Older Adults and Technology Design from the HCI Perspective

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***Abstract*—Older adults are an important segment in all societies worldwide, and this category of users cannot be ignored, considering technological progress, especially in the proliferation of smartphone applications. The expected growth in this age group in the following years, specifically in some developing countries, will present interaction challenges and opportunities in several areas for both older adult users and smartphone application designers. The main purpose of this review study is to create a better understanding of such a group from different angles and to identify this group of users from the perspective of the Human-Computer Interaction field, as well as explore current and future challenges to build a solid literature review emphasizing findings from HCI and human sciences. This literature review concludes with current and future trends to help address technology designs and older adults' characteristics and needs.**

Keywords*—*Older adults; HCI; smartphone applications; human science; technology design; older adults challenges

I. Introduction

In 2020, there was a notable acceleration in older adults in the population, even faster than in the group of children aged between 0 and 5 [1]. According to the United Nations (2021) [2] and the World Health Organization (2018) [3], developing countries expect a demographic change in their population due to the growing number of older adults. Statistically, they expect a fast increment in the older adult population to reach 1.4 and 2.1 billion by 2030 and 2050, respectively. Furthermore, the United Nations expects older adults to make up a quarter of the global population by 2060 [4]. This will generate new challenges and opportunities for older adults in the upcoming years in various aspects of life, such as healthcare, migration, employment, and social systems [5].

Based on various scientific papers and societies, the group of people aged 65 and above are categorized under numerous terms, such as "elders" or "elderlies", "seniors", "older", or "aged". This study has adopted the term "Older Adults" due to the wide use of this expression in most authorities (e.g., the American Medical Association, American Psychological Association, Associated Press, Gerontological Society of America) [6], National Institute on Aging [7], Saudi General Authority of Statistics [8], and Saudi Ministry of Health [9].

The age range of the group of older adults is either diverse across studies, however, the common criterion is the chronological age starting from 60 to 65 and older [10], [11]. Although there are many philosophies to specify accurate age range, this study follows government agencies and gerontology studies that specify that individuals who are 65 and above are "Older Adults".

The older adult population is heterogeneous groups in most societies [12], [13], [14], who have special needs and preferences in designing technology features compared to other society groups [15], while they were counted as heterogeneity under consideration in other studies [16].

Schwaba and Bleidorn [17] discussed that personality trait development, particularly in old age, tends to show increased individual differences compared to earlier life stages, as physical, cognitive, and social changes contribute to greater personality variability. In addition, aging reduces the stability rate of personality traits, leading to more pronounced individual differences in personality change during this stage of life.

The purpose of this literature review study is to represent the importance and the need for technology design for the population of older adults from the HCI perspective, as well as to identify current gaps, limitations, and future work across related papers in this field. The structure of this study starts with an introduction, the personal and technological challenges that older adults face when using technologies, related work (including facilitators for overcoming these challenges and barriers), a discussion, a conclusion and future work.

II. Older Adults' Challenges and Barriers

This study divides the challenges and barriers that older adults face when interacting with technology into: 1) personal challenges to using technology, including cognitive, physical, sensory, social, and emotional impairments; and 2) technological challenges that include digital divide and usability concerns; physical, cognitive barriers, privacy and security concerns; lack of support and training; and interoperability and technical issues, as shown in Fig. 1.

A. Personal Challenges

Aging may result in a decline in cognitive, physical, and visual skills [12]. This explains that the change of skills in older adults is related to various personal challenges, such as age-related cognitive decline, sensory impairment, lack of technological familiarity and experience, technology anxiety, health-related issues, and motivational barriers.

