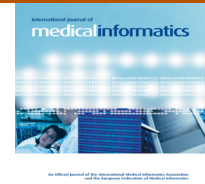




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Review

Factors influencing acceptance of technology for aging in place: A systematic review

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ABSTRACT

Purpose: To provide an overview of factors influencing the acceptance of electronic technologies that support aging in place by community-dwelling older adults. Since technology acceptance factors fluctuate over time, a distinction was made between factors in the pre-implementation stage and factors in the post-implementation stage.

Methods: A systematic review of mixed studies. Seven major scientific databases (including MEDLINE, Scopus and CINAHL) were searched. Inclusion criteria were as follows: (1) original and peer-reviewed research, (2) qualitative, quantitative or mixed methods research, (3) research in which participants are community-dwelling older adults aged 60 years or older, and (4) research aimed at investigating factors that influence the intention to use or the actual use of electronic technology for aging in place. Three researchers each read the articles and extracted factors.

Results: Sixteen out of 2841 articles were included. Most articles investigated acceptance of technology that enhances safety or provides social interaction. The majority of data was based on qualitative research investigating factors in the pre-implementation stage. Acceptance in this stage is influenced by 27 factors, divided into six themes: concerns regarding technology (e.g., high cost, privacy implications and usability factors); expected benefits of technology (e.g., increased safety and perceived usefulness); need for technology (e.g., perceived need and subjective health status); alternatives to technology (e.g., help by family or spouse), social influence (e.g., influence of family, friends and professional caregivers); and characteristics of older adults (e.g., desire to age in place). When comparing these results

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to qualitative results on post-implementation acceptance, our analysis showed that some factors are persistent while new factors also emerge. Quantitative results showed that a small number of variables have a significant influence in the pre-implementation stage. Fourteen out of the sixteen included articles did not use an existing technology acceptance framework or model.

Conclusions: Acceptance of technology in the pre-implementation stage is influenced by multiple factors. However, post-implementation research on technology acceptance by community-dwelling older adults is scarce and most of the factors in this review have not been tested by using quantitative methods. Further research is needed to determine if and how the factors in this review are interrelated, and how they relate to existing models of technology acceptance.

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1. Introduction

The majority of older adults prefer to live independently for as long as they possibly can [1–4]. Supporting older adults to remain in their own homes and communities is also favored by policy makers and health providers to avoid the costly option of institutional care [5]. Research shows that several interrelated factors can challenge the independence of older adults: primarily functional and cognitive impairment,

chronic diseases, a diminishing social network, and a low level of physical activity [6–9]. Technology might provide a solution for some of these challenges, and particularly in the last decade, much effort has been invested in the development of technology to support aging in place, such as sensor-based networks for activity monitoring, fall and wandering detection, and various e-health applications. However, older adults explicitly reserve the right to decide for themselves what they allow into their own homes [10], and questions have been raised on the readiness of community-dwelling older

adults to accept and use these technologies [11–13]. Acceptance of technologies that are electronic or digital may be more difficult for the current generation of seniors which did not grow up with these types of technologies [14–16]. In an effort to understand older adults' usage and non-usage of modern technology, researchers often turn to two technology acceptance models, stemming from the field of information systems.

1.1. Technology acceptance models

Technology acceptance research is dominated by the Technology Acceptance Model (TAM) [17] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [18]. The key variables in TAM are Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). Systematic reviews have shown that these two variables typically explain 40 percent of an individual's intention to use a technology in a variety of contexts including healthcare [19–21], and that intention to use may [22] or may not [23] predict actual use of technology. UTAUT is capable of explaining up to 70 percent of intention to use at the expense of parsimony by adding two additional variables (Social Influence and Facilitating Conditions) and four moderating factors (Gender, Age, Experience and Voluntariness of Use) [18].

While being powerful and robust, TAM and UTAUT have also received criticism for disregarding the fact that technology acceptance may fluctuate over time [24–27]. Furthermore, several studies demonstrate that the influence of PU, PEOU, and other relevant factors is different between the pre-implementation stage (when a technology has not been used yet) and the post-implementation stage (when users have used and experienced a technology) [28,29]. Acceptance research is also criticized for being too reliant on TAM and UTAUT, overlooking essential determinants [30,31,26]. In a recent literature review, Chen and Chan discussed 19 studies that used TAM or related models and constructs to explain technology acceptance by older adults [32]. They found that specific biophysical (e.g., cognitive and physical decline) and psychosocial (e.g., social isolation, fear of illness) factors related to aging are overlooked in the current literature.

Chen and Chan also note that the factor cost (price) of technology is neglected in many studies, although it seems to be a critical factor in determining an older adult's acceptance of technology [32]. Furthermore, most research has focused on communication- and assistive technology in the home domain, neglecting other types of technology [32]. These concerns indicate that more research is needed to develop a better understanding of acceptance of various types of technology by older adults.

1.2. Research question

This systematic review of qualitative, quantitative, and mixed methods studies examines the following research questions: which factors influence the acceptance of different types of technology for aging in place by community-dwelling older adults, and how do these factors differ between the pre-implementation stage and the post-implementation stage?

The aim of this study is to provide an overview of factors that can facilitate the implementation of technology for

community-dwelling older adults, and to provide directions for further technology acceptance research within this specific group.

Technology acceptance in this study is defined as the intention to use a technology or the actual use of a technology [17]. Technology for aging in place is defined as electronic technology that is developed to support the independence of community-dwelling older adults by alleviating or preventing functional or cognitive impairment, by limiting the impact of chronic diseases, or by enabling social or physical activity. Community-dwelling older adults are defined as older adults who are not living in a long-term care institution.

