, these findings suggest that there is a need for more studies that both utilise new and emerging technologies and evaluate their effectiveness in extended field studies and broader user evaluations. Technology use needs to be assessed in terms of how it works in the routines and contexts of people's everyday lives, as use develops over time. It is only through in-depth analyses of technologies in use that researchers can gain a full understanding of their impact [44].

Conclusion

This study reports a systematic review of literature from the social sciences as well as the field of HCI to explore how technologies are being used to redress social isolation and promote social participation among older adults. The review identified 36 papers that addressed this topic, highlighting the importance of technology as one way to reduce social isolation. A unique aspect of the review was that it sought to include studies that aimed to provoke new conversations about the way ICTs can respond to the needs of older adults. Despite this, most of the reviewed articles involved using or adapting pre-existing systems drawing on touch-screen technology and SNS, with relatively few examples of new technologies. This suggests a gap in knowledge relating to the use of emerging technologies. Finally, current evidence is somewhat limited due to

inadequacies in methodology, as well as insufficient attention to key social concepts. This makes it difficult to assess the effectiveness of specific technological interventions aimed at combatting social isolation or increasing social participation for older adults.

Acknowledgements

This research was supported by the Australian Research Council (DP160101368). The authors declare no conflicts of interest.

References

- 1 The McKell Institute. *Positive Disruption: Healthcare, Ageing and Participation in the Age of Technology*. World Square: The Institute; 2015. [Cited 12 April 2017.] Available from URL: <http://mckellinstitute.org.au/>
- 2 World Health Organization. *World Report on Ageing and Health*. Geneva: The Organization; 2015. [Cited 15 March 2017.] Available from URL: <http://www.who.int/ageing/publications/world-report-2015/en/>
- 3 Castells M. *The Rise of the Network Society*. Malden, MA: Blackwell Publishers; 1996.
- 4 Cornwell E, Waite L. Social disconnectedness, perceived isolation, and health among older adults. *Journal of Health and Social Behavior* 2009; 50: 31–48.
- 5 Eng P, Rimm E, Fitzmaurice G. Social ties and change in social ties in relation to subsequent total and cause-specific mortality and coronary heart disease incidence in men. *American Journal of Epidemiology* 2002; 155: 700–709.
- 6 Nicholson NR Jr. Social isolation in older adults: An evolutionary concept analysis. *Journal of Advanced Nursing* 2009; 65: 1342–1352.
- 7 Bartlett H, Warburton J, Lui C-W, Peach L, Carroll M. Preventing social isolation in later life: Findings and insights from a pilot Queensland intervention study. *Ageing and Society* 2013; 33: 1167–1189.
- 8 Chen Y, Schulz P. The effect of information communication technology interventions on reducing social isolation in the elderly: A systematic review. *Journal of Medical Internet Research* 2016; 18: 1–17.
- 9 Dickens A, Richards S, Greaves C, Campbell J. Interventions targeting social isolation in older people: A systematic review. *BMC Public Health* 2011; 11: 647.
- 10 Khosravi P, Rezvani A, Wiewiora A. The impact of technology on older adults' social isolation. *Computers in Human Behavior* 2016; 63: 594–603.
- 11 Poscia A, Stojanovic J, La Milia DI et al. Interventions targeting loneliness and social isolation among the older people: An update systematic review. *Experimental Gerontology* 2018; 102: 133–144.
- 12 Levasseur M, Richard L, Gauvin L, Raymond É. Inventory and analysis of definitions of social participation found in the aging literature: Proposed taxonomy of social activities. *Social Science and Medicine* 2010; 71: 2141–2149.
- 13 Piskur B, Daniels R, Jongmans MJ et al. Participation and social participation: Are they distinct concepts? *Clinical Rehabilitation* 2014; 28: 211–220.
- 14 ten Bruggencate T, Luijckx KG, Sturm J. Social needs of older people: A systematic literature review. *Ageing and Society* 2017; 1–26.
- 15 Castells M. A network theory of power. *International Journal of Communication* 2011; 5: 773–787.
- 16 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *British Medical Journal* 2009; 339: b2535.
- 17 Burneister OK. Virtuality improves the well being of seniors through increasing social interaction. In: Berleur J, Hercuui MD, Hilty L, eds. *What Kind of Information Society? Governance, Virtuality, Surveillance, Sustainability, Resilience*. New York, NY: Springer; 2010: 131–141.
- 18 Pfeil U, Zaphiris P. Investigating social network patterns within an empathic online community for older people. *Computers in Human Behavior* 2009; 25: 1139–1155.

