DISABILITY AND REHABILITATION: ASSISTIVE TECHNOLOGY
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REVIEW ARTICLE

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A scoping review to explore the health, social and economic outcomes of home automation for people with disability

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ABSTRACT

Purpose: People with disability often require long-term care. Long-term care is changing with the availability and advances in cost and function of technologies, such as home automation. Home automation has the potential to reduce paid carer hours and can potentially offer many benefits to people with a disability. The aim of this scoping review is to identify the health, social and economic outcomes experienced by people living with a disability who use home automation.

Materials and methods: Two electronic databases were searched by title and abstract to identify international literature that describes home automation experiences from the perspectives of people with disability. A thematic approach was taken to synthesise the data to identify the key outcomes from home automation.

Results: The review identified 11 studies reporting home automation outcomes for people living with a disability. Seven outcomes were associated with home automation: independence, autonomy, participation in daily activities, social and community connectedness, safety, mental health, and paid care and informal care.

Conclusion: Advances in technology and changes in funding to support people living with a disability have made access to home automation more readily available. Overall, the study findings showed that there is a range of potential benefits of home automation experienced by individuals living with a disability.

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➤ IMPLICATIONS FOR REHABILITATION

- A wide range of outcomes have been evaluated following the installation of home automation systems for people with disability.
- Key outcomes evaluated to date include independence, autonomy, participation, safety, mental health, and reduced need for paid carers.
- Outcomes of home automation appear to be connected; for example, improved participation may lead to improved mental health.

Introduction

In Australia, 1 in 6 people (4.4 million) are living with a disability, and 5.7% of the Australian population report living with a severe disability [1]. Physical disability is the most common type of disability. World-wide, one billion people are living with a disability and the number is increasing in all countries due to the ageing population and the increase in chronic diseases [2]. In 2018, nearly 3.9 million Australians experienced some form of limitation in their core activities such as communication, mobility, employment, education, or self-care [1]. Three-fifths of people with disability require assistance with daily activities, and just over half require aids or equipment for support [1]. Currently 40% of people living with a disability in Australia require formal care [3].

Home automation refers to the installation of technology that automates or remotely controls household functions *via* technological devices and programs linked *via* a wired or wireless connection [4–6]. Home automation can control doors, blinds, heating and cooling, lighting, windows, doorbells and intercom systems, taps, showers, and entertainment systems *via* smartphones or tablets, and/or voice control operated systems. Some home automation is intended to increase independence and enhance the quality of life of a person living with a physical, sensory, or intellectual disability. The costs of home automation vary, and while cost-effectiveness has not been assessed to date, it is possible that the installation of home automation is a way of reducing reliance on paid carers [7].

Funding for home automation is available in some developed countries such as the UK and USA through registered disability charities and programs for assistive technology [8,9]. In Australia, the majority of funding for home automation for adults aged over 65 years old is provided by the National Disability Insurance

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Agency (NDIA). It is estimated that only 5% of NDIA funding is spent on assistive technology, however, a review of the social and economic impacts of assistive technology more broadly found that assistive technology has the potential to reduce costs in health and aged care [10]. Funding for home automation for people living with a disability is relatively new and evaluation of the social and economic impact has been limited to date. Indeed, many current and early adopters of home automation are self-funded [7].

This scoping review identified the outcomes of home automation by people living with a disability (cognitive and physical). This was achieved by (1) searching published literature for studies relating to outcomes of home automation for people living with a disability and (2) synthesising the outcomes experienced of home automation for people living with a disability into themes. As far as we are aware, no current scoping review has been undertaken identifying the outcomes of home automation for people living with a disability.

Material and methods

The scoping review followed the PRISMA guidelines with the extension for scoping reviews [11] to identify the literature describing outcomes of home automation for people with a disability. Unlike a systematic review that critically appraises literature, a scoping review aims to provide an overview of literature on a given topic and does not involve a critical appraisal of the literature [12]. A scoping review was chosen to identify the body of literature relating to the research aim and provide an overview of what evidence is available [12,13].

