Touch-screen application's design guidelines for older adults with dementia

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Abstract: Dementia is a complex syndrome of neurological diseases that affects a person's cognitive abilities, memory, and behavior. It progressively deteriorates over time and has no cure yet. As the world population ages, the prevalence of dementia is expected to rise. According to many studies, touch-screen technology has the potential to offer support to older adults with dementia in their daily activities. However, there is a significant gap in the availability of dementia-friendly touch-screen applications for this group of users. This research aims to propose a set of guidelines and design recommendations for touch-screen applications targeted toward older adults with dementia. In addition, the research explores the cognitive and physical impairments that come with aging and dementia, examining their impacts on the design of the touch-screen application's interface, functionality, as well as interactions. Interviews have been conducted with experts to validate the design guidelines. Findings show that the proposed guidelines could assist the developers in designing touchscreen applications to improve user accessibility and experience.

Key Words: elderly users, human-computer interaction, dementia, touch-screen, design.

1 INTRODUCTION

Dementia is a medical condition that involves a decline in a person's cognitive abilities over months and years. In 2010, it was estimated that approximately 35.6 million individuals were living with dementia globally, and this number was expected to nearly double every two decades, reaching 65.7 million in 2030 and 115.4 million in 2050 [1]. While dementia can occur in individuals of all ages, it is most commonly associated with the elderly population, particularly those over the age of 60 [2]. Common symptoms of dementia include memory loss, communication problems, and mood changes. As the condition progresses, it can affect all areas of cognitive function, making social activities and interactions increasingly difficult [3]. Consequently, individuals with dementia may experience social isolation and miss out on the range and diversity of social interactions that are commonplace for those without the condition. This can have a profound impact on their mental well-being, placing significant strain on their family and caregivers [4].

To aid older adults with dementia maintain their social connections and enjoy aging in place, "assistive" technology is increasingly used in dementia care [5]. Among them, touchscreen tablets and smartphones are relatively low-cost and highly portable forms of technological support. Some studies have been conducted to show that people with dementia are usually capable of utilizing touch-screen applications thanks to their intuitive and simple control methods [6, 7]. In addition, some touchscreen applications integrate the therapeutic intervention or track the user's health status to support dementia care [8, 9]. However, most of these applications are typically not intended for users with dementia, but rather for family members or formal caregivers [8].

Designing an application for older adults with dementia presents some challenging problems [10] since they experience not only disease-related conditions but also issues that link to the natural aging process. Furthermore, dementia patients are often reluctant to use IT applications due to the mismatch between their needs and abilities and the applications' features. Many applications are excessively complex, have an unsuitable visual appearance, and contain an overwhelming number of functions [11]. Therefore, applications for dementia users require finding a delicate balance between incorporating accessibility and usability features while enhancing the overall user experience. There are existing guidelines about designing applications for older adults [12–16]. However, these do not take into account the special needs of a person who is living with a diagnosis of dementia.

Therefore, to find out the list of related design guidelines' requirements, this research aims to answer the following research question:

How can touchscreen applications be designed to improve the overall user experience for older adults with dementia?

The main research question is supported by two sub-research questions:

(1) *What are the accessibility challenges that should be considered when designing touchscreen applications for older adults with dementia?*
(2) *How should design principles be incorporated into touchscreen applications to enhance the ease of use for older adults with dementia?*

Based on the findings from the research, the final proposed design guideline is extracted and used as a foundation to instruct designers and developers about interface layout, functionalities, and interactions in the development of touchscreen applications for use by elderly individuals with dementia. This will contribute to improving older adults with dementia' accessibility and facilitating their engagement with touchscreen applications.

Within the next section, the literature review in section 2 will explain potential accessibility challenges that should be considered when designing applications for older adults with dementia. Section 3 will outline the research methodology with four details stages. Following that, section 4 will present the proposed design guidelines. Section 5 will describe the research's validation process using a low-fidelity prototype and expert interviews. After that, section 6 will be dedicated to the discussion of the interview's feedback and the research's limitations. Finally, the paper will finish with a conclusion in section 7 answering all research questions and potential future improvements.

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2 RELATED WORKS

2.1 The elderly and challenges

The American Association of Retired Persons (AARP) [17] defined an older person as an individual aged 50 and up, irrespective of work status. In medical research, individuals between the ages of 18 and 44 are categorized as adults, those between 45 and 64 are considered middle-aged, and individuals over 65 are referred to as elderly [18]. As people age, it is associated with a decrease in physical and mental capabilities. This gradual deterioration impacts the capabilities and adjustments in how the elderly interact with others and the surrounding physical environment [19]. Since the majority of dementia patients are older, it is important also to consider age-related issues [2]. In addition to suffering from dementia, these older persons need to deal with aging physical and cognitive ailments. The authors in [10, 14, 20] list several aging areas to consider when designing for older adults:

2.1.1 Vision. According to a study by Fozard [21], vision problems tend to appear after the age of 40. One of the noticeable issues is presbyopia which affects near-focus vision. According to the authors in [22], the near-point focus of eyesight is 10 cm at age 20 and changes to 100 cm at age 70. As presbyopia progresses, it affects the elder's contrast sensitivity and the ability to see and notice fine details. Owsley et al. [23] found that contrast sensitivity significantly declines when comparing compared 50-year-olds to 20-year-olds individuals. The next visual issue is the increase in sensitivity to glare and adapts slowly to changes in illumination [24]. This condition causes discomfort for the elderly when exposed to bright lights or sudden changes in brightness. At the age of 60, the reduction in the width of the visual field is the next common issue [25], making it harder for older people to detect and estimate the speed of moving objects, especially things with minimal motion. Color perception is also being impacted by aging, especially colors in the blue, purple, and green range [26, 27].