1) Cognitive Impairments: Cognitive impairment refers to the fact that at least one or more cognitive domains that interfere with an individual's autonomy in everyday activities,

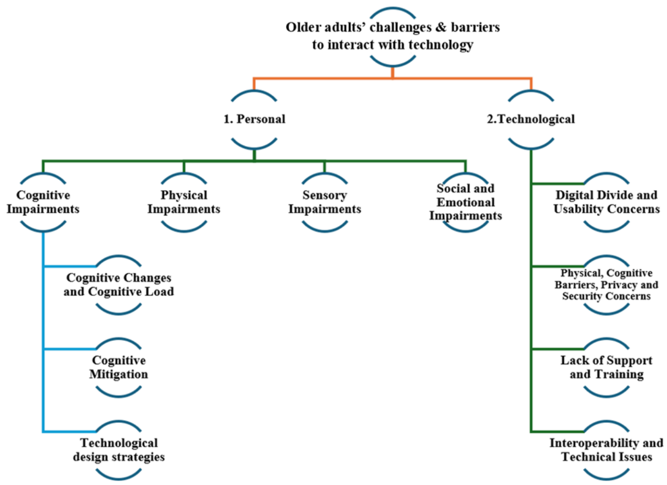

Fig. 1. The challenges and barriers for older adults to interact with technology.

which negatively affect older adults to varying degrees due to various causes [18], [19]. Cognition is considered as one of the most significant aging barriers influencing technology usage [20]. According to Salthouse [21], the change in cognition is continuously increasing to reach a peak in adulthood and shifts to decrease negatively at older ages, specifically at the age of 60 and above.

Cognitive functions and attention are the most strongly linked and affected by aging, in addition to memory [22]. Although not all cognitive decline leads to disability, individuals can experience varying degrees of declining across different domains of memory and attention [23]. According to Salthouse [24], cognitive decline typically accelerates in middle adulthood, around the 40s and 50s, with memory decline often becoming more noticeable by the late 50s or early 60s, depending on health factors for individuals. Therefore, their ability to use technology is negatively affected [25].

Memory decline and attention issues across the human lifespan are complex and multifaceted processes [26]. Aging leads to declining certain types of memory, while some brain changes may serve a compensatory function. Compared to younger adults, these memory changes can be obvious in some cognitive tasks [27]. Thus, while cognitive ability changes are closely linked to the aging process, it is important to note that aging does not necessarily equate to disability [28], [29]. Memory decline is one of the abilities that typically starts to change later in life [22]. Cognitive changes, such as slower processing speed and attention difficulties, can impact older adults' ability to perform tasks requiring focused interactions with technology interfaces, like using smart devices or electronic services.

2) Physical Impairments: There is a great urgency to discuss the challenges facing older adults in the field of technology, and this indicates the importance of researchers shedding a great deal of light on understanding the roots of the challenges and problems associated with the stage of aging process and understanding them appropriately. Physical degradation is one of the most important concepts accompanying aging, where most symptoms appear clearly. Older adults engage with digital systems and devices. Gao et al. [30] have shown that the physical impairment rate notably increases with age, specifically at 80 and above, causing a decline in their physical functions. Thus, it is important to understand older adults' challenges, the usefulness of physical activities, and thoughtful design considerations to address their physical impairments through HCI. This will effectively support researchers and technology designers to create new, effective, supportive technologies that can improve older adults' quality of life.

3) Sensory Impairments: Age is commonly accompanied by declining sensory functions, such as vision and hearing, or dual sensory impairments (hearing and vision together), that pose challenges for older adults to live independently, with good cognitive health, and to have a decent quality of life [31], [32], [33]. These sensory impairments are frequently found among the group of older adults in most societies. According to Völter et al. [34], nearly 40 per cent of individuals who are between 70 and 79 years old may suffer dysfunction in at least one sense, while more than 25 per cent are facing deficits of multiple senses. In addition, 30 per cent of females and 50 per cent of males at the age of 65 may have less social interaction due to severe hearing loss [35].

Regarding visual degradation, presbyopia (when older adults find it difficult to focus on close objects), decreased sensitivity to contrast, and diminished color discrimination are common age-related changes [36]. As a result, older adults may face difficulties in their daily activities, such as reading, driving vehicles, and recognizing facial features [36]. Similarly, with hearing degradation (hearing loss or presbycusis), aging is related to hearing high-frequency sounds, understanding speech in noisy environments, and localizing sound sources that are difficult for older adults [36]. These auditory changes can lead to communication and social interaction challenges for older adults [36].