Identification and selection of studies

Search strategy

Two databases (SCOPUS and IEEE Xplore digital library) were searched (July 2022) by title and abstract using the following search terms: ("home automation" OR "environmental control system" OR "environmental control unit" OR "smart home" OR "smart house" OR "smart device" OR "home technology") AND ("disab*" OR "injur*" OR "*plegia" OR "impair*" OR "disorder" OR "difficult*"). These databases were chosen as the most likely to provide literature from the fields of health and information and communication technologies. Scopus was included as it is one of the largest electronic databases which covers the health, social and physical sciences. Scopus includes a range of publication types including book chapters and covers the majority of titles included in Medline. IEEE Xplore was included as it provides comprehensive coverage of literature from engineering, computer science and electronics publications.

Eligibility criteria

The review searched for articles published from 2011 onwards as home automation has become more readily available in the last decade following technological advances [7,14]. Eligible studies included adults with any type of physical and/or cognitive disability using home automation. For this review, home automation was defined as any form of technology that automates or remotely controls household functions [5,6]. The review did not exclude any study based on their design, which allowed case studies, quantitative, qualitative, and mixed methods studies to be included. Included studies had to have identified at least one outcome of home automation experienced by a person with the disability. Studies were excluded if they were theses, reviews, book reviews, editorials, opinion pieces, conference abstracts or were not published in English. Outcomes of interest were health, social and economic outcomes.

Procedure

Citations were extracted from the electronic databases into Covidence, a web-based software platform [15] and duplicates removed. The first stage of screening involved two reviewers independently screening the articles by title and abstract. Any articles that appeared irrelevant were excluded at this point. The second stage of screening involved three reviewers screening the full-texts of the articles which were potentially relevant with any conflicts being resolved *via* a discussion between the reviewers.

Data analysis

A thematic approach was taken to synthesise the data to identify the key outcomes of home automation. Firstly, the two reviewers read the articles to become familiar with the content. Secondly, data extraction (author, year of publication, country, aim, study population and sample size, setting, methods and key findings, as recommended by Tricco et al. [11]) for the first 20% of articles was completed by two reviewers and then both reviewers met to discuss the extracted data. The remainder of the extraction was completed by one reviewer and checked by the second reviewer. Finally, the two reviewers met to identify the outcomes emerging from the sources and to group the outcomes into themes.

Results

Flow of studies through the review

A total of 1048 articles were imported into Covidence. After removing one duplicate, 1047 articles were screened by title and abstract with 1011 articles excluded. Thirty-six full text articles were assessed for eligibility, with 25 articles excluded. The most common reasons for exclusion were not identifying outcomes ($n = 9$), wrong population ($n = 5$) and wrong intervention ($n = 5$). A total of 11 studies were included in the scoping review. The results of this process are shown in Figure 1. Table 1 provides further details of the final studies included in the review.

Characteristics of studies

All articles reviewed were published between 2013 and 2022. Four studies were conducted in Australia, two in Ireland, one in France, one in Italy, one in Slovenia, one in England, and one in the USA. Six studies presented quantitative data on the outcomes of using home automation [16–21] with two of these studies involving a non-randomised control group [17,18]. One study presented quantitative and qualitative data [7], and the remaining four presented qualitative data [22–25]. Study quality was not appraised.

Participants

Overall, studies were relatively small and sample sizes of studies ranged from one participant (case study) to fifty-nine participants. The age of participants ranged from 18 years to 86 years, with over half of the participants in all studies being males (56%). Six of the eleven studies included individuals with spinal cord injuries. Other studies included individuals with moderate to severe functional limitations ($n = 1$), neurotrauma ($n = 1$), down syndrome ($n = 1$), motor neurone disease ($n = 1$) and individuals who had experienced a stroke ($n = 1$).