2. Methods

2.1. Search strategy

In January 2012, seven databases (ACM Digital Library, CINAHL, IEEE Xplore, MEDLINE, PsycINFO, Scopus and Web of Science) were searched using a combination of four groups of keywords: (1) "older", "senior" and synonyms for these terms; (2) "living independently", "community-dwelling" and similar search terms; (3) search terms to find electronic technology that is aimed at supporting aging in place. Since this type of technology is studied in many different fields, it was decided to be broadly inclusive and include search terms such as "system", "e-health", "gerontechnology", "telemonitoring", "smart home", "assistive technology", and "robotics"; and (4) search terms that are related to "acceptance" and similar terms such as "use", "adoption", "adherence" and "rejection". A full list of all 150 search terms, including options and limits that were selected in the different databases, is available as supplementary material in the online version (<http://dx.doi.org/10.1016/j.ijmedinf.2014.01.004>).

2.2. Article selection

Titles, abstracts and full articles were subsequently screened by one author [SP] applying the inclusion criteria mentioned in Table 1. In case of doubt, three authors [SP, EW and JvH] discussed the selection. In addition, references of the included articles were checked for other articles eligible for this review (snowball method).

2.3. Data extraction

Three authors [SP, EW and JvH] each read all included articles, and separately entered data using a data extraction form,

Table 1 – Inclusion criteria.

Inclusion criteria:

- Original and peer-reviewed research written in English;
- Qualitative, quantitative or mixed methods research;
- Research in which participants are community-dwelling older adults aged 60 years or older; and
- Research aimed at investigating factors that influence the intention to use or the actual use of electronic technology for aging in place.

which is available as supplementary material in the online version (<http://dx.doi.org/10.1016/j.ijmedinf.2014.01.004>). The first part of the extraction form includes entries on inclusion and exclusion criteria, quality assessment, methods used, type of technology studied and implementation stage (pre-implementation/post-implementation). Articles were also checked for working definitions of acceptance and the use of existing technology acceptance models.

Articles under review used either qualitative methods, quantitative methods or a combination of both (mixed methods). In order to extract factors from all types of articles, the data extraction form contains a section for factors extracted from qualitative data and a section for factors extracted from quantitative data.

In the case of qualitative articles and qualitative data from mixed methods articles, factor names and their perceived influence on acceptance were coded and subsequently entered in the qualitative section of the form. In the case of quantitative articles and quantitative data from mixed methods articles, the following information was entered in the data extraction form: variable name, standardized or unstandardized regression coefficients, level of significance, and proportion of variance explained.

2.4. Data analysis

In the first stage of the analysis, the three authors [SP, EW and JvH] had to reach consensus on every entry in the data extraction form, for each article. This was done in weekly sessions, and articles were discussed in random order. In the second stage, thematic synthesis [33] was used to synthesize qualitative data on factors. Multiple sessions were held to group factors derived from qualitative articles and qualitative data from mixed methods articles in descriptive themes for acceptance in the pre-implementation stage, and for acceptance in the post-implementation stage. Additionally, SP, EW and JvH each created a conceptual model of the relationships between themes, and subsequently one combined model was developed. In the final stage, factors derived from qualitative articles and qualitative data from mixed methods articles were compared to factors in quantitative articles and quantitative data from mixed methods articles. This was done to determine whether factors present in qualitative research are statistically tested in quantitative research and to find significant factors in quantitative research that are not present in qualitative research.

2.5. Quality assessment

Qualitative articles were screened using the Critical Appraisal Skills Program (CASP) [33], which contains 10 criteria on items such as study design, recruitment strategy, the relationship between researcher and participants, ethical considerations, data analysis and explicitness of the findings. Quantitative articles were screened using the Health Evidence Bulletins Wales checklist [34]. This checklist covers 11 criteria on cross-sectional studies including the appropriateness of sampling, the level of protection against biases and confidence in the use of statistical methods. The mixed methods articles were screened using the Mixed Methods Appraisal Tool

(MMAT) [35] which, in addition to specific criteria for qualitative and quantitative research, also contains specific criteria on the relevance of the use of a mixed methods design and the integration of different types of results. It was decided not to exclude articles based on quality assessment because there is little empirical evidence on which to base exclusion decisions in mixed studies systematic reviews [35–37]. Instead, it was decided to report on the quality of the reviewed articles and to apply independent triangulation: factors had to be present in at least two studies in order to be included in the results. Furthermore, we decided that in the event of an article not meeting the minimal screening criteria of a checklist, we would examine the contribution of that article to our findings.

3. Results

The search in seven databases for factors influencing the acceptance of electronic technologies that support aging in place by community-dwelling older adults generated a total of 4692 results. After the removal of duplicate results, a total of 2841 unique articles were identified (Fig. 1). The selection process initially led to the inclusion of 15 articles [38–52]. The snowball method added one article [53], bringing the total number of articles included in this review to 16.