User interface design features, such as small fonts, low-contrast color schemes, and complex navigation, can cause difficulties for older adult users with visual impairment in interacting with digital interfaces [37]. Similarly, non-adjustable audio cues might be ineffective for those with hearing loss impairment [38]. Thus, HCI research has been instrumental in addressing these issues to help older adults meet these challenges, such as developing user interface design principles and adding features that fill the gaps in the capabilities of this segment of the population. For instance, implementing large-text size, high-contrast color schemes, and simplifying interface layouts can improve readability and navigation for users with visual impairments [39]. Likewise, providing adjustable volume controls and visual alternatives to auditory information to accommodate users with hearing impairments [40]. According to Macík et al. [41], the user modeling approach can help to provide personalized care and accessible technology interaction, especially for visually impaired older adults. In addition, in order to make technology more accessible to older adults with sensory deficits, it can be useful to develop interactive systems that can utilize physical objects (that users can touch, grasp, or manipulate) to represent digital information, namely "The Memories Chest" using Tangible User Interfaces (TUIs) [42]. Furthermore, designing clear visual cues and implanting easily identifiable interactive elements can effectively aid users with dual sensory impairments [43].

Vacher et al. [44] discussed the importance of simplifying user interfaces for older adults as they commonly suffer from visual, physical, and cognition impairments. As audio is a modality of choice for communication for individuals without hearing impairments, worldwide older adults might also be able to benefit from the added accessibility that is provided by a voice user interface (VUI). For example, voice searching tool helps to simplify access to information, improve accessibility, and reduce some related challenges (e.g., generating and typing queries), particularly for older adults with mobility and vision impairments [45].

Some studies have involved a multidisciplinary approach integrating various technologies and strategies to help older adults with sensory impairments overcome related challenges. For example, a review paper by Haanes [33] discussed the efficacy of the multidisciplinary intervention for older adults with sensory impairments. Results indicated that assistive technology-based medicine, exercise programs, and cognitive strategies can manage and prevent sensory impairments. Dual sensory impairment in older adults may reduce social communication and sense of well-being that can, therefore, increase the likelihood of social isolation, depression, decreased independence, mortality, and cognitive impairment [46]. Since older adults with dual sensory impairments are at high risk of cognitive decline and dementia, a scope review study by Dumassais et al. [32] categorized strategies to evaluate cognition of older adults with dual sensory impairment into five main categories, namely the assistance of experts, the modification of standardized test scoring procedures, the use of communication strategies, environmental modifications, and the use of cognitive tests.

While older adults often experience auditory degradation that might affect their ability to process information effectively, HCI research seeks to explore various assistant methods to help older adults with auditory degradation through understanding and compensating for age-related auditory processing challenges. Auditory interfaces and information retention may participate to overcome these related challenges. For example, a study by Lin and Hung [47] explored the effectiveness of different auditory presentations and sound orientations and how they could affect older adults' retention of healthcare information. The study involved 18 young university students (control group) and 20 older adults aged 65 and over. Results showed that although older adults had lower recall performance in comparison to younger adults, combining narration and earcon presentation (auditory icons) was preferred by both groups and significantly improved recall. Auditory training techniques can improve working memory, attention, and communication in older adults with hearing loss [48]. The study findings demonstrated an improvement in self-reported hearing, speech perception, and cognitive tasks. These outcome measures are associated with executive functions, highlighting the crucial role of cognitive abilities in improving communication, particularly for individuals with hearing loss.

Understanding age-related compensation mechanisms can inform the development of more effective auditory assistance technologies. Anderson et al. [49] state that older adults characteristically easily comprehend speech in quiet environments. Compared to younger adults, they experience more difficulty understanding speech when the signal is degraded. In addition, this difficulty increase might be partly due to age-related deficits in temporal processing and/or high-frequency hearing loss. This can affect individuals with normal or near-normal hearing thresholds within the speech frequency range.