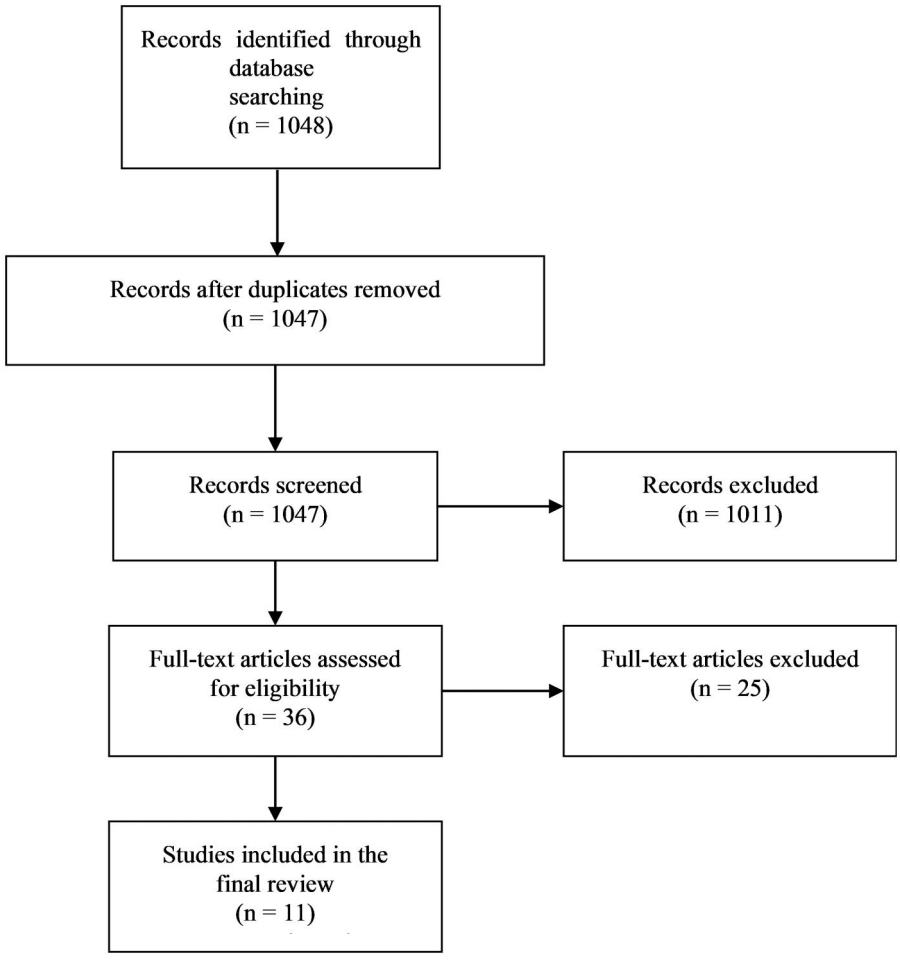

Figure 1. Flow chart of study identification process.

Type of home automation

Studies included a range of different home automation technologies. The most common type of home automation used by participants was technology to control televisions ($n = 7$ studies), lights ($n = 7$ studies), air conditioning/heating units ($n = 7$ studies) and doors ($n = 5$ studies). Opening windows, voice-controlled emails and kitchen appliances were the least common type of home automation identified ($n = 1$ study).

Outcomes

The analysis of the studies identified seven outcomes. Table 2 provides detail of the outcomes of home automation experienced by individuals living with a disability for each study.