3.1. Characteristics of reviewed articles

The included articles were aimed at exploring factors that influence the willingness of older adults to use technology for aging in place, as well as their perceptions and expectations of this type of technology. As shown in Table 2, articles described acceptance of different types of technology, and six articles described combinations of types of technology. Technology that enhances safety (e.g., monitoring technology and personal alarms) was the most prominent type of technology, followed by technology that provides social interaction (e.g., video telephony). Technology that supports older adults in their Activities of Daily Living (ADL) or Instrumental Activities of Daily Living (IADL) (e.g., electronic memory aids) was less prevalent. Results also show that 12 of the articles solely describe acceptance of technology in the pre-implementation stage. In these pre-implementation studies researchers typically use presentations, vignettes or scenarios to explain one or more types of technology for aging in place to the participants. In three studies, participants were allowed to interact with prototypes [38,42,44]. Evaluation of acceptance in the post-implementation stage (one article) or a combination of evaluation in the pre- and post-implementation stage (three articles) was far less common. Eleven of the 16 reviewed articles used qualitative research methods (using interviews or focus groups), four articles used a combination of qualitative and quantitative research methods (mixed methods), and one article was based on quantitative methods alone (using a cross-sectional survey). Convenience and purposive sampling was used by all articles with the exception of the article by Zimmer et al. [53], which used stratified sampling. Two articles made use of a theoretical framework to guide the search or interpretation of factors influencing acceptance: Steele et al. [42] used TAM and UTAUT [17,18], and Zimmer et al. [53]

Table 2 – Characteristics of the 16 reviewed articles.

Article First author, year [reference]	Technology type(s)			Implementation stage		Method			
	(I)ADL	Safety	Interaction	Pre	Post	Type	Instrument	N	Country
Lorenzen-Huber et al., 2011 [38]	×	×	×	×	–	Qualitative	Focus groups	65	USA
van Hoof et al., 2011 [39]	–	×	×	×	×	Qualitative	In-depth interviews	18	The Netherlands
Lai et al., 2010 [40]	–	×	–	×	–	Mixed methods	Face-to-face survey	333	China ^d
Steggell et al., 2010 [41]	×	×	×	×	–	Qualitative	Focus groups	32	USA
Steele et al., 2009 [42]	–	×	–	×	–	Qualitative	Focus groups	13	Australia
Courtney et al., 2008 [43]	–	×	–	×	–	Qualitative	Focus groups, in-depth interviews	14	USA
Demiris et al., 2008 [44]	–	×	–	×	–	Qualitative	Focus groups	14	USA
Horton, 2008 [45]	–	×	×	×	×	Qualitative	In-depth interviews	35	England
Mahmood et al., 2008 [46]	–	×	×	×	–	Qualitative	Focus group	9	USA
Mihailidis et al., 2008 [47]	×	×	×	×	–	Mixed methods ^c	In-depth interviews, face-to-face survey	15 ^a	Canada
Wild et al., 2008 [48]	–	×	–	×	–	Qualitative	Focus groups	23 ^b	USA
Cohen-Mansfield et al., 2005 [49]	×	–	–	×	–	Mixed methods	Face-to-face survey	100	USA
Porter, 2005 [50]	–	×	–	–	×	Qualitative	In-depth interviews	7	USA
Ezumi et al., 2003 [51]	–	–	×	–	×	Mixed methods ^c	Face-to-face survey	28	Japan
Porter et al., 2002 [52]	–	×	–	×	–	Qualitative	In-depth interviews	11	USA
Zimmer et al., 1999 [53]	–	×	–	×	–	Quantitative	Face-to-face survey	1406	USA

×, present in article; –, not present in article.

^a A second group of 15 older adults that did not meet our age criterion was excluded from the review.

^b A second group of 16 family members and friends was excluded from the review.

^c Statistical methods were not used on quantitative data in this article.

^d Research was conducted in the Hong Kong special administrative region.