Improving and supporting the auditory needs of older adults can reduce auditory degradation by enhancing auditory rehabilitation and cognitive training methods. The effectiveness of auditory and cognitive training programs (e.g. auditory-cognitive training, auditory training, and cognitive training) on both auditory ability and cognitive functions for older adults has been investigated by Kawata et al. [50]. It was found that these technology-based training methods can improve the plasticity of their brain and cognitive functions and performance, specifically in healthy older adults. In addition, both factors, auditory and cognitive training, might be useful to improve the quality of life of older adults. From different perspectives, music-based auditory training has been used to improve auditory function and cognitive abilities for older adults with impairments of hearing loss and mild cognitive [51]. This training program was designed to include activities such as singing, playing instruments, and music discrimination games. Moreover, hearing aid treatment can lead to reducing older adults' hearing loss disability as well as improve hearing function and immediate memory [52]. Additionally, hearing loss impairment is significantly related to neural effects in the brain, including executive functioning and speech processing. Furthermore, auditory rehabilitation programs are mainly designed for hearing aid users. Lai et al. [53] examined the effectiveness of the auditory training program (Listening and Communication Enhancement) on the auditory and cognitive abilities of older adults, specifically including older adult users without hearing aids. Auditory training has proven its role in improving communication ability in older adults. However, there was no significant impact on their short-term memory or attention.

Since auditory degradation can impact older adults' quality of life and their communication abilities, it is necessary for application designers to understand the auditory and cognitive challenges they may face. For instance, peripheral hearing and auditory processing can affect older adults' ability to understand speech, especially in noisy environments [54]. In addition, a review paper by Windle et al. [55] investigated the factors related to auditory processing and cognition that possibly influence setting hearing aids for normal aging older adults. The study found that distortion to the speech envelope cues (e.g. compression speed and compression ratio) must be considered when setting hearing aids to improve their effectiveness. Thus, hearing aids should be set professionally to assist older adults with hearing impairments.

4) Social and Emotional Impairments: Older adults usually live lonely, and according to the U.S. Centers for Disease Control [56], the risk of loneliness in older adults aged 65 and over is highly related to social isolation. In addition, this frequent family members' absence may cause emotional loneliness, leading to feelings of solitude and seeking companionship through technological support [57].

B. Technological Challenges

Since electronic and mobile services are growing digitally among worldwide societies, it is important to pay more attention to research addressing issues related to this dynamic topic. Older adults are part of these societies who face various challenges when using technology, including the digital divide and usability concerns, perceptual issues, limited technological literacy, and adaptability challenges. Such barriers can affect their ability to effectively engage with digital tools and services, highlighting the need for tailored solutions that address these needs. From the perspective of technological challenges for older adult users, technological challenges may hinder their abilities to fully benefit from advancements in technology that stem from the technology design and the specific needs and abilities of this kind of user.

1) Digital Divide and Usability Concerns: Technology literacy plays a critical role in increasing technology use and adoption. Due to low technology literacy and usability issues, older adults often experience a digital divide. Although many older adults are enthusiastic about learning and adopting new technologies in order to maintain independence and improve their quality of life, many technologies are not designed with older adults in mind, which can lead to frustrations and limitations in use [58]. What distinguishes the elderly group from other groups is that they have different and unique needs and interests [59]. Thus, technology designers must consider these dynamic needs to help this population category [59].

2) Physical, Cognitive Barriers, Privacy and Security Concerns: One of the most common challenges among older adults is physical challenges, where age is the most closely related factor. According to Wang et al. [60] and Shandilya et al. [61], these challenges, such as reduced dexterity and vision, and cognitive decline, can majorly cause difficulty for them to adopt and use new technologies effectively. As well as AI-enabled products can attract older adults. However, the lack of learning avenues, privacy concerns, and the impact of decision-making can clearly highlight the need for inclusive, secure, and controllable technology design. Furthermore, older adults with limited hand dexterity or motor impairments suffer from interacting or communicating with technologies effectively [62].

