Designing User Interfaces for the Elderly: A Systematic Literature Review

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Abstract

A globally ageing population is more frequently required to utilize information systems as caregiving agencies and government policies adapt newer technologies to sustain efficiency. This unique user group commonly has difficulty with the solutions presented to them, and recent studies have focused on establishing the causes of these difficulties and possible solutions to them. However, these approaches are spread over a variety of technology domains (e.g., Mobile, Web, Desktop) and there seems to be little alignment between them, despite some obvious overlaps. In this paper, we conducted a systematic literature review to provide a structured overview of the current state of the literature regarding user interface development for elderly users over a variety of domains. Possibilities for future research and significant findings are also discussed.

Keywords elderly users, human-computer interaction, literature review, user interface design.

1 Introduction

Most developed countries are currently experiencing an ageing population, and facing a future of a smaller workforce and less budget to manage it (Mayer et al., 2013). The economic burden of caring for elderly population must be reduced to be sustainable, and research shows that keeping older people as self-sufficient as possible in their own homes is the best way to manage this (Queirós et al., 2015; Sutter and Müsseler, 2007; Zajicek, 2004). This challenge has resulted in a wave of literature on how advancing technologies can be leveraged to this end, and these ideas are beginning to make their way into government policy and mainstream usage. Many of these technological solutions rely on using information systems to automate or increase efficiency in caregiving sectors. Elderly users will need to interact with these systems in some capacity. Hence, user interface design, which is concerned with various aspects of human-computer interaction (Newell et al., 2011), needs to carefully consider their requirements in order to achieve targeted outcomes. However, there are several challenges that elderly users experience with typical user interfaces that a younger person would not experience (Chun and Patterson, 2012), either as a result of the effects of ageing (Garcia-Sanjuan et al., 2017), or unfamiliarity with modern technology (Patsoule and Koutsabasis, 2014). The age that these symptoms become apparent vary from person to person, but is generally defined with elderly or older as 65+ (Chun and Patterson, 2012; Mayer et al., 2013). It is important to note that the symptoms of ageing that appear to affect human-computer interaction can also be found in younger users with similar disabilities.

Corresponding to the adoption of information systems for elderly users, there is an emerging body of literature on the development of systems addressing the needs of elderly users by researching and developing how user interface design can best cater to this target audience (Liu and Joines, 2012). The variety of user interfaces and modern devices means this literature is widespread, with studies often focusing on smaller fragments such as (1) how a symptom of ageing affects interaction with the user interface, or (2) how a particular design practice can address ageing (Liu and Joines, 2012). In addition, this knowledge is spread over a variety of domains of human-computer interaction, including ambient assisted living (AAL), conceptual user interface, mobile user interfaces, user input devices, and website user interfaces. This paper aims to review the literature that addresses the challenges faced in developing user interfaces for elderly users. To best achieve this aim, it was decided that a Systematic Literature Review (SLR) would be developed, according to the guidelines established by Kitchenham and Charters (2007). In particular, we address the following two research questions:

> **RQ1:** *Which challenges have been identified in the literature that elderly users experience with user interfaces?*
>
> **RQ2:** *Which solutions have been proposed by the literature to address the identified challenges in user interfaces for elderly users?*

The results of such a SLR will provide both a valuable research for developing current systems, and a useful launchpad for future research. For practitioners, the review can serve as a reference when designing user interfaces for elderly users.

The remainder of this paper is organised as follows: Section 2 presents the research methodology for the SLR. Synthesizing the reviewed literature, section 3 summarizes the challenges identified in the literature. We then continue with the solutions investigated in the literature to address those challenged in Section 4. Finally, Section 5 concludes and discusses future research avenues.

2 Research Methodology

Building on the guidelines by Kitchenham and Charters (2007), Figure 1 summarizes the three phases of the SLR as employed in our study, namely planning, conducting, and reporting. After identifying the need for a SLR (Stage 1.1) and specifying the research questions (Stage 1.2), the following subsections will define the subsequent two stages of the planning phase, namely developing and then evaluating the review protocol (Stage 1.3 and Stage 1.4). Sections 2.2 and 2.3 then continue with summarizing the results of the conducting phase and the reporting phase, respectively.