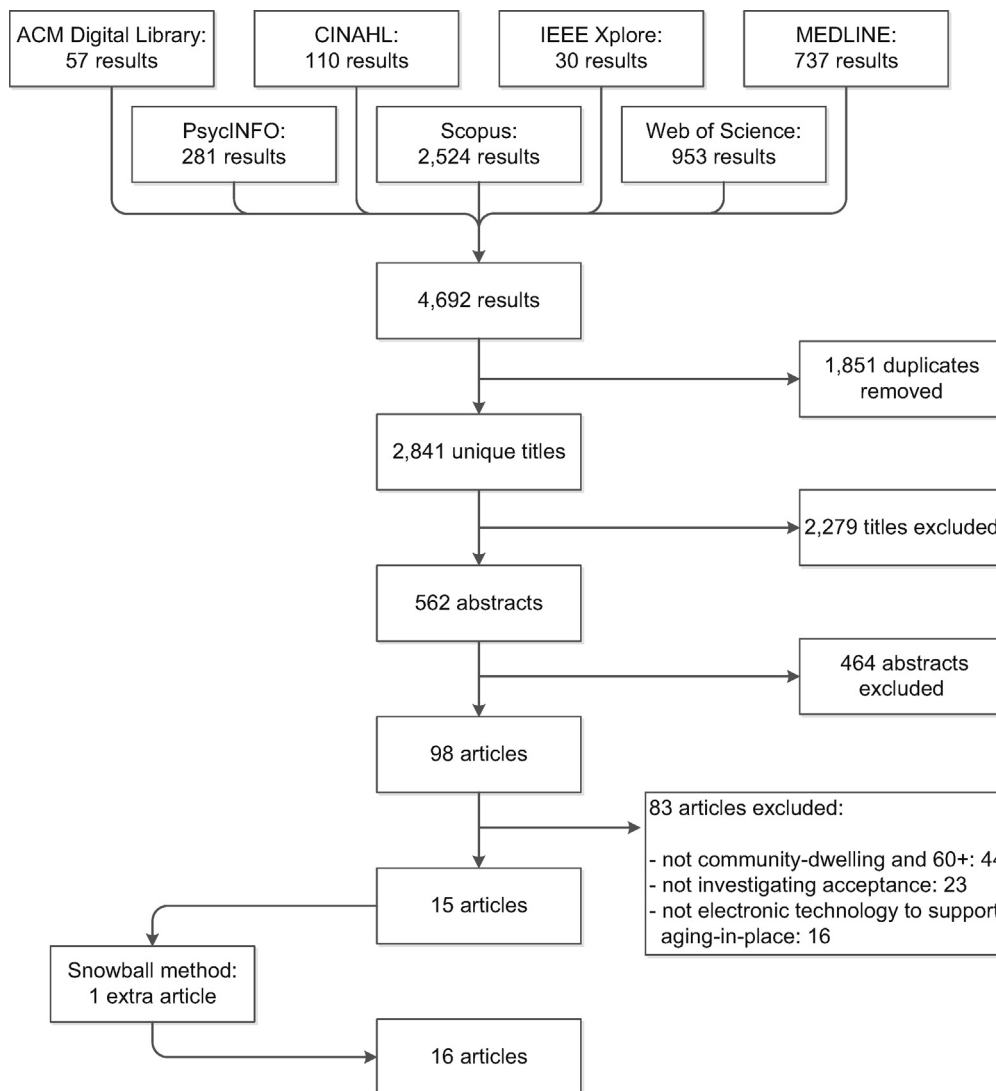


Fig. 1 – Flow diagram of the article selection process.

used Andersen's Model of Health Services Utilization [54]. The majority of the included research was carried out in Anglo-Saxon countries.

3.2. Quality of reviewed articles

Looking at the quality of the qualitative articles, the majority of the articles met most of the criteria. There was one criterion that was only met by one article [38]. In this criterion it was assessed whether researchers critically examined their own role, potential bias and influence in the process of conducting the study. A criterion on the consideration of ethical issues was met by half of the included articles.

The one quantitative article [53] met all the criteria except for a criterion on the consideration of alternative explanations for effects, and a criterion on the validation of survey questions.

Looking at the mixed methods articles, the quality of one article [51] could not be assessed completely because we

considered the research question of this article ambiguous and it therefore did not meet the screening criteria of the MMAT [35]. The other mixed methods articles met the majority of the criteria, but none of the articles met the criteria on consideration toward the influence by the researcher, the validity of quantitative measurements and consideration of the limitations associated with integration of qualitative and quantitative data.

3.3. Qualitative results on pre-implementation acceptance

Qualitative results show that acceptance of technology for aging in place in the pre-implementation stage is influenced by 27 factors, divided into six themes (Table 3). The largest theme contains concerns that have a negative influence on the pre-implementation acceptance of technology for aging in place (Fig. 2).

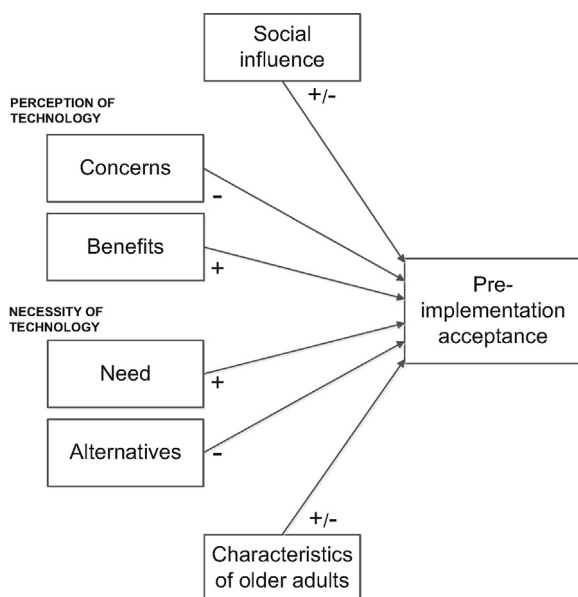
Table 3 – Pre-implementation acceptance factors.

Theme	Factor	Number of articles	References
Concerns regarding technology	High cost	7	[40–42,45,47,49,52]
	Privacy implications	7	[38,41–44,47,48]
	Forgetting or losing technology	4	[41,42,48,49]
	False alarms	3	[44,45,47]
	Obtrusiveness	3	[42,44,48]
	Burdening children	2	[38,41]
	Ineffectiveness	2	[40,52]
	Impracticality	2	[47,49]
	Low ease of use	2	[42,49]
	Negative effect on health	2	[41,42]
	No control over technology	2	[42,47]
Stigmatization	2	[42,49]	
Benefits expected of technology	Increased safety	6	[38,40,41,44,46,48]
	Perceived usefulness	3	[38,42,47]
	Increased independence	2	[39,41]
	Reduced burden on family caregivers	2	[38,48]
Need for technology	Perceived need	9	[38,41–45,47,48,52]
	Subjective health status	2	[43,44]
Alternatives to technology	Help by family or spouse	5	[40,42,44,47,52]
	Current technology	2	[43,48]
Social influence	Influence of family and friends	3	[38,43,52]
	Influence of professional caregivers	2	[38,43]
	Use by peers	2	[44,52]
Characteristics of older adults	Desire to age in place	6	[38,39,42,46–48]
	Cultural background	2	[40,41]
	Familiarity with electronic technology	2	[42,47]
	Housing type	2	[42,43]

