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Chapter 2

Aging barriers influencing mobile health usability for older adults: a literature based framework (MOLD-US)

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Abstract

Background: With the growing population of older adults as a potential user group of mHealth, the need increases for mHealth interventions to address specific aging characteristics of older adults. The existence of aging barriers to computer use is widely acknowledged. Yet, usability studies show that mHealth still fails to be appropriately designed for older adults and their expectations. To enhance designs of mHealth aimed at older adult populations, it is essential to gain insight into aging barriers that impact the usability of mHealth as experienced by these adults.

Objectives: This study aims to synthesize literature on aging barriers to digital (health) computer use, and explain, map and visualize these barriers in relation to the usability of mHealth by means of a framework.

Methods: We performed a scoping review to synthesize and summarize reported physical and functional age barriers in relation to digital (mobile) health applications use. Aging barriers reported in the literature were mapped onto usability aspects categorized by Nielsen to explain their influence on user experience of mHealth. A framework (MOLD-US) was developed summarizing the evidence on the influence of aging barriers on mHealth use experienced by older adults.

Results: Four key categories of aging barriers influencing usability of mHealth were identified: cognition, motivation, physical ability and perception. Effective and satisfactory use of mHealth by older adults is complicated by cognition and motivation barriers. Physical ability and perceptual barriers further increase the risk of user errors and fail to notice important interaction tasks. Complexities of medical conditions, such as diminished eye sight related to diabetes or deteriorated motor skills as a result of rheumatism, can cause errors in user interaction.

Conclusions: This research provides a novel framework for the exploration of aging barriers and their causes influencing mHealth usability in older adults. This framework allows for further systematic empirical testing and analysis of mHealth usability issues, as it enables results to be classified and interpreted based on impediments intrinsic to usability issues experienced by older adults. Importantly, the paper identifies a key need for future research on motivational barriers impeding mhealth use of older adults. More insights are needed in particular to disaggregating normal age related functional changes from specific medical conditions that influence experienced usefulness of mHealth by these adults.

Keywords: mHealth, eHealth, elderly, aging barriers, human factor design, user experience

1. Introduction

The extensive functionalities of current smartphones, tablets and other devices allow the development of mobile health applications (mHealth) to thrive; it is estimated there are 259,000 mHealth apps in the major app stores from 2016 onwards [1-3]. This boost in innovation finds its foundation in the potential of mHealth to assist patients in self-management of diseases and independent living [4-5]. For the older adult patient population, this advancement is especially important as risks for functional decline and loss of independence increase with normal aging and accumulation of chronic diseases, approximately from the age of 50 and onwards [6]. MHealth apps may provide medication assistance by prompting alerts, provide self-care advice to patients, facilitate self-monitoring of various biometrics or educate patients on disease outcomes [1, 7]. These mHealth advances align well with the upcoming interest of older adults to integrate technologies into their own health care [1-2].

Despite the interest and intention of older adults to use mHealth, studies report that actual usage and adoption of mHealth amongst this patient population is low and inconsistent [4, 8-9]. When mHealth is aimed at older users, it is important to understand specific facilitators and barriers potentially impacting acceptance of mHealth by this population. Prominent technology acceptance models such as the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Senior Technology Acceptance Model (STAM) provide a theoretical basis for this [4, 10]. These models define usability and usefulness as important constructs impacting user acceptance, as well as age as a moderator of these constructs. Yet these models fall short in defining which age-related barriers and facilitators influence usability and usefulness of technology, and how. Furthermore, several studies on older adult acceptance of mHealth emphasize the importance of user-centered interface design and clear user instructions [2, 5, 11]. However, these studies do not disaggregate the specific aging characteristics and barriers faced by older adults related to the encountered usability issues that influence their acceptance of mHealth. A more detailed understanding of how aging characteristics of older adults affect mHealth usability and usefulness is thus valuable to facilitate mHealth adoption - as well as to ensure safe and effective use of mHealth by this population [9].