3) Lack of Support and Training: Older adults' confidence and ability to use technology independently can be influenced by ten factors: value, usability, affordability, accessibility, technical support, social support, emotion, independence, experience, and confidence [63].

4) Interoperability and Technical Issues: Although wearable sensors and IoT-based devices proved their capability to address older adults' independent living issues, the main challenges for them are related to interoperability issues, inaccurate sensors, and power limitations (e.g., low usability, battery issues, and lack of interoperability) [64]. These challenges can restrict their effectiveness and user satisfaction. For example, most wearable and IoT technologies for healthcare services are non-scalable, siloed systems, and designed for a specificity use case. This can limit their integration and application into existing systems [64].

III. Related Work: Facilitators for Overcoming Challenges

1) Cognitive Mitigation: Furthermore, certain strategies, such as personalized online lifestyle interventions, including exercise and cognitive training, can help mitigate cognition decline in older adults [65], [66]. HCI research addresses different issues and challenges related to older adult users, such as memory impairments or attention issues. Thus, understanding these cognitive changes is essential for designing interfaces that can accommodate the unique needs of older adult users [67], since designing computer hardware and software is a main concern of human-computer interaction. Technology products should not ignore older adults' needs and support them as a part of society [25], and technology designers can be essential to improve the quality of life for older adults [68]. As older adults' needs are distinctive (e.g., prioritize health monitoring and emergency alarms), technology designers should not ignore them [69]. Thus, technology interfaces must be age-friendly to minimize cognitive load and support tasks requiring memory and attention [70].

Icon design, for example, Skeuomorphism (realistic) versus Flat Icons, studies highlighted that younger adults who are familiar with graphical user interface perform better with flat icons. Unlike older adults, they perform better with skeuomorphic, concrete icons that improve usefulness and reduce the cognitive load of older users [71]. Additionally, the study validated the effectiveness of concrete icons with older adults, as they prefer icons that present icon functions visually. Furthermore, Chen and Liu [72] investigated the usefulness of different features in designing daily living technology product interfaces (e.g., television controllers and electric rice cookers) to minimize older adults' cognitive load, such as less complexity, number of control functions and buttons, text size, and direct operation and voice control. An extended study by Chen et al. [73] agreed that complex interface is a serious challenge among older adults, more specifically those with mild cognitive impairment or dementia. The experiment used a programmed interface that records participants' time to complete tasks, operation errors, and tap locations. Results indicated that usability can be improved by considering the simplicity of designing (e.g., in operating procedures, reducing the number of functions and buttons, and enlarging text and buttons). This has supported their ability to respond faster and more accurately than their initial actions.

The role of smartphones and tablets in assisting the cognition of elderly people has emerged in many ways. Smartphones and tablets are effective technologies and tools that assist in improving cognitive function in older adults who do and do not suffer from cognitive impairment, particularly in processing speed and executive function, and also serve as a memory support solution for those with health problems [74]. In addition, good user experience, improved cognitive abilities, and enhanced daily life for older adults can be achieved by well-designed applications, such as a training working memory application that considers training content, motivation, emotion, interaction, current state, and experience [75]. Furthermore, Acosta et al. [76] have stimulated cognitive functions (e.g., attention, memory, reasoning, planning, language, and perception) by developing cognitive stimulation software for older adults in order to improve usability and user experience. The study [77] has provided a comprehensive understanding of smartphones and tablets' effectiveness and efficiency by evaluating cognitive intervention technologies' usability and user experience for older adults with mild cognitive impairment or dementia. This was achieved by collecting objective data (e.g., task completion rates and error counts) and subjective data (user feedback through questionnaires, interviews, and behavioral observations). As a result, 60 per cent of older adults with cognitive impairment were able to complete tasks, and 45 per cent required more time, while 40 per cent needed assistance.