2.1.2 Hearing: The overall ability to perceive sound also declines with age. According to Fozard [21] and Kline and Scialfa [28], approximately 20% of individuals aged 45 to 54 experience some level of hearing impairment or hearing loss (presbycusis) and it significantly increases to 75% among those aged 75 to 79. Hearing loss affects the perception of conversational speech and a report by [29] shows that by age 80 people may miss 25% of the words in a normal conversation. Furthermore, as age goes up, most older adults cannot detect high-pitched sounds [30]. It might lead to missing certain alarms and high-frequency sounds like morning alarm clocks, phone ringing, doorbells, or birds chirping. [31].

2.1.3 Motor and psychomotor functions: There are noticeable changes in hand and motor function in older people, primarily characterized by a decline in strength, dexterity, and range [32]. From the age of 30 to 80, muscle loss starts happening and there is a significant 40% decline in strength, and the average 65-year-old individual possesses only 75% of their maximum strength [33]. Older adults also experience a decline in their ability to control and modulate the forces they apply [34]. For the psychomotor, some research [35, 36] shows that the deterioration in psychomotor could lead to older adults often having difficulties with tasks requiring quick response times or performing complex movements. These challenges, coupled with changes in motor functions, pose obstacles for older individuals when performing precision-based activities such as quickly selecting multiple targets or pressing small buttons [20].

2.1.4 Cognitive process: According to [36], older adults experience difficulty maintaining attention over a long time. They are also less able to inhibit competing information and show slower in directing their attention from one task or stimulus to another [20]. In terms of short-term memory, working memory refers to the active retention of information currently perceived or being thought about. While working memory storage capacity remains unaffected in the elderly, there is a decline in processing efficiency over time [37]. This results in difficulties in recalling multiple instructions or complex sequences of information [14]. With regard to long-term memory, according to [14], long-term memory is responsible for storing information for periods longer than 60 seconds. It consists of several components, including episodic memory for specific events, procedural memory for knowledge of how tasks are carried out, and semantic memory for ideas, concepts, and facts commonly regarded as general knowledge. Unlike episodic and procedural memory, semantic memory rarely declines with age. Overall, this shows that the ability to recognize familiar items from previous exposure remains mostly unaffected, but there is a significant decline in the ability to recall content [38]. Consequently, the elderly need more time, a slower pace, and more practice and repetition to learn new skills. [14].

In general, as humans age, their physical and cognitive abilities decline, affecting how they interact with others and their environment. Since most dementia patients are older, age-related issues are crucial when proposing the design guideline. Presbyopia and decreased contrast and glare sensitivity can impair fine detail perception. To improve visibility, designers should use appropriate text sizes, spacing, and colors. Hearing impairments require adjusting the sound and speech within applications to ensure effective communication. Motor, psychomotor, and cognitive issues require simple functions and control to accommodate reduced strength, dexterity, control, and cognition. These challenges can help the design guideline meet older people's needs and improve their well-being.

2.2 Dementia and challenges

Dementia is an irreversible syndrome that is caused by different diseases that damage the brain. It progressively deteriorates over time and the progress has no cure yet [39]. There are clinical stages of dementia: mild, moderate, and severe [40]. The symptoms of these stages can cause decreased functional abilities to complete daily activities [41]. In the early stage of dementia, symptoms are noticeable but patients can still manage daily tasks with some help. As the condition progresses to the moderate stage, patients require daily assistance due to worsening symptoms. In the severe stage, patients need extensive care and cannot be left alone. There are some types of dementia, and according to the World Health Organization (2012) [3], Alzheimer's disease is the most common one, accounting for 60-70% of cases worldwide. It is followed by 10% of dementia cases worldwide are vascular. Lewy bodies, Frontotemporal lobar degeneration, Parkinson's, and Creutzfeldt-Jakob diseases are rarer.

However, studies [42–44] indicate that the distinctions between different dementia subtypes are less apparent. Therefore, according to [45], dementia symptoms can be categorized into three main groups:

2.2.1 Cognitive: Cognitive symptoms affect thinking and intelligence. Early dementia symptoms include memory loss, especially short-term memory [46]. Short-term memory loss impairs recent memories. For example, a person with dementia may forget whether they ate lunch an hour ago. However, long-term memories like languages or things that happened long ago may be preserved at the early stages of dementia. Dementia patients struggle to organize memories, making it hard for them to remember, recall, or learn. As memory loss get worsen, it also affects normal conversation and the ability to follow a speech or find the proper word [39]. Another cognitive symptom associated with dementia is difficulty concentrating, planning, or organizing. As a result, individuals with dementia may experience challenges with decision-making and problem-solving tasks. Besides that, dementia can affect an individual's orientation sense and being confused with respect to time and space. They may have difficulty distinguishing between day and night and locating items. As dementia progresses advanced, previously mentioned difficulties make daily tasks more challenging or even impossible.

2.2.2 Psychological: Depression symptoms are common among dementia patients, but they are often overlooked due to the presence of other symptoms [47]. Patients may barely feel sadness, unhappiness, or hopelessness, but they may easily lose interest in activities they once enjoyed and express somatic concerns and anxiety [45, 47]. Dementia patients have also been reported to experience delusions and hallucinations [48], which can lead to a distorted perception of non-existent stimuli such as hearing, seeing, smelling, or feeling sensations that do not exist and the presence of false beliefs [49].