2.1 Planning Phase

Search strategies generally culminate in a search string which will be executed against academic databases. However due to the common usages of the terms user interface and elderly in texts unrelated to elderly users this approach was not feasible for our study. Instead, an initial exploratory search was undertaken in Google Scholar to determine the domains of human-computer interaction that are relevant for this study. The identified domains were: (1) AAL, (2) conceptual user interfaces, (3) mobile user interfaces, (4) user input devices, and (5) website user interfaces. These domains focus on aiding self-sufficient elderly users with common technology, and were incorporated into the search. Domains including robotics, physical interfaces and special aid were excluded, as they either do not contain a common user interface component or focus on users with disabilities that are so severe that they require a very high level of support. Finally, as stated earlier, the disabilities that affect elderly users are more likely for this cohort but not exclusive to them as also younger users can be affected by similar disabilities in human-computer interaction. Hence, the terms “disabled” and “disability” were added to recognize papers that address relevant disabilities.

The search string to be executed as a title comparison in Google Scholar was then defined as allintitle: user (elderly OR older OR disabled OR disability) AND (interface OR interfaces OR "ambient assisted living" OR website OR mobile). To account for the search string’s drawback in only checking against titles, it was determined that references of studies found when conducting the search would need to be thoroughly searched for additional relevant documentation in a backward search. Study selection criteria were required to create a filter for what literature resulting from the search strategy would be appropriate for analysis and reporting. Studies were only included if they matched any of the following inclusion criteria. First, in order to only include high-quality research articles that focus on user interface design we added the inclusion criteria that studies needed to (1) be peer-reviewed articles, (2) that present completed research, (3) include an investigation of the user interface, and (4) include an empirical evaluation component. Further, as our study focuses on elderly users in general rather than severely disabled users with a specific condition (e.g., locked-in patients, intensive care patients), studies that (1) focused on a specific minority or (2) severely disabled users were excluded from the review. Evaluation of the review protocol was iterative, with the search string and domain list changed several times until results from each identified domain were apparent in search results.

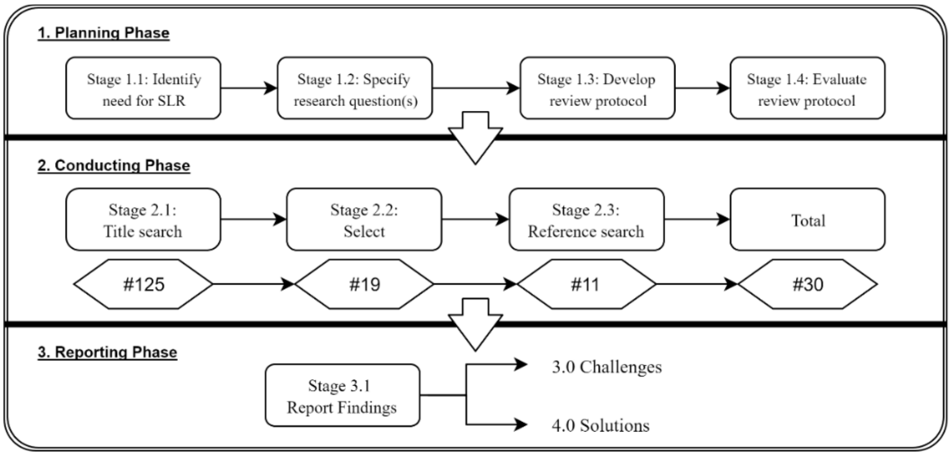

Figure 1. Phases and Stages of the Systematic Literature Review (SLR)

2.2 Conducting Phase

Conducting the search follows the stages developed in the planning phase (see Figure 1). The title search (Stage 2.1) was conducted using Google Scholar on 3 April 2017 and yielded 125 results. After applying the study selection criteria in Stage 2.2., this number was reduced to 19 results. Applying the same study selection criteria to relevant references in a backward search from those 19 results yielded another 11 articles in Stage 2.3, bringing the total to 30. A forward search was attempted but did not produce any additional relevant results within the scope of the defined inclusion and exclusion criteria.