Assistive technologies can support the cognitive impairment of older adults. Belkacem [78] addressed how assistive non-invasive Brain-Computer interface (BCI) applications (e.g., controlling devices like exoskeletons, wheelchairs, and smart homes) improve the impairment of cognitive decline and motor control for older adults and elderly patients, which can lead to improving their quality of life. The advantages of such technologies were seen due to their high accuracy, minimal daily setup, rapid response times, and multi-functionality. In addition, this study cited two papers that addressed related issues [79], [80]. Both experiment studies discussed memory impairment by using BCI and cognitive tests to improve memory and attention among elderly patients. Lee et al. [79] involved participants in playing a card-matching game and command control. In contrast, Gomez-Pilar et al. [80] used imagining hand movements, where both studies resulted in memory and cognitive function enhancement. Virtual Reality-based training, furthermore, was used by Liao et al. [81] and significantly improved physical and cognitive function, instrumental activities of daily living (IADL), and neural efficiency in older adults with mild cognitive impairment. This experiment significantly improved global cognition, verbal memory, and IADL by p¡0.001, delayed recall, p=0.002, and p¡0.001 after the intervention, respectively. In addition, the PRISM-CI system, proposed by Czaja and Ross [82], has proven the ability of technological applications to improve independence and quality of life for older adults with cognitive impairments. It can support their information, resource access, and social and cognitive engagement.

According to an experimental study by Tsai et al. [83], prospective memory declines with age and is considered a challenge for most older adults. The study found that external reminders as a cognitive offloading strategy effectively mitigate memory challenges. Results showed that, compared to younger adults, older adults used more reminders with a reduced preference for them. ENCODER, proposed by Shin et al. [84], has been developed by multidisciplinary human-centered perspectives to support older adults' prospective memory, promoting self-determination and daily activities. The prospective memory has been discovered to be a critical predictor of the functional independence in name of the older adults with objective indicators of the prospective memory performance having a convincing relationship to the degree to which daily activities might be executed with no supplementary support [85].

2) Technological Design Strategies: Effective technology design guidelines additionally contributed to supporting older adults' cognitive impairment. According to Zhu et al. [75], a better understanding of older adults' psychological and physiological characteristics led to designing mobile training applications and improving their working memory and user experience. This study concluded that daily practice, challenge modes, level-by-level difficulty selection, novice teaching, practice modes, sharing functions, two-player modes, ranking, and desktop components are effective design strategies for cognitive training applications. Technology designers and developers should consider older adults' needs for user-friendly interfaces, optimized portable devices, and personalized training program capability to overcome this population's cognitive impairments [86].

VUIs can improve user-technology interaction because they use natural language processing, which makes complex graphical interfaces easier to use, especially for older adults with mild cognitive impairments [87].

The ability of older adults to navigate user interfaces on digital devices is influenced by increasing cognitive impairments. Despite the high adoption of smartphones by seniors, new challenges have emerged, especially for this age group, due to the high interaction requirements and the ever-changing design patterns in various applications [88]. The study highlighted the usability challenges for older adults navigating various interfaces. The applied usability test and qualitative study made it difficult for older adults to understand and interact with icons, and assistance was needed. Besides, content-oriented navigation was more effective for older adults than menus and buttons. Similarly, Leung et. al. [89] discussed three main factors influencing icon usability: 1) user-Related Characteristics (including intelligence, experience, and user culture), 2) context of Icon Usage (mobile device capabilities, task requirements, and software application interface), and 3) visual Characteristics (animation, spacing, size, concreteness, and visual complexity). In addition, it is more challenging for older adults to use mobile device icons than for younger ones due to demographic differences. It was hard for older adults to interpret icon meanings and identify icon objects, as younger adults were better to so. The study highlighted that icon usability for older adults can be improved by designing icons with respect to semantically close meanings, familiar objects, labels, and concrete representations. As well as this will also lead to designing age-friendly mobile device interfaces in order to improve the quality of life for older adults. Furthermore, user interface design guidelines and checklists in relation to phones and smartphone features were suggested to improve older adults' usability [90]. It also discussed the relationship between mobile phone design for older adults and cognitive function through menu structure, function naming, and screen properties. For instance, older adults usually have cognitive slowing, which makes them feel stressed with a deeper menu structure, and considering the simplicity and flattened menu structure may support decision-making.