For almost two decades it is known that older adults interact differently with information technology compared to younger people [12-13]. In 2000, design guidelines to enhance website interfaces and desktop computer usability attuned to older adults' cognitive abilities were published [14]. Smith et.al. have likewise reported motor control barriers in relation to older adults' performance of computer mouse tasks [15]. At the same time, literature on this topic remains fragmented across different domains, and mostly focusses on older technologies (such as computer desktops) that preceded the introduction of smartphones, tablets and other modern devices.

Design issues related to user data entry and screen size of these earlier technologies cannot automatically be applied to mobile devices. Although aging barriers experienced by older adults may remain the same, the effect of these aging barriers differs for the use of modern devices compared to preceding technology use. Research on touch screens for example, shows a reduction of cognitive and physical workload of older adult users because the interface on the display can be directly controlled with one's fingers [9]. The direct input on the interface of large touch screen devices, such as an iPad, make the software installed on those devices easy to use for older adults [16]. Certain design aspects of mobile devices may have the opposite effect and hamper, instead of support, older adult usage. To recognize icons and interpret their functionality as buttons within the interface of apps is problematic for older users since they may be more familiar with website interfaces having different and larger buttons. Therefore, they might fail to locate relevant information that is only visible after clicking an icon [17].

Age is not only associated with normal physical decline that poses a barrier to effective mobile device use, it is also associated with the development of multiple chronical diseases and related impairments [18]. Developers of apps for diabetes patients for instance, should be aware that diabetes is most prevalent in people aged 65 years old and above and more prevalent in low literate people than in high literate people [19]. Furthermore, one of the complications of diabetes is a diminished eye sight [20]. Designers should thus be aware of these kinds of complexities of user populations and take these into account in developing mHealth apps. At present, these disabilities and complexities of older adults (with chronic conditions) are often overlooked. This results in mHealth apps that consist of many hard to understand features, thereby decreasing their usability for the older adult target group [7-8] and are more susceptible to induce user errors and thus to comprise patient safety [21].

This fragmentation of knowledge on aging barriers across various medical domains combined with knowledge gaps regarding mHealth design in the context of older (chronically ill) adults, pose a key barrier to improving (safe) use and adoption of mHealth by these user groups. This paper aims to synthesize and centralize knowledge on aging barriers in mHealth by relating complexities of medical conditions to their influence on mHealth user experience. We conduct a structured scoping review to synthesize and explain aging barriers to usability of mHealth by older adults. To map and visualize the review results we suggest a framework of these barriers and complexities associated with chronic diseases, and their potential impact on specific usability aspects of mHealth. The framework aims to support designers of mHealth and to improve analysis of usability evaluation studies.

2. Methods

We performed a scoping review as such a review provides a rigorous and transparent method for structured mapping of a certain research domain [22]. This is important because existing literature on aging barriers influencing mHealth usability is fragmented across technologies, health concerns and age groups, and lacks a comprehensive and up-to-date synthesis for older adults. We first identified and examined key literature on aging barriers that may hamper hardware and software use by older adults by prominent authors in this field. Based upon this key literature and the snowballing method, we identified (common) medical conditions related to specific aging barriers. We then performed a literature search to assess if the aging barriers were addressed in articles on older adults' user experience of healthcare systems, including mHealth usage. We searched four databases - PUBMED, EMBASE, ScienceDirect and WebofScience - for relevant publications using the following search terms related to aging barriers and digital user experience: *aging*, *elderly*, *older adults*, *usability*, *experience*, *adoption*, *barrier*, *barriers*, *eHealth*, *mHealth*, *mobile health* and *computer (use)*. We reviewed the identified articles based upon their relevancy to usability and usefulness of consumer healthcare hardware and software. Studies were included in which: 1) study participants => 50 years; and 2) aging barriers were mentioned related to interface design/usability of computers, eHealth or mHealth. Studies were excluded if they reported on 1) participants < 50 years old or if mean age was below 50 years old; and 2) adoption/acceptance of eHealth/mHealth by older adults without mentioning usability issues. Author GAW screened for title and abstract. Full text reviews were independently performed by authors GAW and LDP, any disagreements on inclusion of articles were discussed until agreement was reached.