2.3 Reporting Phase

The two research questions defined in the introduction are crucial for the reporting phase. Each study identified in the review was analysed against the backdrop of the identified research questions using thematic analysis, systematically identifying the challenges of user interface design for elderly users (RQ1) and the solutions devised in those studies (RQ2). The report is then built around how each article contributes to answering each of these research questions. Table 1 provides a high-level summary of the identified challenges and solutions. The following two sections outline the challenges and solutions that have been categorized through thematic analysis of topics in the reviewed articles, allowing the different groups of challenges and solutions to be easily distinguished and compared.

		Challenges			**Solutions**			
	Articles	***Physical Issues***	***Cognitive Issues***	***Computer Experience***	***Interface & Control Design***	***Natural Language***	***Cognitive Evaluation***	***Input Controls***
MOBILE	*Häikiö et al. (2007)*	X						X
	Jin et al. (2007)	X			X			X
	Lepicard and Vigouroux (2010)	X			X			
	Kobayashi et al. (2011)	X		X	X			X
	Bobeth et al. (2012)			X				X
	Gonçalves et al. (2012)	X			X		X	X
	Leitão and Silva (2012)				X			X
	Harada et al. (2013)	X			X			X
	de Barros et al. (2014)		X	X		X	X	
	Grindrod et al. (2014)			X	X	X		
GENERAL	*Galitz (2002)*	X	X	X	X	X	X	
	Gregor et al. (2002)	X	X	X				
	Zajicek (2004)	X	X		X	X		
	Sutter and Müsseler (2007)	X			X	X		
	Balakrishnan et al. (2012)	X	X		X	X		
	Hellman (2012)		X			X	X	
	Lányi et al. (2012)				X	X		
	Pitt (2012)	X		X	X			
	Patsoule and Koutsabasis (2014)	X	X	X	X	X	X	
	Wilson (2014)		X				X	
INPUT	*Iwase and Murata (2003)*	X		X				X
	Umemuro (2004)			X				X
	Hickey et al. (2009)		X		X			X
	Dias et al. (2012)	X						X
	Granata et al. (2013)		X	X	X	X		
	Jochems et al. (2013)	X		X				X
	Garcia-Sanjuan et al. (2017)		X	X	X	X		
AAL	*Picking et al. (2012)*		X	X				X
	Queirós et al. (2015)		X	X		X		X
	Wang et al. (2016)	X						X
	Total	**17**	**14**	**15**	**17**	**12**	**6**	**15**

Table 1. Mapping reviewed articles to challenges and solutions of elderly users by domain.

Note: Due to overlaps, the general domain covers conceptual as well as website user interfaces.

3 Challenges

This section synthesizes the results of the review to address RQ1, namely the challenges that elderly users experience with user interfaces. Overall, we identified three higher level challenges related to physical issues, computer experience, and cognitive issues, as summarized in more detail below. Literature identified each challenge with similar frequency as shown in Table 1. Notably, most studies in the review address at least two of the identified higher-level challenges. The number of articles that identify each challenge is noted in the heading. Subsections are ordered according to number of studies.

3.1 Physical Issues (17 Studies)

The most apparent issues when designing for the elderly is those caused by deteriorating physical condition. Reading text and listening to audio becomes increasingly difficult with age, and precise movements are often unreliable (Gregor et al., 2002):

a) **Impaired eyesight:** Most of our interaction with computing systems is through graphical user interfaces, which are exactly that, graphical. If the user has trouble just seeing the interface, every operation in the system will suffer accordingly (Patsoule and Koutsabasis, 2014; Zajicek, 2004). This problem extends beyond small text making reading hard. If the users' eyesight is affected to the point that viewing images and text is arduous, then comprehension is going to be severely affected. This lack of comprehension has far more of an impact than increasing the time taken to perform tasks, even if that is a large factor (de Barros et al., 2014). When accessing a user interface such as a website, there is an inherent path that the user takes before making any action. This involves analysing any images and text, identifying the purpose of the page, and identifying key information and instructions (Wilson, 2014). All of these tasks rely on visual comprehension of the supplied graphics. While even a poorly designed website might have minimal (yet irritating) impact on a user with unrestricted vision, the time taken to complete these necessary tasks increases exponentially when visual acuity is reduced.