3) Content-Oriented Navigation: Li and Luximon [91] found that the performance of older adults was clearly better with designs of content-oriented navigation. In addition, they found this design approach easier to understand and interact with than traditional menu-based systems, especially for mobile interfaces. Moreover, as it is less complicated, it helps older adults avoid struggling with menus and buttons, and reduces the cognitive load required to understand and interact with digital interfaces, making electronic services easier for older adults to use. Content-oriented navigation helps facilitate digital engagement [92]. It assists users in focusing on content rather than complex navigation structures. As a result, older adults are more likely to engage with digital services. Furthermore, it helps overcome barriers like a lack of digital literacy and users' confidence, which are common among the older adult community [93]. The study found that older adults prefer smartphones and computers and value personalization and access to credible information in HITs, but they have concerns about data privacy and security. Strategies like co-design, digital navigators, and education materials can enhance the adoption and efficacy of HITs for older adults.

4) Design for Dynamic Diversity (DDD): DDD is an approach that involves creating interfaces that adapt to the changing older adults' abilities, accommodating memory, cognitive, and visual impairments [25].

5) Elderly-Friendly Mobile Applications: Previous related works recommended designing interfaces that mainly consider some features, such as perceptual, motor, and cognitive challenges, and incorporating persuasive features (e.g., reminders and personalized interventions) to enhance engagement effectively [94].

6) Voice User Interfaces (VUIs): Compared to visual interfaces, VUIs offer more accessibility for older adults with visual impairments and support their inclusive education and daily activities by providing an auditory method of interaction [95]. Furthermore, VUI enables hands-free interaction, which improves usability [96], [97]. Leveraging natural language interaction, in addition, VUIs helped significantly simplify the use of technology for older adults by focusing on ease of use and addressing critical non-functional requirements like social connectedness and psychological well-being [98]. In order to effectively support older adults in digital technology usage, designing such a simple and adaptable interface and considering sensory and cognitive limitations is critical. However, implementing content-oriented navigation, customization settings, and voice interfaces has improved usability and adoption among older users. The results of such strategies were limited to enhancing user experience and promoting healthy aging by facilitating access to digital services.

IV. Discussion

The population of older adults continues to grow globally, which highlights the urgent need to address challenges (e.g. the complex and varied experiences) they face when interacting with technology. Although the literature consistently identifies personal challenges (e.g cognitive decline, sensory impairments, and reduced motor abilities), it fails to account for subgroup differences within the population of older adults, namely young-old (60 to 69), mid-old (70 to 79), and old-old (80+) [99]. There is a significant difference between each subgroup in regard to their characteristics, including cognitive functionality, physical capacity, and technological adaptability. However, it is notable that there is a lack of current technology designs that reflect this diversity, which results in insufficient generic technological solutions to serve all users.