Performance of daily activities

Daily activities refer to the ability of an individual to perform everyday activities such as meal preparation or showering. Ten studies reported the association between home automation and individual engagement in daily activities [7,16–22,24,25]. Of the ten studies that reported outcomes related to daily activities, seven used quantitative standardised tools. These included the Assessment of Quality of Life measure (AQoL-4D) [26]; the Residential environment impact survey – short form (REIS-SF) [27]; Association for the Retarded Citizens self-determination scale (ARC) [28]; Psychological Well-being Scales (PWS) [29,30]; Activities of Daily Living (ADL), [31]; Instrumental Activities of Daily Living Scale (IADL), [32]; Functional Independence Measure (FIM) [33]; The Barthel Index (BI) [34] and the Frenchay Activities Index (FAI) [35]. Study participants included those with Down's syndrome, spinal cord injury, motor neurone disease, and stroke with findings indicating an increase in ability to perform daily activities [7,16–21]. Two of these studies compared individuals accessing home automation to a control group (no access to home automation) and both studies reported an increase in ability to manage daily activities in the intervention group compared to the control group [17,18]. Three further studies which adopted a qualitative approach with individuals with spinal cord injuries described how home automation could increase people's ability to manage daily activities [22,24,25].

Paid care and informal care

Paid care is performed by care workers who receive renumeration for their work caring for individuals. Informal care is provided by people who have an existing relationship with the individual such as a family member, a friend or neighbour [36]. The impact on paid care and informal care in relation to home automation was presented in six studies [7,20,22–25]. Two studies, (a single case study of a woman with spinal cord injury [20] and a multi-method study for individuals with functional limitations [7] measured paid carer's support pre and post home automation, and both studies reported a reduction in the need for care assistance after home automation. A further four studies adopted a qualitative approach and described outcomes for individuals with spinal cord injuries [22–25]. Two studies suggested that home automation enabled individuals to be left alone for longer periods of time, which

Table 1. Study details.

Author, year, country of study	Aim	Sample and characteristics (where reported)	Type of home automation	Methods	Findings
Bridge et al. 2021 [7] Australia	To understand how a smart home control system can benefit older people and people with disabilities.	Individuals with moderate to severe functional limitations *Survey* $n = 21$ (7 males, 6 females, 8 missing) Age = 18+ *4 focus groups* $n = 24$	Cameras, television, lights, kitchen appliances, air conditioning and heating, curtains, blinds, doors, fans, alert systems for dangerous items being unattended	Survey including the standardised tool (AQoL-4D) Focus groups	Home automation reduces reliance on care, increases independence, improve social and community connectedness, and improves mental health.
Callaway et al. 2016 [16] Australia	To evaluate the features of purpose-built apartment living on access, environmental control, and home and community mobility of people living with neurotrauma	Individuals with neurotrauma $n = 3$ (3 males) Age = 30–55 years	Doors, blinds, lighting, air conditioning, heating	Case studies, standardised tools (REIS-SF; PIADS)	Users experienced enhanced competence, independence, self-esteem, productivity, usefulness, self-confidence, quality of life, eagerness to try new things and ability to adapt to activities of daily living, and mobility.
Hooper et al. 2018 [22] Australia	To explore users' experiences with smart-devices	Individuals with spinal cord injuries $n = 5$ (5 males) Age = 21 = 60	Telephones, televisions, air conditioning and heating	Semi-structured interviews	Participants believed smart-devices increased their ability to independently control aspects of their environment, reduced reliance on others, reduced carer hours, increased choice and gave opportunities for better connections with family.
Landuran et al. 2022 [17] France	To assess the usability of the smart home platform and the impact of the use	Individuals with down syndrome $n = 8$ (4 males, 4 females) Age = 26–46 years	Alert messages for dangerous items left unattended, door or fridge left open, voice-activated emails	Standardised tools (IALS; ARC; WHOQOL-Bref; RSE; PSWQ; PWS)	Results demonstrated positive impacts on living skills, self-determination, quality of life, self-esteem, anxiety, and psychological well-being.
Maggio et al. 2020 [18] Italy	To evaluate the effects of home automation on cognitive functions and personal/social autonomy	Individuals who had experienced a stroke $n = 40$ (22 males, 18 females) Mean age = 58 years	Air conditioning and heating, alerts for dangerous items left unattended	Standardised tools (HRS-D; SF-12; SASS; ADL, IADL)	Home automation improves social and cognitive functioning, autonomy and functional recovery in patients affected by chronic stroke.
Myburg et al. 2017 [23] Australia	To investigate environmental control systems' prescription and utilisation from the consumer perspective.	Individuals with spinal cord injuries $n = 15$ (15 males, 3 females Age = 22–68 years	Air conditioning and heating, lights, fans, telephone, television, doors	Semi-structured interviews	Participants perceived improvements in autonomy, increased wellbeing, increased independence and reduced reliance on others.
Ocepek et al. 2013 [19] Slovenia	To identify if the use of home automation has positive impact on functional independence and occupational performance and satisfaction with occupational performance.	Individuals with disabilities (spinal cord injuries, neuromuscular disease, amputations, cerebral palsy, cerebral vascular insult) $n = 59$ (30 males, 29 females) Age = 24–81 years	Doors, windows, curtains, television, air conditioning and heating	Standardised tools (COPM; FIM)	Results demonstrated a higher occupational performance, satisfaction with performance and higher functional independence.
Squires et al. 2013 [20] U.K	To evaluate an environmental control system in a single case study	Individual with tetraplegia $n = 1$ (1 female) Age = 46 years	Switches, plug sockets, doors, lights, television, telephone,	Standardised tools (EQ-VAS; LOT-R; BI; FAI; GHQ-12; WHO-5	Increased activity for everyday tasks, increased independence and