b) **Haptic deterioration:** Fine motor skills deteriorate as people age, which becomes an issue when trying to interact with a mouse and keyboard or touch device. Mouse and keyboard is especially difficult for these users, as the abstraction between physical and digital movement can be difficult. These input schemas generally rely on small hand movements and actions, which become difficult for elderly users to articulate (Iwase and Murata, 2003; Lepicard and Vigouroux, 2010). Further, with increasing age, the time it takes to complete tasks such as pointing with mouse, and also the amount of errors that occur with tasks like "dragging" or "double click" increases (Iwase and Murata, 2003; Jochems et al., 2013).

c) **Reduced hearing:** Hearing was the least discussed physical problem in the identified articles as it is not strictly necessary for typical user interface interaction. It is included despite this as sound has practical applications in good user interface design, such as sound effects denoting successful or failed actions (Dias et al., 2012). Hearing acuity is also relevant in text-to-speech or voice interfaces such as those suggested by Wang (2016). It was noted that there is a linear increase in the comfortable decibel range for speaking as a person ages and this would affect these interactions (Galitz, 2002; Wang et al., 2016).

3.2 Computer Experience (15 Studies)

Computer experience has a pronounced effect on a user's systems usage (Granata et al., 2013). While this affects all age ranges, computer usage in elderly people is lower than it is for younger populations (Sutter and Müsseler, 2007). Further, there a reduced acceptance of technological innovation in elderly groups that presents a barrier against wanting to gain experience, where potential users do not see or disagree with benefits of computer systems (Bobeth et al., 2012). Resulting challenges are:

a) **Unfamiliarity with interface:** The most common user interfaces device, the QWERTY keyboard, is considered to be a major source of reluctance towards technology use by the elderly. Limited understanding of underlying computer principles forms a barrier between the user and the action they wish performed (Umemuro, 2004). This unfamiliarity extends to common Graphical User Interface (GUI) styles such as buttons, folders, and menus. Where a younger user is generally familiar with the terms and interactions between digital objects, users who are unfamiliar with these concepts have been shown to exhibit great difficulty understanding a set of tasks or actions (Grindrod et al., 2014).

b) **Limited understanding of processes:** Many users have difficulties conceptualizing the processes that take place behind the scenes of an information system, but younger users are more familiar with typical actions having predictable results. Elderly users are less likely to understand what an information system is "doing," especially if there is no explicit feedback or confirmation. For instance, for an unexperienced user a form being submitted on a webpage and then being redirected to another page may appear to have deleted the user's entries. This experience can cause anxiety in users as they will not understand that the correct process is happening without an appropriate feedback response from the system (Zajicek, 2004).

c) **Un-intuitive controls:** In order to speed up usage time of familiar users, input elements such as *NumericUpDown* and *DateInput* are implemented in place of text inputs or button controls. While this can greatly enhance the experience for competent users, older or unfamiliar participants have problems understanding the function of these more complex controls, which negatively affects usability (Granata 2013).

3.3 Cognitive Issues (13 Studies)

Deteriorating cognitive abilities are the third most commonly mentioned challenge. Glisky (2007) identified three main cognitive issues as a result of ageing, namely attention, long term memory, and working memory, all of which affect users' interaction with information systems:

a) **Attention:** *Selective* attention, which deals with filtering stimuli in the environment of the user, and *divided* attention, which manages multiple tasks or information sources at once, are both affected by ageing (Glisky, 2007). Some of the identified impacts on user interface interaction are the same as poor eyesight, where reduced attention skills increase the time it takes to filter information on a display and form comprehension. Focusing on the desired content once it has been identified is also found to be difficult for many users, due to the number of distractions like flashing ads in some user interfaces (Balakrishnan et al., 2012). The impact on task management is also considered, where the user has trouble keeping track of the actions required to complete a task, and the chain of actions that makes up user interface interactions. The more steps or layers of complexity are added to the chain, the greater the chance that the user will lose track or make mistakes (Granata et al., 2013).