We performed a thematic analysis to capture and synthesize the data from the included studies. To map reported user experiences of older adults to aging barriers categories, we used the five usability aspects that influence user experience, as defined by Nielsen: learnability; efficiency; memorability; errors; satisfaction [23]. Finally, we developed a framework to visualize the aging barriers, and medical conditions related to those barriers, and their possible influence on usability aspects of mHealth.

3. Results

3.1 Aging barriers for mHealth user experience

Four aging barrier categories were identified in key literature of Holzinger, Rogers & Fisk, Cjaza as well as the W3C [24-27], which we use to organize our findings: (1) cognition; (2) physical abilities; (3) perception; (4) motivation. Supplementary file A shows the 23 included studies of the scoping review. Information regarding prevalence of age related barriers is mostly described in literature for the elderly age cluster (65+ years old); therefore we provide prevalence numbers for this target group only. Tables 1-4 list the diminishing age dependent abilities and their impact level on usability per aging barrier, and include relevant (common) medical conditions related to each specific barrier. These medical conditions involve diminished cognitive, physical, perceptual or motivational capacities as a complexity of a medical condition.

3.1.1 Barrier 1: Cognition

Cognitive aging barriers are related to a reduced capacity of working, prospective, semantic and procedural memory as well as attention [28-34], which may all negatively influence software use. Moderate to severe impairments affects 15% of men aged 65+ and memory impairment affects 11% of women aged 65+ [35]. The impact of age is that older people can process fewer discrete information bits in a given time, and recall also decays faster [28]. For example, recall of future based time-based tasks (such as taking a pill after 4 hours) becomes more difficult [28, 36]. In addition, older people need more time to learn new skills [24, 25, 28]. Mentally transforming spatial information becomes more difficult with age and influences computer task performance negatively [28, 36-37]. In addition, a decline in numeracy and representational fluency hampers older adults in understanding content specific to eHealth and mHealth interventions, such as tables and charts on biometrics [33, 38-39]. Cognitively impaired older adults showed a significantly smaller percentage of task success than unimpaired older adults in a usability study of an electronic medication delivery unit, because of confusing terminology used [40].

Table 1: *Cognitive barriers*

Impact level	Diminishing age dependent abilities	(Possible) cognitive diminishment as complexity of medical condition
Errors	Working memory [24-26, 28-34, 37-38, 42] Spatial cognition [28, 37] Dynamic/selective attention [24-25, 28, 30, 37] Phonemic/semantic fluency [28, 33] Reasoning [31] Numeracy and representational fluency [33, 38-39]	Diabetes [43] Stroke [43] (more likely to develop dementia): Multiple sclerosis [43] Motor neurone disease [44] Parkinson's disease [44] Huntington's disease [44]

3.1.2 Barrier 2: Physical ability

Physical impairments due to aging are difficult to quantify universally, yet a common age-related illness (though not exclusively) mentioned in literature that may influence software use negatively is rheumatoid arthritis [24, 31]. For example, diminished motor skills make it more difficult to click on small buttons in website interfaces and rheumatoid arthritis can make holding a device in one hand uncomfortable [29, 31]. Functional limitations such as arthritis and other rheumatic conditions are reported to affect 60% of the American population aged 65+ [35], while Arthritis Care in the United Kingdom (UK) report that 20% of all adults in the UK are affected [44]. Other age related physical changes are slower movement and reflexes, stiffer muscles and joints, tremor (in hands) and a diminished balance [28, 36, 41]. According to the Centers for Disease Control and Prevention, more than 75% of the American population aged 65+ has a difficulty in physical functioning [45]. Regarding computer use these impairments might influence learning time, speed of performance, error rate, retention of time and subjective satisfaction [24-25, 41].