3.4. Concerns regarding technology

Community-dwelling older adults express various concerns when they consider technology for aging in place that they have not yet used. One of their major concerns is high cost, which is mentioned in half of the articles. When it is described, it has a prominent role: “Costliness was identified as the

major concern most often” (p. 15) [49] and “Cost was the most significant concern to the elderly participants . . . and is the most likely topic for participants to refer back to regardless of what issue was being discussed.” (p. 793) [42]. Privacy implications are another concern mentioned in half of the articles, although participants from different studies mention that they would be willing to give up (some) privacy as long as the use of technology would be beneficial to them; for instance: “You’d have to come to an agreement. You give up some of your privacy and give up some of these things in order to stay where you are.” (p. 242) [38]. A number of concerns are related to usability; community-dwelling older adults mention that they fear that technology may be hard or impractical to use. Some participants are also concerned that they have no control over the activation and de-activation of the technology: “You’ve got to be able to have control of it. I think you should have a screen somewhere, that maybe you can check if you think you may have set it off, well you can go see if you have or not. . .” (p. 795) [42]. In addition, participants regularly express concerns regarding the consequences of using technology, such as the burden it might put on their children in their role as family caregivers, or the possible negative effects on their personal health: “Could the sensor radio waves give you cancer? I think this is what I would be worried about.” (p. 793) [42]. Others are concerned that the use of technology might fail to achieve its goal and may prove to be ineffective. Regarding the appearance of technology, community-dwelling older adults express concerns that the technology might be too noticeable or obtrusive within their homes.

**Fig. 2 – Model of pre-implementation acceptance.**

In a related concern, participants are worried that other people may perceive them to be in poor health or frail, once they are seen wearing technology that is specific to frail older adults. This fear of stigmatization can be very powerful, and one participant described wearing a personal alarm button as like wearing a “badge of dishonor” (p. 31) [50]. When older adults think about using personal alarm buttons or portable health monitoring sensors, they are concerned that they might forget to use them or lose them. In the case of health or safety monitoring technology, participants are concerned about false alarms: “. . . if you’re in the shower and you bend over to pick up your soap and it thought you’d fallen—there could be false alarms. . . and I don’t want it sending for the ambulance if I’ve only bumped my knee.” (p. 793) [42].

3.5. Benefits expected of technology

Although community-dwelling older adults express technology related concerns, they also expect the use of technology for aging in place to be beneficial. These expected benefits have a positive influence on their pre-implementation acceptance. Older adults mention that they would use technology when they perceive it as useful, although often it is not made clear what constitutes this perceived usefulness: “If the thing is good, and it works, then we go for it. However, if we see something that is useless, and obtrusive, and is change for change’s sake, then no. Not Interested.” (p. 796) [42]. In other cases, the benefits are more concrete, and the most frequently mentioned benefit is an expected increase in safety: “It will increase the life time because if you get into an accident. . . you will be discovered sooner and can get to emergency room before it is too late. . .” (p. 442) [41]. Additionally, participants mention that they expect that the use of technology for aging in place will increase their independence or reduce the burden on family caregivers.

3.6. Need for technology

Whether or not community-dwelling older adults are willing to use technology also depends on their perceived personal need for technology. Perceived need is the most frequently mentioned factor overall, and when it is present the acceptance of technology is more likely. However, in most articles participants state that technology for aging in place is needed for a hypothetical other older person, rather than for themselves: “I don’t need this now, but perhaps at a later point—I have friends who’d benefit from this a great deal, I am not there yet. . .” (p. 122) [44]. In some instances, an older adult’s negative subjective health status positively influences his or her perceived need and acceptance of technology; for example, in the case of a participant who recently fell: “If you had told me two months ago [about these technologies] I’d say who needs it, but after what I have been through, I see the benefits.” (p. 122) [44]. In other cases, however, a negative health status does not increase the perceived need for technology: “One woman who had balance issues and a history of falls described her health condition and then stated that she did not need fall detection technology at this time.” (p. 199) [43].

3.7. Alternatives to technology

Available alternatives to technology for aging in place can negatively influence its acceptance. For instance, help by family members or a spouse can reduce the need for technology-based monitoring [44]. Additionally, certain types of technology that are currently used can make other types of technology seem redundant in the perception of participants. An example of this is the reduced need for a fall-detection system when a personal alarm button is available [43].

3.8. Social influence

Community-dwelling older adults are also influenced by key figures within their social environment when deciding whether or not to use technology for aging in place. An example of this is the influence of their children: “Several noted the importance of their children’s concerns when determining if they needed a service or a technology.” (p. 199) [43]. In some cases, the children’s influence can be compelling: “I am very compliant about these kinds of things. I am not compliant with the thoughts of my mind, but I am compliant about following directions [from my adult children].” (p. 241) [38].

Besides children, professional caregivers and friends and family can also positively or negatively influence acceptance. Furthermore, community-dwelling older adults are influenced by the acceptance of technology by their peers: “Everybody I’ve talked to that’s tried it out, they don’t care for it. . . My general feeling is that people don’t care for them. [Are you thinking about getting it now?] Not at this point.” (p. 195) [52].

3.9. Characteristics of older adults

Several characteristics of community-dwelling older adults can positively or negatively influence acceptance of aging-in-place technology. One of the more prominent factors is the desire to age in place: “All the respondents in this study want to stay in their current dwelling because of attachment to the own home, memories of the past, and their possessions in the home, as well as the quality of the neighborhood.” (p. 318) [39], and “I would choose home, I think most people would. . . Nobody chooses to go to a nursing home.” (p. 792) [42]. The desire to age in place sometimes leads to acceptance of technology for aging in place, but not in all cases. Other factors are the familiarity of the older adult with modern electronic technology, and the fit between housing type and certain types of technology. Lastly, there is the issue of whether or not the technology is compatible with the older adult’s cultural background: “A uniquely Korean value emerged in the discussion of the sleep monitor. Dying while sleeping is considered very lucky in the Korean tradition. Participants were concerned that technology might interfere with their luck.” (p. 442) [41].