- 19 Zaphiris P, Sarwar R. Trends, similarities, and differences in the usage of teen and senior public online newsgroups. *ACM Transactions on Computer-Human Interaction* 2006; 13: 403–422.
- 20 Ballesteros S, Toril P, Mayas J, Reales JM, Waterworth JA. An ICT-mediated social network in support of successful ageing. *Gerontechnology* 2014; 13: 39–48.
- 21 Chaumon M-EB, Michel C, Bernard FT et al. Can ICT improve the quality of life of elderly adults living in residential home care units? From actual impacts to hidden artefacts. *Behaviour and Information Technology* 2014; 33: 574–590.
- 22 Czaja SJ, Boot WR, Charness N et al. The personalized reminder information and social management system (PRISM) trial: Rationale, methods and baseline characteristics. *Contemporary Clinical Trials* 2015; 40: 35–46.
- 23 Gao Q, Ebert D, Chen X, Ding Y. Design of a mobile social community platform for older Chinese people in urban areas. *Human Factors and Ergonomics in Manufacturing* 2015; 25: 66–89.
- 24 Godfrey M, Johnson O. Digital circles of support: Meeting the information needs of older people. *Computers in Human Behavior* 2009; 25: 633–642.
- 25 Grosinger J, Vetere F, Fitzpatrick G. *Agile life*. Proceedings of the 24th Australian Computer-Human Interaction Conference – OzCHI '12; 26–30 Nov 2012, Melbourne, VIC, Australia. New York, NY: ACM Press; 2012: 162–165.
- 26 Waycott J, Vetere F, Pedell S et al. *Older adults as digital content producers*. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems – CHI '13; 27 Apr–2 May 2013, Paris, France. New York, NY: ACM Press; 2013: 39. [Cited 29 May 2016.] Available from URL: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84877991034&partnerID=tZ0tx3y1>
- 27 Baker S, Warburton J, Hodgkin S, Pascal J. The supportive network: Rural disadvantaged older people and ICT. *Ageing and Society* 2017; 37: 1291–1309.
- 28 Neves BB, Franz RL, Munteanu C, Baecker R, Ngo M. *My hand doesn't listen to me!* Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems – CHI '15; 18–23 Apr 2015, Seoul, Republic of Korea. New York, NY: ACM Press; 2015: 1593–1602.
- 29 Davis H, Pedell S. *Older adults' use of a novel communication system*. Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer-Human Interaction – OzCHI '15; 7–10 Dec 2015, Melbourne, VIC, Australia. New York, NY: ACM Press; 2015: 269–273. [Cited 31 May 2016.] Available from URL: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84963588876&partnerID=tZ0tx3y1>
- 30 Garattini C, Wherton J, Prendergast D. Linking the lonely: An exploration of a communication technology designed to support social interaction among older adults. *Universal Access in the Information Society* 2012; 11: 211–222.
- 31 Beacker R, Sellen K, Crosskey S, Boscart V, Barbosa Neves B. *Technology to reduce social isolation and loneliness*. Proceedings of the 16th international ACM SIGACCESS conference on Computers and accessibility – ASSETS '14; 20–22 Oct 2014, Rochester, NY, USA. New York, NY: ACM Press; 2014: 27–34.
- 32 Davis H, Pedell S, Lorca AL, Miller T, Sterling L. *Researchers as proxies for informal carers: Photo sharing with older adults to mediate wellbeing*. Proceedings of the 26th Australian Computer-Human Interaction Conference – OzCHI 2014; 2–5 Dec 2014, Sydney, NSW, Australia. New York, NY: ACM Press; 2014: 270–279. [Cited 05 June 2016.] Available from URL: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84945332082&partnerID=tZ0tx3y1>
- 33 Waycott J, Vetere F, Pedell S, Morgans A, Ozanne E, Kulik L. *Not for me*. Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems – CHI '16; 7–12 May 2016, San Jose, CA, USA. New York, NY: ACM Press; 2016: 745–757.
- 34 Nazzi E, Sokoler T. *Walky for embodied microblogging*. Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services – MobileHCI '11; 30 Aug–2 Sep 2011, Stockholm, Sweden. New York, NY: ACM Press; 2011: 563.
- 35 Chun-Ting L. INVITATION: An elderly friendly ICT-enabled interactive installation to promote social participations. *International Journal of Automation and Smart Technology* 2015; 5: 225–231.
- 36 Sayago S, Sloan D, Blat J. Everyday use of computer-mediated communication tools and its evolution over time: An ethnographical study with older people. *Interacting with Computers* 2011; 23: 543–554.
- 37 Achilleos AP, Mettouri C, Papadopoulos GA et al. *The connected vitality system: Enhancing social presence for older adults*. Proceedings of the 12th International Conference on Telecommunications, ConTEL 2013; 26–28 Jun 2013, Zagreb, Croatia. New York, NY: IEEE; 2013: 199–206. [Cited 10 July 2016.] Available from URL: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84883701554&partnerID=tZ0tx3y1>
- 38 Australian Communications and Media Authority. *Communications Report 2016/2017*. Sydney: The Authority; 2016. [Cited 17 January 2018.] Available from URL: <https://www.acma.gov.au/>