2.2.3 Behavioural: The behavioral and psychological symptoms of dementia are closely related, and most of the behavioral problems are the result of underlying psychological issues[50]. According to authors in [51, 52], dementia behavioral problems include agitation, aggression, and apathy. Agitation is uncontrollable behavioral, vocal, or motor activity that is not directly related to the agitated person's wants[53]. This includes symptoms like aimless wandering, agitation or irritability, fidgeting, tapping fingers, or making other repetitive movements [54]. A person with dementia may suddenly become agitated due to a change or specific cause, such as increased noise or the inability to perform a task they were previously able to do. Aggression is a more severe level of agitation and can be both physical and verbal. The cause for the aggression can vary from pain and depression to agnosia [47]. Examples of behavior are hitting, pinching, throwing, shouting, or making threats. Finally, apathy is a disorder of motivation characterized by a loss or reduction in goal-directed behaviors, cognitive activities, and emotions [55], and it might occur in the absence of depression [56]. As apathy progresses, patients become more dependent on their carers to suggest and organize their daily activities and lose interest in the conversation and daily routine [57].

In general, dementia is a syndrome characterized by progressive cognitive disease decline, resulting in decreased functional abilities. It is important to understand the clinical stages of dementia, ranging from mild to severe, as they determine the level of support and care required. Cognitive symptoms, such as memory loss, difficulty concentrating, and orientation challenges, are prevalent in dementia. Psychological symptoms, including depression, delusions, and hallucinations, can also manifest. Behavioral symptoms, such as agitation, aggression, and apathy, are often linked to underlying psychological issues. These symptoms impact the daily activities of individuals with dementia. Therefore, touchscreen application design must promote simplicity and intuitiveness to provide a comfortable and enjoyable experience for users.

2.3 Touch screen as "assistive technology"

"Assistive technology" is defined as "any item, piece of equipment, product or system, whether acquired commercially, off-the-shelf, modified or customized, that is used to increase, maintain or improve functional capabilities of individuals with cognitive, physical or communication disabilities" [58]. According to Gordijn and Have [59], with the help of assistive technology, dementia patients gain independence and autonomy. It also prevents them from being isolated and enjoying living in place. New technologies are being developed to improve information and communication for everyone, including the elderly and people with special needs. There are many forms of "assistive" technology ranging from nursing robots, location tracking devices to prevent wandering, personalized sensors to track health conditions, smart living spaces to telehealth systems [59] and also notably the use of touch screen devices such as smartphones and tablets. Several examples can be mentioned to highlight the diverse ways touchscreen technology has been employed in dementia care. CIRCA [60] is a communication touchscreen computer that utilizes digital reminiscence materials to promote communication between dementia patients and their caregivers. The "Living In the Moment" [61] project focuses on developing touchscreen games and activities in collaboration with people with dementia. Bayen et al. [62] conducted a study on an app that enables video monitoring of individuals with dementia. Hashim et al. [63] developed an individualized digital memory book on the tablet for patients with Alzheimer's disease. The growing use of touchscreen technology devices in everyday life has prompted healthcare professionals and researchers to explore their potential effects on individuals with dementia [64]. Joddrell's study outlines three reasons why dementia patients should use touchscreen devices [6]:

2.3.1 Intuitive Control: Touchscreen devices are considered intuitive and have simple control methods for people with dementia. Compared to computer desktops, Wandke and Sengpiel [65] found that touchscreens are better for dementia patients than computer desktops because they demand less hand-eye coordination. Furthermore, despite little understanding or previous knowledge about touchscreens, most people can easily use touchscreen applications with simple instructions [7].

2.3.2 Multifunctional use: The second reason is that touchscreen devices like smartphones or tablets often can come with various other technical functions [66]. These functions can include motion sensing through the camera, voice recognition, and the ability to see,

hear, and interact with the surrounding environment (used as an online controller through Wifi/Bluetooth). Therefore, touchscreen devices can meet the various needs of individuals with dementia, such as increasing socialization, providing memory prompts, facilitating activities, and delivering educational tools [6]. Furthermore, with multifunctional uses, a touchscreen device is an ideal solution to easily integrate with the therapeutic intervention to help people with dementia [67].

2.3.3 Practicalities and customization: Compared to other "assistive" technology, touchscreen devices are more flexible, inexpensive, and portable. Within an affordable budget, touchscreen devices are accessible to most users to use their functions. These devices also come in various sizes for easy portability. Furthermore, most touchscreen devices and their applications are highly customizable with many setting options that allow users, caregivers, or therapists to tailor the program to each individual. Customization is important for users, especially people with dementia, as it is easy to adapt and respond to their specific needs [6].

2.4 Design guidelines for people with dementia:

According to Interaction Design Foundation [68], design guidelines are sets of recommendations on how designers should apply design principles to provide a positive experience for users. These guidelines serve as essential directives to create user-centered designs that prioritize user satisfaction and meet diverse user needs, including those with disabilities. Design principles, on the other hand, are widely applicable design rules and considerations that designers use as a foundation to create effective and attractive applications or products. By following design guidelines, developers and designers can evaluate how to adopt principles such as intuitiveness, learnability, efficiency, and consistency to create compelling designs and meet user requirements. Thus, the use of design guidelines assists in creating a clear and consistent design, reduces development time, and increases usability and accessibility for users.

However, research done by Ancient and Good [69] showed only a few studies focused on dementia-friendly interfaces. Due to users' physical and behavioral constraints, designing applications for older adults with dementia is challenging [10]. It is also necessary to consider both personalization and user acceptance for the design to effectively meets the unique requirements of this user group [69]. Therefore, proposing design guidelines is a good start to guide designers in creating dementia and elder-friendly applications.

With regards to design guidelines for older adults with dementia, although there are already some studies about designing guidelines for older adults and touchscreen applications [12–16, 70–72], there are only a few and incomplete design guidelines or principles considering people with dementia [45, 73, 74]. Studies about design guidelines can be categorized into three areas: interface, functionalities, and interactions. For interface guidelines, studies by [13, 15] provide general interface guidelines about visual layout to design applications for older adults. Research by [70, 71] focused on suitable touchscreen interactions and provides a detailed analysis of how they relate to aging issues. [72] proposes familiar functionalities and interactions that can speed up elderly users' learning process with new applications. Notably, [12, 14, 16] comprehensively researched all aspects of designing touchscreen applications for older people, taking into account age-related issues and implications for suitable design, including characteristics related to users with cognitive decline. Recent studies have investigated designs suitable for touchscreen applications for dementia users. For example, [74] proposed design guidelines for interface and interactions suitable for Alzheimer's disease (AD), a form of dementia. Furthermore, research by Pang and Kwong [73] on activity and memory mobile apps for dementia has summarized some design considerations for use by older adults with dementia. Niklasson and Sandström's study [45] on interactive interface design has also proposed a comprehensive set of guidelines considering how to adapt the interface design for users with dementia.