b) **Working memory:** Manipulation of information relevant to the currently performed activity is core to mental processes like decision making and problem solving (Glisky, 2007). Naturally, these processes make up most of what we do. The challenge is to reduce the subjective difficulty experienced by an user in a system (Hellman, 2012). The reduced capacity in working memory and attention manifests in difficulty remembering the steps taken to complete a task, and trouble chaining together more than 3 actions to complete a task (Galitz, 2002).

c) **Long-term memory:** The two sub-types of long-term memory that are affected by ageing are (1) *episodic*, for example being able to recall a specific event, and (2) *prospective*, which deals with remembering scheduled tasks when they are not immediately relevant (Glisky, 2007). In user interfaces, this relates to how a user remembers task chains and actions taken to complete a task. Older users are less likely to be able to recall a chain of events without any prompting (Granata et al., 2013). Un-intuitive interfaces are especially problematic in this regard, as the user will have to relearn the same path to a point several times, which can cause frustration (Garcia-Sanjuan et al., 2017; Granata et al., 2013). Inability to remember future tasks should also be considered when there is a period of time between consecutive actions in a task. If the user is not prompted to continue with the next step when appropriate, it may be forgotten (e.g., taking food out of the oven in an AAL environment; Picking et al., 2012)

4 Solutions

This section addresses the second research question (RQ2): What are the proposed solutions to these challenges in developing user interfaces? There were four identified solution areas as listed below as a collection of themes. Similar to the challenged discussed in Section 3, most studies in the review employ at least two solutions in the design of their user interfaces. A large number of articles focused on mobile development. There were few articles that addressed the inclusion of elderly or disabled users in the initial design process, probably due to many of the articles working on existing systems rather than new ones (e.g., Patsoule and Koutsabasis, 2014). The number of articles that identify each challenge is noted in the heading, all headings and sub-headings are listed from most-to-least referenced.

4.1 Interface and Control Design (17 Studies)

The design and use of controls is a crucial part of modern GUI development (Newell et al., 2011). Controls are tools such as links and text inputs that the user interacts with as part of an interface. Having these elements be as usable as possible is therefore key to building a user interface for the elderly (de Barros et al., 2014). How these controls should look, and how they should be assembled to form a cohesive interface was the most commonly cited solution.

a) **Text and object standards:** The most commonly cited method for ensuring a user interface is accessible, is to conform to established standards regarding text size, colour and font. Articles from older disciplines than software engineering have already established many of these standards, and these are translated to computer terms such as font size and weight (Galitz 2002). As seen in Table 1, many studies in the domain of mobile interfaces address how this translates to mobile interfaces, where manual dexterity is more of a problem and interface size is restricted. Conventions have been created and tested to provide "optimal button size and spacing for touch screen user interfaces" (Jin et al., 2007, p. 933) in the context of older users. These guidelines include details on what gestures should be used or avoided, for example the pinch gesture was very difficult for older users (Kobayashi et al., 2011), and optimal amount of tactile targets on a screen (Leitão and Silva, 2012; Lepicard and Vigouroux, 2010).

b) **Intuitive control elements:** A major source of confusion for elderly users was found to be complex controls such as *DateInput* and *NumericUpDown* designed to speed up proficient users (Granata et al., 2013). More intuitive elements like the Calendar implemented by Patsoule and Koutsabasis (2014) were found to be much easier to understand. Control elements such as buttons or navigation links that represent an action greatly benefited from images or icons that visually imitated the action (e.g., a save disk; Hickey et al. 2009).

c) **Confirmations and errors:** An extension of intuitive controls, having those controls explicitly state the action occurring in the system to the user is identified as very beneficial to helping elderly people understand action chains for a task (Pitt, 2012; Zajicek, 2004). This stems from inexperience with computer systems where the user does not trust the computer to take the correct action or the user accidentally chooses an incorrect action. Having constant feedback on progress through a task eases anxiety and assists elderly users in learning how different controls affect the system (Granata et al., 2013; Kobayashi et al., 2011).

d) **Context help:** The use of context sensitive help options is identified as a very helpful addition to an interface when targeting elderly users. This control provides information about the currently selected feature or event, so if a user is unable to progress they have a resource available to extricate themselves (Patsoule and Koutsabasis, 2014; Pitt, 2012).