(*continued*)

Table 1. Continued.

Author, year, country of study	Aim	Sample and characteristics (where reported)	Type of home automation	Methods	Findings
			air conditioning and heating		less reliance on carers.
Verdonck et al. 2014 [25] Ireland	To explore user's experience of using an environmental control system.	Individuals with spinal cord injuries $n = 6$ (4 males, 2 females) Age = 22–65 years	Switches, plug sockets, telephone, television, lights, fans	Semi-structured interviews	Most participants experienced enjoyment by using an environment control system, were less reliant on others and were able to do daily activities.
Verdonck et al. 2018 [24] Ireland	To provide an in-depth exploration of the subjective meaning of Environmental Control System	Individuals with spinal cord injuries $n = 5$ (4 males, 1 females) Age = 22–55 years	Switches, plug sockets, telephone, television, lights, fans	In-depth interviews	The use of environmental control systems increased participants' ability to make preferred, spontaneous choices, being able to carry out simple everyday activities, reduced reliance on carers, feeling good and feeling better about oneself, increased feelings of safety.
Wallock et al. 2021 [21] U.S.A	To understand smart home technology use and the impact of that use on occupational performance	Individuals with Motor Neurone disease $n = 19$ individuals (12 males, 7 females) Age = 26 -86 years	Audio, plug sockets, television, lights	Survey	Functional independence increased and participants became more engaged in daily activities.

AQoL-4D: The assessment of quality of life; REIS-SF: Residential environment impact survey – short form; PIADS: Psychosocial impact of assistive devices scale; IALS: Inventory of Apartment Living Skills; WHOQOL-Bref: World Health Organization Quality of Life – Bref; RSE: Rosenberg's Self-Esteem scale; PSWQ: anxiety with Penn State Worry Questionnaire; PWS: Psychological Well-being Scale; HRS-D: Hamilton Rating Scale Depression; SF-12: 12 item Short Form Survey; SASS: Social Adaptation Self-evaluation Scale; IADL: Instrumental Activities of Daily Living Scale; ADL: Activities of Daily Living; COPM: Canadian Occupational Performance Measure; FIM: Functional Independence Measure; EQ-VAS: EuroQol Visual Analogue Scale; LOT-R: The Life Orientation Test; BI: The Barthel Index; FAI: Frenchay Activities Index; GHQ-12: The 12-item General Health Questionnaire; WHO-5: The World Health Organisation-Five Well-Being Index.

Table 2. Outcomes of each study.