3 RESEARCH METHOD

3.1 Study Design

This research methodology is based on User-Centered Design (UCD) [75] approach. The methodology focuses on understanding end-user needs and requirements before creating products and services. There are four stages involved in this research as follows:

Step 1 - Literature study: The literature study is carried out to gain more insights into dementia symptoms, the challenges that older adults and people with dementia face in daily life, the potential of "assistive" technology such as touch screens, and the impact of proposing design guidelines to improve the situation.

Step 2 - Studies selection: After understanding the targeted user's context, this research continues with a literature search for the most relevant works on touch screen design guidelines for older persons or people with dementia. The search procedure uses Google Scholar, Research Gate, Scilit, and Research Rabbit App. Some examples of search terms and keywords are "designing touchscreen applications for older adults", "elders with dementia", and "the benefits of touchscreen applications". The details are mentioned in Section 3.2.

Step 3 - Extraction: After collecting relevant studies, the guidelines and design principles are extracted from them and grouped into three sections: interface, functionalities, and interaction. To avoid redundancy, a filtering step will remove duplicate or similar statements and add missing design principles for each category. The result is an earlier version of the guidelines.

Step 4 - Validation: In the final step, a low-fidelity prototype application is made according to the design guideline to evaluate the proposed design guidelines. There are three interviews with experts in Human-Computer Interaction, elderly health, and dementia care to assess the proposed prototype and guidelines. After that, a final review of the principles is done in each section, carefully comparing the research results to improve and finalize the set of principles. This process also involves removing the principles that are less applicable or describing principles in more detail.

3.2 Literature search and selection

To gather relevant studies about design guidelines and principles, a literature search was conducted on designing touchscreen technology for older adults with dementia. The search was performed on Research Gate, Google Scholar, Research Rabbit App, and Scilit

between the 8th of May and the 19th of May 2023. The following search terms were applied on Research Gate and Google Scholar ((design*) OR (design guidelines*) OR (design principles*) OR (design interface*) OR (interactions*)) AND ((dementia) OR (Alzheimer*)) AND ((touchscreen) OR (touch screen) OR (tablet computer) OR (tablet device)) AND (app*). After the searching, a screening step is applied to filter found articles based on the inclusion criteria as shown in Table 1. The list of studies after the screening is then put into Scilit and Research Rabbit App to find more relevant work based on their AI mapping algorithm.

Table 1. Inclusion criteria used for the literature search

Criteria	Description
Language	English
Participants	Older adults or dementia patients
Technology	Any featuring touchscreen interface, interactions, applications
Article type	Academic Journals, Conference Proceedings, and Books

The search strategy mentioned above resulted in 172 references being returned through the database searches, and 16 articles were finally used as research resources. Figure 1 shows the study selection phase details.

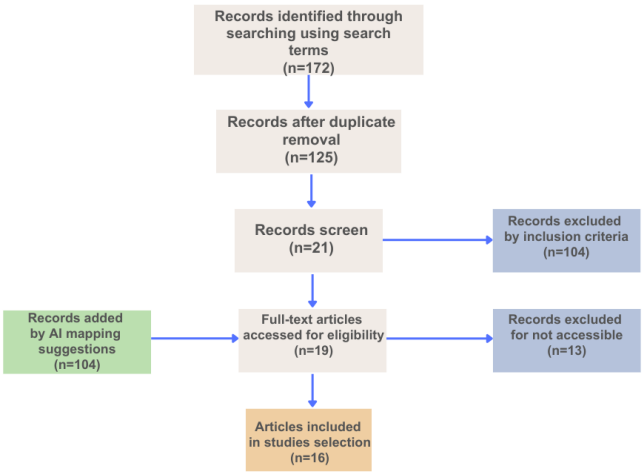

Fig. 1. Flow diagram of search strategy

4 RESULTS

4.1 Design guidelines

After a comprehensive literature search and selection, 16 articles are used as resources to develop design guidelines. There are 66 design principles extracted from the resources. They are classified into three main categories: interface, functionalities, and interaction, and within each category, further sub-criteria are defined. The "Interface" category suggests guidelines about the application's visual appearance, structure, and content. The "Functionality" category covers features and functions that should or should not be implemented to maximize user experience. The "Interaction" comprises a list of suitable touch screen interactions, ensuring a user-friendly and accessibility for older adults with dementia. Details about the classification are illustrated in Figure 2. Moreover, each group of criteria is accompanied by a detailed discussion on related dementia and aging issues. This discussion outlines how the corresponding design principles address these issues, ensuring that the design guidelines meet the unique needs and challenges faced by people with dementia and aging-related concerns. The final set of design guidelines with 16 reference articles is presented in Appendix A.