3.10. Comparison with qualitative results on post-implementation acceptance

Analysis of qualitative results on post-implementation acceptance shows that some pre-implementation factors are also present in the post-implementation stage. For example, when older adults have used and experienced technology, they

are still concerned about privacy implications [39,45] and stigmatization [50,51]. Furthermore, many participants are still not sure if they themselves actually need technology for aging in place, and the perceived personal need of these community-dwelling older adults [39,45] continues to play a role in their technology acceptance. Lastly, the expected benefit of increased safety [39,50] continues to positively influence acceptance.

At the same time, new factors emerge in the post-implementation stage. Some of the older adult's pre-implementation concerns turn into real life problems; for example the occurrence of false alarms [39,50]: "I've not been very successful with it. I don't think it really worked for me; it kept giving these false alarms and they became quite a nuisance that I'd never bothered to wear it after a while." (p. 1188) [45]. This also happens with the concern of forgetting or losing personal alarm buttons or other types of portable technology [39,45,50]: "... I was good for the first few months, then I went away for a few days, and I couldn't have it with me because it wouldn't work in my daughter's house. Then I came home and I suppose it's like most things, you try it for a while and then you forget it." (p. 1189) [45]. Besides concerns becoming reality, there is also the problem of technology not working in certain locations [50,51], thereby lowering its acceptance. An example of this is portable technology that does not work in the shower. Another inhibitor of technology acceptance that was not mentioned in the pre-implementation stage, is the availability of home care as an alternative to technology for aging in place [39,50]. Lastly, the level of satisfaction with the new technology [45,51] and the affect toward the new technology as a result of using it [39,50] influence technology acceptance in the post-implementation stage.

3.11. Comparison with quantitative results on pre-implementation acceptance

Analysis of quantitative results shows that several variables that are similar to qualitative factors have been statistically tested on pre-implementation data, using regression analysis. At the same time, a small number of variables not present in the reviewed qualitative pre-implementation research were also tested. In this section, significant results are presented (Table 4).

In the study by Cohen-Mansfield et al. [49], the number of concerns regarding using a device (including high cost, low ease of use, impracticality, and stigmatization) has a significant negative influence on the acceptance of electronic memory aids. Furthermore, the importance attributed to functions of the device, which resembles the qualitative factor of perceived usefulness, positively influences acceptance. Cohen-Mansfield et al. [49] also found that acceptance of electronic memory aids is positively influenced by the number of different prescriptions taken; a variable that is not present in the reviewed qualitative research.

Lai et al. [40] studied community-dwelling older adults' acceptance of a vital signs monitoring system and their acceptance of a motion monitoring system. They found that the number of self-reported chronic illnesses, which bears resemblance to the qualitative factor of subjective health status, positively influences acceptance of a vital signs monitoring

system. At the same time, this variable has no significant influence on the acceptance of a motion monitoring system. This also applies to age, which was found to negatively influence the acceptance of a vital signs monitoring system, but not the acceptance of a motion monitoring system. In addition to age, two other variables that are not present in the reviewed qualitative research were studied: gender and level of education. Both negatively influence the acceptance of a motion monitoring system, but not the acceptance of a vital signs monitoring system. Lai et al. did not specify whether the motion monitoring system was more accepted by males or females.

Lastly, in the study by Zimmer and Chappell [53], the acceptance of electronic safety devices is positively influenced by two variables that are similar to the qualitative factor of subjective health status: the number of self-reported health symptoms and the number of self-reported dexterity problems. The number of safety and security concerns (which corresponds to perceived need) also positively influences acceptance. Finally, three variables that are not present in the reviewed qualitative research also influence acceptance of electronic safety devices: age (negative influence), level of education (positive influence), and rural residency (positive influence).

4. Discussion

4.1. Main findings

This is the first systematic review to identify factors that influence acceptance of electronic technology for aging in place. Since technology acceptance factors fluctuate over time, a distinction was made between factors in the pre-implementation stage and factors in the post-implementation stage. Sixteen articles based on qualitative, quantitative or mixed methods were identified. Most articles investigated acceptance of technology that enhances safety or provides social interaction. The majority of the data was based on qualitative research investigating factors at the pre-implementation stage. Results show that acceptance of technology at this stage is influenced by 27 factors, divided into six themes: concerns regarding technology (e.g., high cost, privacy implications and usability factors), expected benefits of technology (e.g., increased safety and perceived usefulness), need for technology (e.g., perceived need and subjective health status), alternatives to technology (e.g., help by family or spouse), social influence (e.g., influence of family, friends and professional caregivers) and characteristics of older adults (e.g., desire to age in place). When comparing these results to qualitative results on post-implementation acceptance, analysis shows that some pre-implementation concerns, such as the fear of forgetting or losing technology, turn into real life problems in the post-implementation stage. Furthermore, factors such as perceived need and stigmatization are persistent. New factors also emerge, for example satisfaction with technology and affect toward technology. Quantitative results show that a small number of variables, such as subjective health status, that are similar to qualitative factors, have a significant influence in the pre-implementation stage. Results for background variables, such as age and level of education, are mixed. Fourteen

Table 4 – Significant pre-implementation variables and similar qualitative pre-implementation factors.