- 39 Australian Communications and Media Authority. *Digital Lives of Older Australians*. Sydney: The Authority; 2016. [Cited 14 May 2017.] Available from URL: <http://www.acma.gov.au/theACMA/engage-blogs/engage-blogs/Research-snapshots/Digital-lives-of-older-Australians>
- 40 Sedghi A. Facebook: 10 years of social networking, in numbers. *The Guardian* 2014; 4 Feb. [Cited 18 May 2016.] Available from URL: <http://www.theguardian.com/news/datablog/2014/feb/04/facebook-in-numbers-statistics>
- 41 Anderson BYM, Perrin A. *Tech Adoption Climbs Among Older Adults*. Washington, DC: Pew Research Centre; 2017. [Cited 30 May 2017.] Available from URL: <http://www.pewinternet.org/2017/05/17/tech-adoption-climbs-among-older-adults/>
- 42 Gamberini L, Martino F, Seraglia B et al. *Eldergames project: An innovative mixed reality table-top solution to preserve cognitive functions in elderly people*. 2009 2nd Conference on Human System Interactions; 21–23 May 2009, Catania, Italy. New York, NY: Institute of Electrical and Electronics Engineers; 2009: 164–169. [Cited 31 May 2016.] Available from URL: <http://www.scopus.com/inward/record.url?eid=2-s2.0-70349988079&partnerID=tZ0tx3y1>
- 43 Khoo ET, Cheok AD, Nguyen THD, Pan Z. Age invaders: Social and physical inter-generational mixed reality family entertainment. *Virtual Real* 2008; 12: 3–16.
- 44 Siek K, Hayes G, Newman M, Tang J. Field Deployments: Knowing from using in context. In: Olson J, Kellogg W, eds. *Ways of Knowing in HCI*. Berlin: Springer Science and Business Media Netherlands; 2014.
- 45 Vošner HB, Bobek S, Kokol P, Krečić MJ. Attitudes of active older Internet users towards online social networking. *Computers in Human Behavior* 2016; 55: 230–241.
- 46 Bell C, Fausset C, Farmer S, Nguyen J, Harley L, Fain WB. *Examining social media use among older adults*. Proceedings of the 24th ACM Conference on Hypertext and Social Media – HT '13; 1–3 May 2013, Paris, France. New York, NY: ACM Press; 2013: 158–163.
- 47 Bloch N, Bruce BC. *Older adults and the new public sphere*. Proceedings of the 2011 iConference on – iConference '11; 8–11 Feb 2011, Seattle, WA, USA. New York, NY: ACM Press; 2011: 1–7.
- 48 Choi JH, Kim S, Moon JY, Kang J, Lee I, Kim J. Seek or provide: Comparative effects of online information sharing on seniors' quality of life. *Communications of the Association for Information Systems* 2014; 34: 513–530.
- 49 Coelho J, Duarte C. A literature survey on older adults' use of social network services and social applications. *Computers in Human Behavior* 2016; 58: 187–205.
- 50 Achilleos AP, Mettouri C, Papadopoulos GA et al. *Developing an effective social presence system for older adults: The connected vitality network*. Proceedings of the ITI 2013 35th International Conference on Information Technology Interfaces; 24–27 Jun 2013, Cavtat/Dubrovnik, Croatia. Zagreb: University Computing Centre – SRCE; 2013: 3–8. [Cited 19 May 2016.] Available from URL: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84891278288&partnerID=tZ0tx3y1>
- 51 Brandenburgh A, van Breda W, van der Ham W, Klein M, Moeskops L, Roelofsma P. *Increasing physical and social activity through virtual coaching in an ambient environment*. Department of Artificial Intelligence, Vrije University, Amsterdam, Netherlands BT – Active Media Technology. 10th International Conference, AMT 2014; 11–14 Aug 2014, Warsaw, Poland. New York, NY: Springer International Publishing; 2014: 487–500.
- 52 Chen H-C, Lin Y-C, Liang R-H. Study through designing reminiscing activities for the elderly. *Digital Creativity* 2013; 24: 327–341.
- 53 Siegers K, Van Bostel MPJ, Jolles J. Effects of computer training and internet usage on the well-being and quality of life of older adults: A randomized, controlled study. *Journals of Gerontology Series B* 2008; 63: 176–184.

- 54 Winstead V, Anderson WA, Yost EA, Cotten SR, Warr A, Berkowsky RW. You can teach an old dog new tricks: A qualitative analysis of how residents of senior living communities may use the web to overcome spatial and social barriers. *Journal of Applied Gerontology* 2013; 32: 540–560.
- 55 Bo X. Using the Internet for offline relationship formation. *Social Science Computer Review* 2007; 25: 396–404.
- 56 Cotten SR, Anderson WA, McCullough BM. Impact of internet use on loneliness and contact with others among older adults: Cross-sectional analysis. *Journal of Medical Internet Research* 2013; 15: e39.
- 57 Peek STM, Luijkx KG, Rijnaard MD et al. Older adults' reasons for using technology while aging in place. *Gerontology* 2015; 62: 226–237.
- 58 Pfeil U, Zaphiris P, Wilson S. Older adults' perceptions and experiences of online social support. *Interacting with Computers* 2009; 21: 159–172.