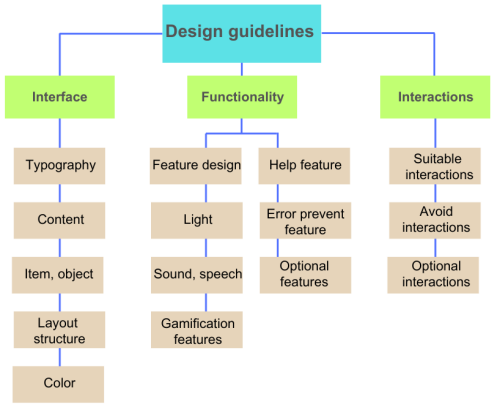

Fig. 2. Design guidelines categories

5 VALIDATION

5.1 Low fidelity prototype

In order to validate the effectiveness of these guidelines, a low-fidelity prototype application has been created using Figma - a user interface design tool. The prototype is a simplified version of a blog or electronic newspaper, aimed at providing dementia users with easy access to information and an interactive and user-friendly interface. The design was tailored specifically for the iPad Pro 11" tablet. This application applies several design principles outlined in the guidelines. It maximizes contrast with black text color and orange buttons on a white background. The text content uses the Arial and Sans Serif font style with a minimum text size of 14 px to enhance readability. All buttons and images feature labels and intuitive icons to improve comprehension. The functionality also supports the use of the "Back", and "Home" buttons to aid navigation. Moreover, the application supports straightforward controls such as single-touch, swipe, and scrolling. Since Figma does not support playing sound, Speechify voice-over tool is used to support playing scripted speech. Fig 3, Fig 4, and Fig 5 show some designs of the prototype application.

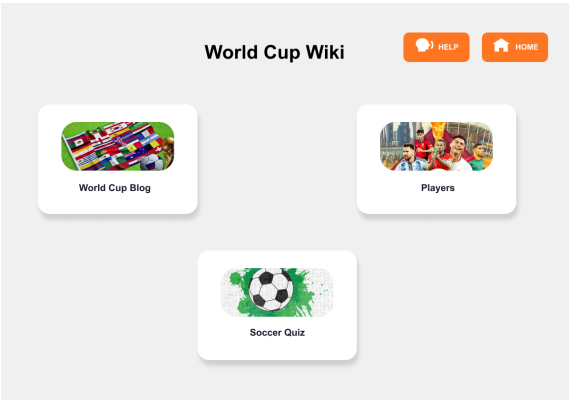

Fig. 3. Prototype - Home page

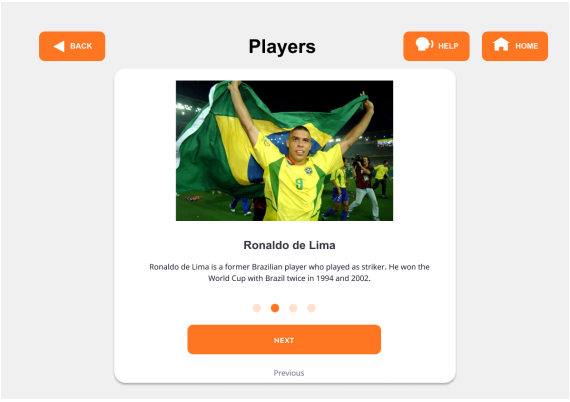

Fig. 4. Prototype - Gallery page

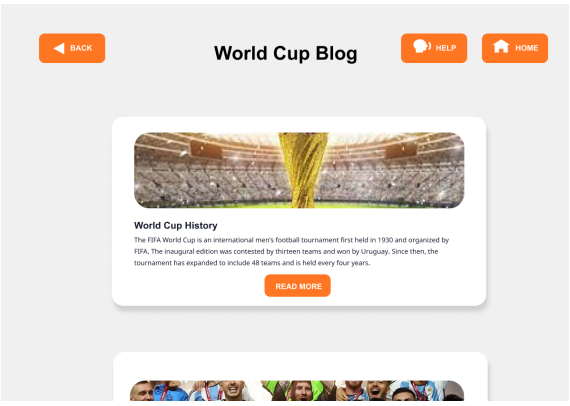

Fig. 5. Prototype - Blog page

5.2 Expert Interviews

To evaluate the design guidelines extracted from the literature search, three semi-structured interviews were conducted with experts in human-computer interaction, elderly health, and dementia care. The first interviewee is a lecturer from a well-known university in The Netherlands with more than 9 years of experience in human-computer interaction. The second interview was with a Vietnamese doctor with over 23 years of Alzheimer's care experience. The last interview involved a professor from a Malaysian university with more than 20 years of experience in clinical psychology and behavioral health of older adults in the healthy aging department. All interviews were conducted online through Zoom between 9th June and 20th June 2023. The duration of each interview ranged from 1 hour to 1.5 hours with voice recorded and received ethics approval (ID 230318) from the University of Twente's Ethics Committee. The questionnaire from the interview covers all categories of the design guidelines in Appendix A. The questions were used to measure the applicability of design principles for older adults with dementia and to validate specific design decisions. Furthermore, experts were also asked for feedback and suggestions to improve the design guidelines.

6 DISCUSSION

6.1 Overall evaluation

During the interview, experts were asked to evaluate the prototype from the perspective of older adults with dementia and rated it on a scale from strongly disagree (1) to strongly agree (5). The final results are summarized in Table 2. In general, it was observed that the prototype based on the proposed design guidelines is highly intuitive and easy to control and navigate. All interviewees agreed that the layout, colors, contrast, contents, and interactions are appropriate for elderly and dementia users. However, the overall assessment noted that several icons and visuals, such as the "Help" button, could not convey their intended functionality. The gerontologist also noted that pictures of recent events might be unfamiliar to recognize for dementia users.