Technological challenges that include non-intuitive interfaces, small text, visual clutter, and the demand for high dexterity disproportionately are more likely to affect older adults, specifically the mid- and old-old groups, which exacerbate usability issues. Previous related works have addressed this topic by proposing several solutions, for instance, user-friendly design, inclusive interface development, accessibility improvements, and digital training programs. However, these studies generalized this population, which ignores the differentiate design practices based on the needs of subgroups or the level of impairments. Furthermore, existing literature emphasized the value of inclusive design principles; however, there is limited practical application of adaptive systems that dynamically adjust to the cognitive and physical capabilities of users. VUIs are a potentially transformative tool that can reduce the complexity of technology interaction remain significantly underutilized in this domain. Some studies have involved this technology as an assistive tool; however, a few have assessed the actual effectiveness or adoption of VUIs among subgroups of older adults. Moreover, age segmentation or contextual variability has not been considerable sufficiently in the designs for many facilitators in the literature (e.g community learning, family involvement, and professional tech support), which leads to a lack of users' personalization. The need of further investigation is highly recommended based on the lack of studies addressing the specific needs of older adult subgroups. These needs are particularly regarding impairment-sensitive designs and emotional barriers to the use of technology (e.g fear of loss of human interaction and concerns about security). Previous studies, additionally, are constrained by small culturally homogeneous samples that do not reflect broader or global aging populations or consider gender diversity. Thus, future research and technology designs should expand these limitations beyond one-size-fits-all models and prioritize inclusive and adaptive approaches. In order to promote sustained engagement and improved quality of life among older adults, account for subgroup variability, integrate VUIs and other assistive technologies, and address the challenges of perception and emotion.

V. Conclusion and Future Work

Older adults face several personal and technological challenges, where understanding and addressing the complex interplay of these challenges is essential to develop inclusive digital solutions. In this group of people, it is common to encounter barriers such as cognitive decline, sensory impairments, reduced motor control, and low digital literacy. Furthermore, older adults frequently encounter barriers such as cognitive decline, sensory impairments, reduced motor control, and low digital literacy, which significantly affect their ability to engage with modern technologies. Meanwhile, the technological design of the majority of digital tools often exacerbates these challenges. For example, small text, cluttered layouts, poor accessibility features, and non-intuitive interfaces mostly fail to accommodate their needs.

The tendency to treat older adults as a single, uniform demographic have been found from the existing research and practice as a critical oversight. There is meaningful differences exist among subgroups of older adults each with distinct physical abilities, cognitive functioning, technological familiarity, and psychological perspectives.

Thus, ignoring these main differences often cause a misalignment of technology development with the capabilities and expectations of users, which can lead to frustration, low adoption, and disengagement. Additional to that, community workshops, family assistance, and digital training initiatives, as existing facilitators, are implemented without considering the characteristics of older adults subgroups or cultural contexts of many developed and developing countries. Consequently, these interventions may lack relevance or effectiveness for broader populations. Moreover, VUIs under-utilization clearly seemed to be another missed opportunity, as VUIs have a vast ability to offer intuitive, hands-free interaction that is beneficial for users in general, and more beneficial for those with visual or dexterity impairments. However, their design, usability, and adoption across different older adult subgroups remain insufficiently explored despite their promise.

Undoubtedly, emotional and psychological factors additionally play an important and critical role in the relationship of older adults with technology. What can act as a deterrent for many users, especially older adults, is privacy, fear of losing human interaction, and lack of confidence in using digital tools. In contrast, the role of enjoyment and emotional satisfaction in technology adoption remains underexplored and a critical gap. It was notable that previous related works addressed usability and accessibility more frequently than focusing on the extent to which digital tools bring joy, entertainment, or a sense of purpose to older adults, specifically in design practices. Motivation, long-term engagement, and quality of digital experience can significantly be improved by enjoyment, and should be a focal point in future HCI research.

This work was limited to review related papers that mainly address user interface design for older adults from the perspective of HCI based on personal (cognitive, physical, sensory, and social and emotional impairments) and technological (digital divide and usability concerns, physical, cognitive, barriers, privacy and security concerns, lack of support and training, and interoperability and technical issues) challenges. Future research is needed to address the gaps found in this study, such as older adults' emotional and social needs, and designing user interfaces for older adults' subgroups who are ignored by technology designers. Older adults' needs must be highly considered in future research, and prioritized adaptive, inclusive, and subgroup-responsive design approaches. Evaluating the use of VUIs as an assistive technology, incorporating participatory methods, and ensuring representation across cultures and age segments can pave the way toward more equitable and empowering digital environments. Moreover, to enrich the emotional and social lives of older adults, technology designers must consider embedding enjoyment (as a key design consideration) alongside functionality and usability, as well as digital tools supporting autonomy and accessibility.

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