Ref.	Significant quantitative variables			Similar qualitative factors	
	Variable	Technology studied	Significance level	Theme	Factor
[49] ^a	Number of concerns regarding using a device (including high cost, low ease of use, impracticality, and stigmatization)	Electronic memory aids	$p < .05$, Beta = $-.17$, $R^2 = .30$	Concerns regarding technology	High cost, low ease of use, impracticality, and stigmatization
	Importance attributed to functions of the device	Electronic memory aids	$p < .05$, Beta = $.44$, $R^2 = .30$	Benefits expected of technology	Perceived usefulness
	Number of different prescriptions taken	Electronic memory aids	$p < .05$, Beta = $.25$, $R^2 = .30$	–	–
[40] ^b	Number of self-reported chronic illnesses	Vital signs monitoring system Motion monitoring system	$p < .001$, $B = 1.718$, $R^2 = .22$ Not significant	Need for technology	Subjective health status
	Age	Vital signs monitoring system Motion monitoring system	$p < .001$, $B = -1.284$, $R^2 = .22$ Not significant	–	–
	Gender	Vital signs monitoring system Motion monitoring system	Not significant $p < .05$, $B = -0.785$, $R^2 = .13$	–	–
	Level of education	Motion monitoring system	$p < .05$, $B = -0.911$, $R^2 = .13$	–	–
		Motion monitoring system	$p < .05$, $B = -0.911$, $R^2 = .13$	–	–
[53]	Number of self-reported health symptoms	Electronic safety devices	$p < .05$, Beta = $.06$, $R^2 = .15$	Need for technology	Subjective health status
	Number of self-reported dexterity problems	Electronic safety devices	$p < .05$, Beta = $.06$, $R^2 = .15$	Need for technology	Subjective health status
	Number of safety and security concerns	Electronic safety devices	$p < .01$, Beta = $.27$, $R^2 = .15$	Need for technology	Perceived need
	Age	Electronic safety devices	$p < .01$, Beta = $-.08$, $R^2 = .15$	–	–
	Level of education	Electronic safety devices	$p < .05$, Beta = $.06$, $R^2 = .15$	–	–
	Rural residency	Electronic safety devices	$p < .01$, Beta = $-.09$, $R^2 = .15$	–	–

–, not described in qualitative articles.

^a Significance levels for this study were confirmed by contacting the corresponding author because these were not reported in the original article.

^b Data on a Personal Emergency Link Service (PELS) was excluded because only subscription status was analyzed, and not actual use or intention to use.

articles did not use an existing technology acceptance framework or model.

4.2. Strengths and limitations

This review's strengths lies in its extensive search strategy, covering databases in the fields of social sciences, health care and technology. This systematic and multidisciplinary approach is also reflected in the extraction of factors from qualitative research, which was done by three independent reviewers from different backgrounds (psychology, medicine and engineering). Another strength is the inclusion of all types of available evidence, regardless of the type of research method (qualitative, quantitative or mixed methods).

One mixed methods article [51] did not meet the screening criteria of the checklist that was used [35], due to an ambiguous research question. However it did contain data that helped us answer our research question. When we look at the contribution of this article to our data, it shows that three post-implementation factors were extracted from this article. Each of these factors were also mentioned by one other article. This indicates that the contribution of this study to the findings was supportive rather than decisive. This is in accordance with findings by Thomas and Harden, who showed that the contribution of studies that were assessed as having a lower quality was modest compared to studies that were assessed as having a high quality [37].

This review provides an overview of factors, but it does not differentiate between types of technology. Furthermore, moderating or mediating relationships between factors have not been investigated due to a lack of available data. This also implies that these types of relationships are not covered in the presented model of pre-implementation acceptance.

4.3. Relation to other studies, reviews and models

The majority of the included articles lack a theoretical approach, which hampers interpretation and comparison of findings between studies in this field. A similar problem has been reported by authors reviewing technology acceptance of consumer health information systems [55] and telemedicine [56]. When relating the results of this review to TAM and UTAUT, it appears that acceptance of technology for aging in place by community-dwelling older adults in the pre-implementation stage is influenced by more factors than just the key constructs of the TAM and the UTAUT. One example of this is the fact that community-dwelling older adults mention more benefits of technology for aging in place than just Perceived Usefulness.¹

However, it is possible that the other benefits that community-dwelling older adults mention, such as increased safety and increased independence, are in fact antecedents to Perceived Usefulness. An alternative explanation is provided by the authors of the value-based adoption model (VAM) [57], who state that TAM is very useful in organizational contexts, but not in the context of consumers who have to make their

own personal evaluation of the costs and benefits of using a technology. Therefore, in the VAM multiple Perceived Benefits and multiple types of Perceived Sacrifices together determine the Perceived Value of a technology to the consumer, which in turn influences an individual's intention to use a technology. Perceived sacrifices can be monetary or non-monetary. Examples of non-monetary costs are time costs, effort costs and psychological costs. In VAM, TAM's Perceived Ease of Use construct is considered to be a Perceived Sacrifice [57]. The theme "concerns" in this review resembles the construct of Perceived Sacrifices. Up until now VAM has been used successfully in explaining consumers acceptance of mobile internet [57] and Internet Protocol TeleVision [58]. At the same time Venkatesh, Thong and Wu have proposed and tested UTAUT2, which is also aimed at explaining consumer behavior, and contains the construct of Price Value which is defined as "a cognitive tradeoff between the perceived benefits of the applications and the monetary cost" [59]. The study by Cohen-Mansfield et al. [49] that is included in this review provides some statistical support for the role of cost-benefit evaluations, but to our knowledge VAM and UTAUT2 have not been tested in the context of older users.