Table 2. Overall evaluation

Interaction	HCI Expert	Dementia Expert	Gerontologist
Do you think the interface is intuitive?	4	4	4
Is it easy to navigate and interact with the prototype?	5	5	4
Do you think the prototype is enjoyable to use?	2	3	4
Do you think the interface of the prototype is visually appealing?	4	3	5

6.2 Interface evaluation

In general, all interviewees agreed on all interface choices according to design principles from the design guidelines. Regarding typography, although all experts agreed that typography is suitable, they

worried about the small font weights. The HCI expert recommended using font weights of at least 600 or bold. About the content, interviewees particularly emphasized the importance of breaking down content into smaller sections, using simple sentences and vocabulary, and compacting the information to improve comprehension for users with dementia. Although users might notice the minimum button size of 10x10mm, all experts agreed that this size should be avoided or bigger spacing between buttons is needed to prevent misclicks. They also agreed that a 20x20mm button size is ideal for users. For the use of pictures, dementia, and gerontology experts advised pictures should be familiar and relevant, preferably personalized to aid comprehension. Regarding the layout, while the HCI expert agreed that having 2-5 elements per page avoids overcrowding, dementia, and gerontology experts noted that people with dementia have trouble remembering recent items and situations. Therefore, they agreed that meaningful icons, text descriptions, and labels for buttons and images are more important. Regarding color choices, all experts agreed that "warm" colors like orange on a white background are better for button visibility than "cool" colors like blue or green. However, HCI experts advised against using shades of red as the primary theme color since they are overly bright or intense and cause overbearing on the eyes. Red is also generally associated with danger or emergency, which could confuse certain situations.

6.3 Functionality evaluation

According to all interviewees, certain popular features in touch-screen applications, such as hidden navigation bars, interactive tables, scroll bars, and drop-down menus, are too complicated. These features require precise motor control or familiarity with their behavior, making them difficult to use. On the other hand, simple and trivial elements like "Back", "Home", "Undo/Redo" and "Confirmation" options are recommended as they enhance usability. For sound and speech, all experts agreed on the hearing range and low-speed speech when using the voice feature. However, since dementia patients can not remember long content, they recommended keeping the speech short. The expert in dementia care also warned about the use of music. Although the expert confirmed that music is a great tool for relaxing and feeling comfortable, it should be chosen carefully to avoid irritation. Furthermore, all experts also recommended the customization feature. Although older users with dementia may struggle with complex configurations, dementia and gerontology experts suggested that caregivers or family members help with the setup to create a personalized and suitable environment. For the gamification features, while all experts agreed that gamification aspects could help dementia patients relax and practice memory, it should be simple, entertaining, and not put pressure on users.

6.4 Interaction evaluation

The interaction evaluation review the suitability of touch screen interactions for older adults with dementia. During the interview, experts were asked to rate each interaction from very easy (1) to very difficult (5). According to the design guidelines, there are six common types of interactions that touch screen application currently supports, namely: single touch, scroll, swipe, double touch, zoom & pinch, drag & drop. Table 3 summarizes the rating results.

Table 3. Interactions difficulty rating

Interaction	HCI Expert	Dementia Expert	Gerontologist
Single-touch	1	1	1
Scroll	2	2	2
Swipe	2	2	2
Double-touch	4	5	4
Zoom and pinch	4	4	3
Drag and drop	4	5	4

Based on expert opinions, single-touch, scroll, and swipe interactions are considered intuitive and familiar to all users, including elderly individuals with dementia. These interactions do not require complex movement or precision. Although HCI experts agreed that zooming and pinching gestures are also simple, he noticed that elderly users might not be familiar with them and noted that users only need to zoom in when content is too small or crowded. Dementia experts also confirmed that despite their unfamiliarity with touch screens and memory-related issues, users with dementia can still learn basic interactions with caregiver direction and daily practice. In the design guidelines, "eye-gaze" and "voice command" are new interactions mentioned. During the interview, experts in dementia care and gerontologist expressed enthusiasm that voice support would be highly convenient and could improve usability. However, the HCI expert mentioned that voice technology is still not fully developed to recognize all speech inputs accurately, and the frustration caused by fixing speech recognition errors may outweigh its benefits. Regarding eye-gaze control, although it has great potential for helping the use of technology, experts noted that most systems require wearable devices, which can be uncomfortable for older users with dementia.

6.5 Limitations

6.5.1 Scope of literature selection: It became apparent during the literature selection process that the design guidelines developed for this research could not cover all the articles and resources available in the field of designing applications for dementia care. There is a possibility of missing relevant studies that could have contributed valuable insights to the design guidelines. The search strategy and the exclusion criteria may also restrict the range of information considered in this research.

6.5.2 Coverage of Dementia characteristics: The design guidelines developed in this study aimed to address the challenges of older adults with dementia. However, dementia includes many subtypes and stages [3], each with unique characteristics and symptoms. As the disease progresses, the challenges and requirements of individuals with dementia may evolve and need further adaptation in the guidelines. While efforts were made to cover a broad understanding of dementia, certain symptoms or considerations of dementia might not be adequately addressed in the design guidelines. Therefore,

future works should focus more on developing specialized design guidelines that cater to the unique needs and challenges of different subtypes and stages of dementia.

6.5.3 Validation limitations: Due to a short duration of 10 weeks of research, only three interviews were conducted with experts in human-computer interaction, elderly health, and dementia care. While these interviews provided valuable insights and perspectives, the small sample size may limit the generalizability of the findings, and there might be potential bias in their responses and feedback. Additionally, since the evaluation is conducted with a low-fidelity prototype, certain design principles, such as light, voice command, and eye gaze could not be fully implemented and integrated into the prototype. Although the interviewer tried to demonstrate their functionality using pictures and GIF images, it might not have fully captured the user experience and features' intricacies in an actual application.

7 CONCLUSION AND FUTURE WORKS

This research proposes design guidelines for touchscreen applications dedicated to the unique needs and challenges faced by individuals with dementia and aging-related concerns. The final design guidelines lay a foundation for application developers, designers, usability specialists, and researchers to guide and review their touchscreen application design for older adults with dementia. By considering the unique characteristics and challenges of this user group, developers and designers not only provide a more inclusive, user-friendly experience and engagement for older adults with dementia but also supports their well-being, independence, and sense of connecting within society.