	Daily activities	Reduced reliance on others (paid and non-paid)	Independence	Autonomy	Mental Health	Social and community connectedness	Safety
Bridge et al. 2021 [7]	■	■	■	■	■	■	■
Calloway et al. 2016 [16]	■		■	■	■		
Hooper et al. 2018 [22]	■	■				■	
Landuran et al. 2022 [17]	■			■	■		■
Maggio et al. 2020 [18]	■			■	■		
Myburg et al. 2017 [23]		■	■	■	■		
Ocepek et al. 2013 [19]	■		■				
Squires et al. 2013 [20]	■	■	■				
Verdonck et al. 2014 [25]	■	■					
Verdonck et al. 2018 [24]	■	■	■	■	■	■	■
Wallock et al. 2021 [21]	■		■				■

Shaded cells indicate that this outcome measure was applied in this study.

could potentially impact carer hours [23,24]. Furthermore, three qualitative studies described how home automation supported individuals to complete tasks independently, such as turning the television on and off, turning lights on and off, and using mobile phones to call and text. As a result of being able to complete these tasks individuals described how they felt less of a burden and how it meant that carers could spend time doing other tasks [22,24,25].

Independence

Independence is having choice and control over your life by making decisions and not having to rely on others [37]. Seven studies described the outcome of independence for individuals living with a disability using home automation [7,16,19–21,23,24]. Four studies used surveys including several instruments to measure independence: the AQoI-4D [26]; Psychosocial impact of assistive devices scale (PIADS) [38]; BI [34]; and FAI [35]. All four studies reported improved independence amongst participants with functional impairment, spinal cord injury and motor neuron disease because of having home automation [7,16,19,21]. Three studies [20,23,24] that adopted a qualitative approach to understand the experience of individuals with spinal cord injuries found home automation provided feelings of independence. Home automation was described as enabling these individuals to do simple everyday tasks without relying on others which increased their sense of independence. Not being a burden on others was deemed important to participants and was often seen as more important than the personal independence they experienced [20,23,24].

Autonomy

Although similar to independence, autonomy refers to self-governance, the capacity to control and make decisions, and is not solely about relying on others, as the term independence often refers to [37]. Six studies identified autonomy as a potential outcome for people living with disability accessing home automation [7,16–18,23,24]. Three studies used standardised tools (PIADS [38]; ARC [28]; PWS [29,30]; ADL [39]; IADL [32] to measure autonomy and reported an increase in the sense of autonomy amongst participants with chronic stroke, motor neurone disease and down syndrome following the use of home automation [16–18]. A further two studies adopted a qualitative approach and explored the experience of home automation by individuals living with functional limitation and spinal cord injury. Participants in all three studies reported that home automation had restored some of their autonomy and this improved their wellbeing [7,23,24].

Mental health

Mental health is a state of wellbeing that enables individuals to manage stresses in life and is an important component of health and wellbeing [40]. Six studies examined the link between home automation and the mental health of people living with a disability [7,16–18,23,24]. Of these six studies, four studies used quantitative standardised tools such as the AQoL-4D [26]; PIADS [38]; Rosenberg's Self-Esteem scale (RSE) [41]; World Health Organization Quality of Life – Bref (WHOQOL-Bref) [42]; Short Form-12 Health Survey (SF-12) [7,16–18,43]. All four studies reported that they found improvements in mental health after using home automation such as improved self-esteem, reduced anxiety and improved psychological wellbeing. Two of these studies compared individuals accessing home automation to a control group (no access to home automation) and both reported significant improvements in mental health in the home automation group compared to the control group although sample sizes were small ($n = 8$ and $n = 40$) [17,18]. Two qualitative studies reported that participants described improvements in mental health related to home automation [23,24]. One study reported that individuals experienced positive mental health due to the increased independence they had from using home automation [24]. The other study described that being able to do things without asking a carer decreased frustration and improved participants' sense of wellbeing [23].