4.2 Input Controls (15 Studies)

The device used to interact with the user interface was a major focus of the literature analysed as seen in Table 1, with an entire domain attributed to studies evaluating input methods. Most mobile domain studies mention the effectiveness of a touchscreen-based device (touch input), which was identified in the input domain studies. AAL domain studies introduced some new input methods that would be incorporated into the home like the TV interface.

a) **Touch input:** Touchscreen based interfaces leads to significantly better performance when used as an input device for elderly users (Bobeth et al., 2012). When compared to mouse/ keyboard inputs, touch input execution time does not increase significantly as the subject ages, while mouse/keyboard inputs exhibit a direct correlation between age and execution time (Jochems et al., 2013; Umemuro, 2004). The same tasks were also rated subjectively easier when performed on a touch input device, due to the more intuitive link between physical and digital action. All evaluating studies strongly argue for the use of a touch interface where possible when targeting older users (Häikiö et al., 2007; Harada et al., 2013; Jin et al., 2007). The use of gestures as an input control is also very effective (Harada et al., 2013; Kobayashi et al., 2011) but reduced haptic capabilities make this difficult when elements are closely spaced (Leitão and Silva, 2012). Computer inexperience was considered less of an impact with touch-based systems, with most users finding basic actions considerably easier to complete and complex interactions easier to learn within a week (Harada et al., 2013; Kobayashi et al., 2011).

b) **Voice input:** When the user has difficulty or is incapable of using a physical interface, voice commands can be used to navigate interfaces by audio commands (Dias et al., 2012), or use voice commands to trigger certain events easily (Wang et al., 2016). Voice input was also identified as a possible improvement where a touch keyboard is used to input text. The keyboard used in smartphones and tablets is commonly considered as too object-dense for many elderly users according to the results of Jin et al. (2007) and exhibited a high error rate for text input (Grindrod et al., 2014). It was suggested that a voice input-to-text component could be implemented to minimize the need for keyboard text input (Dias et al., 2012).

c) **Eye-gaze input:** Eye-gaze is a type of input where the users eye motions are tracked and calculated into digital actions. It allows elderly users to have a faster execution time when compared to mouse and keyboard, though still significantly less than touch interface (Jochems et al., 2013). It also relies on less available devices to be effective, which can limit its implementation. However, it does address issues with advanced cases of haptic deterioration where hand movements are no longer reliable. It is recommended mainly as an option for severely motor-impaired users (Jochems et al., 2013).

d) **TV interface:** Many older users identified their TV as a major part of their lives, attributing a considerable amount of entertainment and social interaction to it (Bobeth et al., 2012). Mainly tested in AAL studies, the user's TV can act as an interface for information systems operating in the home of the user. The TV interface is typically controlled with a TV remote that the user is already familiar with, yielding high levels of technology acceptance (Bobeth et al., 2012; Picking et al., 2012).

4.3 Natural Language (12 Studies)

Information systems rely on jargon to standardize user interfaces among devices, tools, and applications. This is helpful for established users but presents a roadblock for users who have not learnt or formed a conceptual connection between the jargon and the actions being performed (Patsoule and Koutsabasis, 2014; Sutter and Müsseler, 2007). Minimizing jargon and substituting it with plain descriptive language makes the interface more intuitive for unfamiliar users (Grindrod et al., 2014; Sutter and Müsseler, 2007). Further, elderly users are often confused by long messages with many options (Zajicek, 2004). Offering the user too many options is another issue, where users can feel overloaded with concurrent choices and struggle to pick the correct option (Balakrishnan et al., 2012). It was found that short, plain messages like “Would you like to deposit or withdraw money?” (Zajicek, 2004, Section A.1) were important in communicating available options and this information was remembered for longer (Patsoule and Koutsabasis, 2014). It was also found that in most cases, elderly users would prefer to accept a default value that is close to a preferred value, rather than be required to enter in their preferred value (Zajicek, 2004). This was demonstrated effectively by giving choices such as morning, afternoon and evening, which would default to 9 am, 3 pm, or 7 pm (Kobayashi et al., 2011).