The first sub-research question was investigated during the literature reviews. Through the review of existing studies, many accessibility challenges are identified when designing applications for older adults with dementia. These challenges include cognitive impairments, reduced motor skills, visual and hearing impairments for older adults, difficulties in attention and concentration, and short-term memory deficits for dementia patients. Understanding and addressing these challenges is crucial for creating touchscreen applications for the targeted users. The answer to the second research question was conducted aligned with the main research question while creating the design guidelines. After a comprehensive literature search and selection process, 16 relevant articles were identified and extracted to create a total of 66 design principles for the design guidelines, which were further classified into three main categories: interface, functionality, and interaction. The resulting design guidelines provide comprehensive guidance on the visual appearance, structure, content, features, and touchscreen interactions that should be considered when developing touchscreen applications for older adults with dementia. They also cover the primary age-related and dementia challenges that can impact the usability and accessibility of users. To validate the effectiveness of the design guidelines, a low-fidelity prototype application was created based on the proposed guidelines. The design guidelines received positive evaluations and feedback from experts in the field of human-computer interaction, elderly health, and dementia care to confirm the effectiveness of the design guidelines.

For future works, there are several areas that need further investigation and improvement for the research. The first objective is to expand the scope of the research to include characteristics of each stage of dementia and provide deeper insights into their specific needs and challenges. Secondly, conducting user studies and gathering feedback directly from people with dementia and the elderly would offer valuable and more precise perspectives on the usability and effectiveness of the design guidelines. Furthermore, as technology advances, it is crucial to stay updated on emerging interaction techniques and explore their potential benefits for individuals with dementia. The design guidelines have mentioned eye-gaze control and voice command technologies as prime examples that would contribute to developing more inclusive and accessible applications for elderly users with dementia.

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A DESIGN GUIDELINES

Category	Design principles	Older Adults With Dementia Problems
	Interface	
Typography	• Large size and spacing (12px, optimal 16px) [12, 14–16, 20, 45, 73, 74, 76] • Spacing between buttons is between 3.2-12.5mm [12, 15, 16, 73, 76, 77] • Font weight should be bold or 600 • Font style [15, 16, 20, 74, 76]. : Sans Serif is best, Arial, Helvetica, Century Gothic, Serif, Times, Bookman, Book Antigua	• Impaired near focus, eyesight reduce [14, 15] • Increase spacing will lower the performance error rate when clicking on an object due to the user's motor impairment [20, 45, 77]
Content	• Images, pictures, and videos are recommended [74], especially personalized ones, but should be carefully chosen to not cause distraction or irritation [15, 45, 73, 76] • Icons and symbols should be familiar, meaningful, and simple. Examples: The use of the thumb-up icon as agreeing [45, 72, 74, 78]	• Due to issues with recent memory, everything should be intuitive and relevant to avoid recalling, remembering [20] • For people with dementia, since their long-term memory is not affected, using pictures and videos from the past can help them understand and interact more easily. [45]
	• Use short sentences and simple wording [45, 73, 74, 78] • Break down the big paragraph into smaller pieces of information • Avoid flashing light, rapid, moving text, motion [13, 14, 20, 73, 74]	• Due to visual impairment, break down the big paragraph into smaller pieces with spacing between them to make it easier to follow [20] • People with dementia have trouble reading long texts. The long text makes users tired and demotivated to read, reducing the load on their memory. It also makes it hard to focus [15, 45, 74] • Fancy text makes it harder for older people to read and understand the content. Older people also have difficulty adjusting to rapidly changing visual stimuli and get distracted [14, 15]
	• Avoid abbreviations and symbols without a text explanation [74] • Give simple examples whenever possible [74]	• Users with dementia can be easily frustrated or demotivated when they have to guess things. Therefore, content should always be clear to support the understanding of users. [20]
Item, object	• Size of objects [13, 14, 16, 45, 74, 78] text optimally should be at least 20x20mm [16, 77] for the best finger selection. The minimum size can be 10x10mm but needs large spacing • Spacing between buttons [12, 15, 16, 73] should be between 3.2-12.5mm [16, 74, 76, 77]	• Large spacing size of object, the item helps with vision issues and reduces error performance when interacting with. [16, 77]