Social and community connectedness

Social and community connectedness is about the experience of belonging to a group, family or community and the relationships you have with other people and the wider community [44]. Three studies examined how home automation could influence feelings of social and community connections [7,22,24]. One study used a quantitative survey before and after home automation to measure the social isolation of individuals with functional limitations [7]. Participants reported a reduction in social isolation and an increase in the number of close friends they had following home automation being installed due to it facilitating online social participation [7]. Similarly, two separate studies exploring the lived experience of individuals with spinal cord injury using home automation both found home automation improved contact with family and friends [22,24]. The ability to access functions and applications facilitated connections to family and the wider community allowing for more regular contact [22,24]. Furthermore, home automation was also described as improving relationships with family and friends by reducing the reliance and demand placed on friends and family [24].

Safety

Safety refers to the avoidance or reduction of harm from the environment in which the individual lives [45]. Feelings of safety were explored as an outcome in four studies [7,17,21,24]. Three studies evaluated the benefits of home automation for individuals with Down's syndrome, functional impairment, and motor neurone disease using surveys before and after the use of home automation [7,17,21] with one study [17] using a standardised tool; Inventory of Apartment Living Skills (IALS) [46]. All studies reported that there were improved feelings of safety amongst participants when using home automation. One qualitative study explored the experience of individuals living with spinal cord injury using home automation and found participants felt safer [24]. The security of having home automation made individuals feel more relaxed and secure, knowing they had the option of using home automation to contact people if needed and gave individuals the option of choosing to be alone if they wished [24].

Discussion

This review included 11 studies and identified seven key home automation outcomes experienced by people living with a disability. Studies adopted both qualitative and quantitative approaches with six of the studies using standardised tools to measure the outcomes [7,16–20]. Studies were small, represented a heterogeneous population and seldom included a control group. This scoping review summarises the type of outcomes and findings of the studies but unlike a systematic review does not critically appraise study quality. Therefore, findings that home automation improved the various outcomes should be interpreted with caution.

Home automation appeared to impact on people's ability to perform daily activities and this could increase feelings of independence. Home automation could also potentially enhance autonomy as individuals reported relying on others less and being able to complete tasks themselves that were previously completed by carers. Increased independence and autonomy positively impacted upon individuals' mental health, and facilitated important social and community connections which could increase feelings of safety.

Individuals require certain needs to be met to experience a good quality of life [47]. According to Maslow's hierarchy of needs

there are five categories of needs: physiological, safety, love, esteem, and self-actualisation. If these needs are unmet individuals may experience anxiety, loneliness, low self-confidence, and lack of meaning in life. The findings from this scoping review suggest that the introduction of home automation may result in increased ability to meet basic needs through to the highest level of needs as per Maslow's hierarchy, therefore potentially positively impacting the lives of individuals with a disability.

Overall, the study findings showed a range of outcomes associated with home automation experienced by individuals living with disability. Although home automation is not a new concept, advances in functionality and lower costs has meant that access to home automation has become more readily available [7,48]. In Australia the NDIA now supports people with a disability to access home automation through their support plan funding. However, it has been suggested that navigating the NDIA system to access funding is complex and presents many challenges [7]. Therefore, this review could be a useful tool for policy makers to use to raise awareness of the potential outcomes of home automation of people living with disability.

Whilst an extensive search was conducted, we acknowledge that there were only 11 studies identified that reported outcomes of home automation for people with a disability. The studies found were both qualitative and quantitative, and no randomised controlled trials were identified. Despite this review suggesting that home automation can have a wide range of outcomes for people living with a disability, research is limited in this area which highlights the need for further research to be conducted. A possible explanation for the limited research is that home automation is a relatively new concept and the population of people with high levels of disability is relatively low. It would be expected over time that advances in technology and the increase in availability of funding would result in more research in this area.

Overall, these findings suggest the range of outcomes that may stem from home automation for individuals living with a disability and the range of benefits which could be experienced. Further research by the authors will build upon this evidence by conducting a social return on investment analysis to assess the impact of home automation for people living with a disability. This research will attempt to provide an in-depth understanding of the impact of home automation for people with a disability and also value the personal, community and societal outcomes.

Disclosure statement

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