4.4 Cognitive Evaluation (6 Studies)

Cognitive evaluations are a testing method against usability, with a focus on the type of learning and understanding that would be affected by cognitive deterioration. Defined by Wilson (2014), it uses potential users, in this case elderly or disabled people, as evaluators in the testing of a user interface. This approach is particularly beneficial in developing systems for people experiencing cognitive deterioration (see Section 3.3). If done correctly, it increases “initial learning” (Wilson, 2014) which makes the product more intuitive to the users and yields higher levels of familiarity. The type of input used in the testing plays a large part of evaluating usability, and this should be considered when analysing interactions in a cognitive walkthrough by an elderly user (Gonçalves et al., 2012).

5 Conclusion and Future Research

The increasing need for more efficient care systems necessitates that these applications are more accessible for the growing user base of elderly users. This systematic review sought to explore how current literature identifies these challenges and what solutions have been devised to address them. The first research question, “What are the challenges that elderly or disabled users experience with user interfaces?”, was addressed in all domains. The literature assigned equal importance to each challenge, illustrated by the similar reference totals in Table 1. All articles analysed incorporated a solution along with the challenges identified, which allowed us to map the solutions to the challenges they address in each domain (see Table 1 and Table 2). The results of the second research question, “What are the proposed solutions to these challenges in developing user interfaces?”, were far less balanced, and Table 1 shows that each domain tends to address one solution area more heavily than others. What was clear from all domains is that elderly users have vastly different requirements than younger users, and solutions that meet these requirements require some level of participatory or human-centred design.

	Interface and Control Design	*Input Controls*	*Natural Language*	*Cognitive Evaluation*
Physical Issues	11	9	5	3
Computer Experience	7	7	7	3
Cognitive Issues	7	3	9	5
Total	25	19	21	11

Table 2. Number of studies that address solutions for specific challenges

A notable observation of our review is the lack of solutions addressing cognitive issues in the domain of mobile user interfaces. Many articles espouse input through mobile or touch applications as a more intuitive and natural interface. There are also several mentions of how mobiles devices portability and unique tools like geolocation and alarms can be used to assist with poor memory and attention, but these aspects are largely missing from studies focusing on mobile user interfaces. With mobile applications being the most effective at addressing physical characteristics, further study should be done on how to best tailor these applications to suit the cognitive challenges of elderly users as well.

AAL environments are another emerging area that could proof to provide an effective solution to the ageing population crisis, and there will likely be much more research in this domain as well. In this context, particularly two research themes emerge that warrant further investigation. First, there is a need for the development of effective usability testing and evaluation methods specific to elderly users. Second, a comprehensive guide to design exemplars regarding cognitive issues in older users and how to apply these to a mobile or AAL environment is needed for practical applications as new technology expands to fill the needs of these entities.

The information synthesized from the literature in this review also provides a direct benefit to system designers looking to produce a user interface that addresses the needs of elderly users. Giving some clarity to the challenges that these system designers will encounter in their task, while laying out possible solutions investigated in the extant literature, can provide structure for the problem space and support the adoption of best practices to address specific challenges in designing of user interfaces for the elderly. Ultimately, elderly users may benefit the most from this emerging literature, particularly if the solutions adequately address the challenges of elderly users and achieve higher levels of usability for them. Finally, this research may provide a shared frame of reference for researchers to systematically categorize common challenges that need to be addressed when designing user interfaces for the elderly, identify knowledge gaps in the understanding of these challenges, and devise innovative user interface solutions and evaluation methods.

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