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Category	Design principles	Older Adults With Dementia Problems
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	• Provide captions for images, icons, symbols [14, 20, 45, 74] • Icon, label for objects should be familiar and simple [45, 72, 73]	• Meaningful items or object descriptions help users better understand their functionality and prevent unnecessary recall. [20]
Layout structure	• Keep only 2-5 components per page [12, 13, 16, 45, 73, 74, 79]	• Reduce the number of contents that users have to remember and not get overwhelmed [15] • It also makes the screen less cluttered [16].
	• Consistent layout. Examples: Main navigation should be placed identically on all "pages", Warning, success, and instruction should format consistently [12–14, 45, 73, 76, 78, 79]	• Make it easier for users to form an appropriate mental model, and the structure of the application and cause less confusion [78, 79]
	• Important information should be placed in a noticeable location or displayed as a popup message to gain the attention of users [45] • Should be large, highlighted, uncrowded (Upper case is recommended) [14, 73, 74, 76]	
	• Avoid distraction layout [45] • Deep navigation hierarchies [45, 73, 74, 76] • Hidden elements and popups [45, 76]	• Deep hierarchies and hidden elements make people with dementia harder to remember (mnemonic problems) [45, 72, 76]
Colors	• High contrast (50:1). Make use of the black font on a white background or the reverse [13, 14, 16, 45, 73, 74, 76, 78, 79] • Colour choices should be in the long-wavelength end of the spectrum (“warm” colors) [14, 79] • If “cool” colors are used Example: pastel color need high contrast background [14, 79] • Avoid combinations of desaturated colors – Ex: red/purple and green/blue. [14, 20, 74, 79]	• To adapt the user’s potential color or contrast sensitivity impairments [20] • Older people prefer warm colors to cool colors [14]. Colors with a Purple-Blue-Green range make it difficult to perceive [14].
Functionality		
Feature Design	• Avoid functions that need to be remembered or have too many numbers of possible actions. Example: Remember the password to open things	• People with dementia have trouble with short-term memory. Although functions to help users practice memory are encouraged, functions that require remembering a sequence of actions to perform or where there are so many actions can be annoying for people with dementia.
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Category	Design principles	Older Adults With Dementia Problems
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	• Avoid scroll bar [16, 20, 73, 76] • Avoid drop-down menu [12, 13, 20, 73, 74, 76] • Avoid slide keyboard [12, 74] • Avoid interactive table and list [16] • Avoid timeout actions [20]	• Older users find the scroll bar, dropdown menu, interactive table, and list particularly difficult to use because of small buttons and complex interactions [16, 20, 73]
	• Functionality of the same type should be grouped together [12, 16, 45, 78]	• Improve consistency and reduce memory load [45]
Light	• Use appropriate illumination [13, 14] • Brightness should be adjustable [16] • Avoid glare and rapid changes in brightness [20]	• Sensitivity to glare, reduced acuity [14, 20]
Sound, speech	• A slower pace of speech around 140 wpm [14, 76] • Lower frequency tones (in the 500-1500 Hz range). Therefore, a male voice is easier to follow because of the overall lower pitch [13, 14, 20, 74, 76] • Avoid high pitch sound over 2500 Hz [13, 14, 20, 76] • Intensity: 60dB [76] • The tone should be respectful, clear and avoid robotic, synthesized tone [14] • Use short sentences and pause [14, 74] • Avoid long speech, it should only be 3-5 simple sentences [12, 14, 20]	• Low-level sounds are muffled. 25% loss in ability to perceive normally audible speech by age 60 [20] • Words with high-pitched consonants (c, ch, f, s, sh, and z) are more difficult to comprehend [14, 20] • Long speech with advanced words leads to problems in remembering and understanding speech, especially important for dementia people with cognitive impairments [14, 74]
	• Music could be good [45] for relaxing but should be carefully chosen [74]	• Music has proven to have many positive effects on people suffering from dementia. It can be stimulating physically, psychically, socially, cognitively, and spiritually [45]. However, inappropriate music can cause distraction and irritation for people with dementia [74]
Gamification Features	• Always provide positive feedback [45, 70, 74] • Avoid right or wrong features • Avoid timeout actions [20] • Show the progress bar [15] and provide positive feedback • Game should be simple, fun, and should not improve the difficulty level	• Since the mood and behavior of dementia patients are uncertain, irritating options, feedback can easily cause them to feel demotivated, rushed, and annoyed. Gamification features should only be fun and relaxing for users with dementia. • Progress bar is intuitive encouragement to complete tasks and reduce memory load to remember progress.
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Category	Design principles	Older Adults With Dementia Problems
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Help Feature	• A "Support" button is needed [12, 15, 20, 73] • However, avoid full-screen help but a short pop-up with an indication or audio is better	• Help options are an important function that provides context information about the current feature or event when a user is unable to progress.
	• Contextual help, feedback, provide cues to convey information. Example: Make a short banner above the page to instruct users or a reminder [13–15, 20, 73, 74, 79]	• At a later stage, people with dementia can easily forget their routine and become demotivated. Therefore, reminders and additional information are a good way to inform them and keep them using the applications [45, 74]
Error Prevent Feature	• Confirmations of actions and errors [13, 15, 20, 73, 74] • Undo/redo option [14, 20, 45, 73, 74]	• People with dementia are more disrupted by errors; they may benefit if the application has the option to compensate for that [20]
Optional Suggested Features	• Autocomplete and grammatical detection for text input [74]	
	• Customization. Example: color, contrast, font type, size [14, 73, 74, 78]	• The application should make it as easy as possible to adapt the GUI, difficulty, and sound volume to the user's current ability and preference.
	• Show the progress bar [15] and provide positive feedback	• People with dementia and the elderly have trouble keeping track of their progress and need intuitive encouragement to complete tasks
	• A button to return to the home page and "Back" button [12, 74, 76, 79]	• Home screen provides them a sense of control over navigation and helps them understand the mental model of the application • A back button is reported as the most used button [76] and helps users when they get lost [74]
Interactions		
Suitable interaction	• Swipe and scroll [16, 71, 79]	• The swipe and scroll are common gestures for navigation and are familiar to users. However, progress or location tracking should be visible when navigating [16, 71]
	• Single touch [13, 20, 70, 71, 79]	• Single touch is the most intuitive and familiar interaction for older adults and people with dementia to use [13, 20, 70, 79].
Avoid interactions	• Double touch [13, 16, 20, 73, 76, 79]	• Double touch is not intuitive and can cause confusion with single-touch [15, 76].
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Category	Design principles	Older Adults With Dementia Problems
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	• Drag and drop [12, 71, 79]	• Drag and drop require holding the object and a precise place in the correct location, which is not suitable for older adults [70, 71].
	• Zoom and pinch [15, 71, 79]	• Researchers show older adults having problems with zoom and pinch, and content should be in the proper size or can be customized in the setting [71].
	• Parallel or combined interactions [13, 20, 45, 70, 71]	• Parallel or combined interactions normally require complex motor and psychomotor skills, which are not suitable for older adults [13].
Optional suggested interactions	• Voice command to navigate and perform an action, Speech-to-text [13, 15, 45, 76–78]	• Voice input was also identified as an improvement to minimize the need for keyboard text input and prevent errors from typing. Older adults are observed to have limited typing skills [20].
	• Eye Gaze [15, 16, 71]	• Eye command would accommodate motor difficulties associated with aging such as arthritis or tremble [16].