This review also shows that other mechanisms besides cognitive cost-benefits tradeoffs come into play when older adults are considering the use of technology. Whether or not older adults feel the need for technology to support their aging in place is important in their acceptance of technology, both in the pre-implementation and post-implementation stage. Perceived Need plays a similar role in Andersen's Model of Health Services Utilization [54], where it is the most immediate predictor of health service use. The articles in this review indicate that many community-dwelling older adults do not feel the need for supportive technology. This is in accordance with some of the strategies for coping with decline that community-dwelling older adults employ, such as "trying to keep one's' mind from focusing on oneself and one's own vulnerability" [60] and "focusing on the present" [61]. More research is needed to understand how older adults' coping strategies are related to the use of supportive technology, especially since this review also shows the ambiguous relationship between older adults' desire to age in place and the use of technology designed to support that same goal. Perceived Need has also proven to be an influential factor in research on the acceptance of non-electronic assistive devices according to a systematic review by Steel and Gray [62]. Other factors in this review are also similar to factors in our review, such as fear of stigmatization, effectiveness, and cost. Additionally, Steel and Gray stress that acceptance of technology can be improved by training users and making sure that technology matches an individual's level of functioning, goals, preferences and needs [62]. These types of implementation factors have possibly not received much attention in the reviewed literature because the majority of the included studies was performed at the pre-implementation stage.

It is clear that pre-implementation acceptance of technology also depends on social factors since family, friends, professional caregivers and peers are all described as having an influence. Social influence also play an important role in several of the theories that are mentioned in this paragraph [59,18,54,63]. Some of the alternatives that prevent older

¹ Davis [17] and Venkatesh [18] define Perceived Usefulness of Performance Expectancy as "The degree to which an individual believes that using the system will help him or her to attain gains in job performance."

adults from using technology for aging in place, such as help by a spouse or help by a family member, are also social factors. Additionally, alternative technology that is already accepted can prevent the use of new technology. This review also points to other pre-existing conditions that can influence acceptance, such as familiarity with electronic technology and cultural background. These pre-existing conditions are also described in Triandis' Theory of Interpersonal Behavior [63]. Research by Wilson and Lankton [64], that is based on Triandis' theory, shows that pre-existing conditions such as age and presence of chronic health conditions have a direct effect on e-health use by patients. This is partly confirmed by studies in this review that found significant effects of age and the number of chronic illness on the acceptance of a vital signs monitoring system [40] and electronic safety devices [53], but not on the acceptance of a motion monitoring system [40].

4.4. Implications for practice and research

Professional caregivers, product developers, managers, policymakers, and family members who are interested in stimulating community-dwelling older adults to start using technology for aging in place, need to be aware that acceptance depends on a large number of factors that may vary for each individual. Most of the time, an older adult will have a number of specific technology-related concerns, while the perceived benefits of a technology might be more abstract. Therefore, it is necessary to communicate concrete benefits to the older adult and, at the same time, reduce technology-related concerns specific for that individual. Demonstration of the technology, the opportunity to try out the technology in a risk-free environment, and training or coaching can be used for this purpose. It is advisable to involve professional caregivers, family members, and peers who already use the new technology in these interventions, since older people are sensitive to their influence. When an older adult does not see the need for a technology, it is highly unlikely that he or she will be inclined to start using it. However, at this time it is uncertain if perceived need can be influenced, and if it is desirable to do so. It is, therefore, recommended to keep track of an older adult's perceived need for technology in order to coordinate the introduction of technology accordingly. It is also advisable to be sensitive to the fact that community-dwelling older adults do not exclusively look at technology as a means to enable aging in place; they also consider alternatives such as help by others or the use of their current technology. In fact, available alternatives might prevent them from using new types of technology.

Meanwhile, several gaps regarding research on the acceptance of electronic technology for aging in place by community dwelling older adults can be identified. First, while data on factors influencing acceptance in the pre-implementation stage are comprehensive, results regarding acceptance in the post-implementation stage are limited by the small number of studies. In order to support the independence of community-dwelling older adults for long periods of time, more research is needed to understand what drives continued or sustained use of technology once it has been implemented. This requires

longitudinal research investigating the influence of factors in multiple stages of use, such as those proposed by Rogers [65] or Chiu and Eysenbach [66]. Secondly, there is a dearth of quantitative research in the pre-implementation stage and quantitative research in the post-implementation stage is nonexistent. More quantitative research is needed to understand which factors are more influential than others and to investigate moderating or mediating relationships between factors. Thirdly, research until now has primarily focused on technology that provides safety through monitoring, and to a lesser extent on technology that supports (I) ADL or social interaction. More research is needed on the acceptance of other types of electronic technology for aging in place, such as technology for chronic disease management or technology that stimulates physical activity. This is also necessary in order to gain a better understanding of which core factors are influential in explaining the acceptance of multiple types of technology, such as perceived need, and which factors are more technology specific. Lastly, authors investigating technology acceptance by community-dwelling older adults are encouraged to make use of existing theories on the use of technology and to develop theories suitable to the context of community-dwelling older adults. In conclusion, more research is needed to capture the complexity and timeline of the acceptance process of different types of electronic technology for aging in place by community-dwelling older adults.

Author contributions

All authors have made a substantial, direct, intellectual contribution to this study. Peek: study concept and design, data analysis and drafting of the manuscript. Wouters and van Hoof: analysis and interpretation of data, critical revision of the manuscript for important intellectual content. Luijckx, Boeije and Vrijhoef: critical revision of the manuscript for important intellectual content.

All authors provided approval of the final version.

Competing interests

The authors declare they have no conflict of interest for this study.

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Summary points

What was already known on the topic:

- Technology may support aging in place, but questions have been raised on the readiness of community-dwelling older adults to use these technologies, and it is unclear which factors play a role in their acceptance of technology.
- Research from other fields shows that technology acceptance varies between the pre-implementation stage and the post-implementation stage.

What this study adds:

- A comprehensive overview of factors influencing acceptance of electronic technology for aging in place in the pre-implementation stage, based on qualitative research.
- A comparison between qualitative research on pre-implementation factors and qualitative research on post-implementation factors, and a comparison with quantitative research.

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