Table 2: *Physical ability barriers*

Impact level	Diminishing age dependent abilities	(Possible) physical diminishment as complexity of medical condition
Errors Efficiency	Speed of performance [24, 31] Flexibility of joints [24, 31, 41] Hand-eye coordination [31, 41] Retention in hand movement [29, 31] Grip strength [28, 31, 41]	Rheumatoid arthritis [24] Parkinson's disease [44] Diabetes [43]

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3.1.3 Barrier 3: Perception (vision and audition)

It is estimated that 21% of the American population aged 65+ has a visual impairment, such as macular degeneration and bifocal glasses, which makes viewing a digital screen difficult [35, 46]. The Royal National Institute for the Blind (RNIB) estimates that eyesight decline in the older population in the UK, for who this decline in sight significantly affects their daily life, is 15.8% aged 65 to 74 years, 18.7% for ages 75 – 84 years and 45.8% for ages 85+ years [44]. Visual abilities that decrease with age are the ability to resolve detail, the ability to focus on close objects, the ability to discriminate between colors (violet, blues and greens), the ability to detect contrast, the ability to adapt to darker conditions and susceptibility to glare (vision is impaired by direct and reflected light) [24-25, 28, 31, 33-34, 36, 39]. Older people also require more light to see sharply, and have reduced motion estimation and peripheral vision (tunnel vision) [24, 28, 31].

With aging, hearing ability will decline over time [47]. The Royal National Institute for Deaf People (RNID) estimates for the UK that at around the age of 50 the proportion of deaf people begins to increase sharply and 55% of people over 60 are deaf or hard of hearing [44]. While audio is seldom fundamental to interaction with a software product, there are some implications, for example for video content and alerts [48]. In addition, older adults with moderate to great hearing difficulties showed lower computer desktop and internet use than those with no hearing difficulties [47].

Table 3: *Perception barriers*

Impact level	Diminishing age dependent abilities	(Possible) perception diminishment as complexity of medical condition
Errors Efficiency	Vision: Visual acuity/ accommodation [24, 26, 28-34, 41-42] Color vision [24, 26, 28-31, 39, 41, 51] Contrast detection [24, 26, 28-31, 34] Dark adaptation [24, 28] Glare [24, 31] Audition: Auditory acuity [24-25, 28, 30-31, 41-42] Touch sensation [28, 31]	Vision: Cataracts [44] Age-related macular degeneration [44] Refractive error [44] Glaucoma [44] Myopic eye disease [44] Diabetes (retinopathy) [33, 43-44] Audition: Presbycusis [49], High blood pressure [49], Diabetes [49], Depression [50]

3.1.4 Barrier 4: Motivation

Studies on the acceptance of technology by older people report on motivational issues as a barrier; this accounts for older adults as well as elderly [24-25, 27, 42]. A systematic review by Hawley-Hague et. al. shows that usability and feedback are, amongst others, important in supporting attitudes and perception of technology [51]. Several studies reported that older adults are less likely to use a technology if the benefits of the technology do not manifest themselves easily and quickly during the actual use of the technology [24-25, 30, 32-33, 39, 51-52]. For example, in a usability study on an app for heart failure patients, participants were positive about the benefits of the app, yet they found entering data in the app cumbersome [39]. The benefits were not being obvious to the older adults during the actual use, resulting in frustration and the desire to stop using the app [39].

Table 4: *Motivational barriers*

Impact level	Diminishing age dependent abilities	(Possible) motivational issues as complexity of medical condition
Errors Efficiency Learnability Memorability Satisfaction	Trust in own ability [24, 30-31, 33, 35-36, 42] Efficiency in seeing benefits [24-25, 30, 32-33, 39, 51-52] Computer literacy [24, 31, 35-36, 41] Self confidence in using wearables [53] Shift in responsibilities from provider to patient not preferred [29-30] Integration of functions during daily activities [30-32]	Concentration issues [24] Learning disabilities [24]

3.2 mHealth for older users: the MOLD-US framework

The MOLD-US framework (Figure 1) provides a visual overview of the possible impact of each aging barrier category, related diminishing age dependent abilities and medical conditions to the usability of mHealth in older adults. It consists of three dimensions:

- Four aging process barriers categories: cognition, motivation, physical ability and perception. These are presented by pie chart pieces within the diagram.
- Medical conditions that involve a deterioration in capacities related to the barrier as a complexity of the condition. These are presented in a lighter color as an extension of the pie chart pieces.
- Five structural levels of mHealth user experience, based upon the usability aspects defined by Nielsen: (1) errors; (2) efficiency; (3) learnability; (4) memorability; (5) satisfaction [23]. These are represented by the triangular shapes at the outer edges of the diagram.

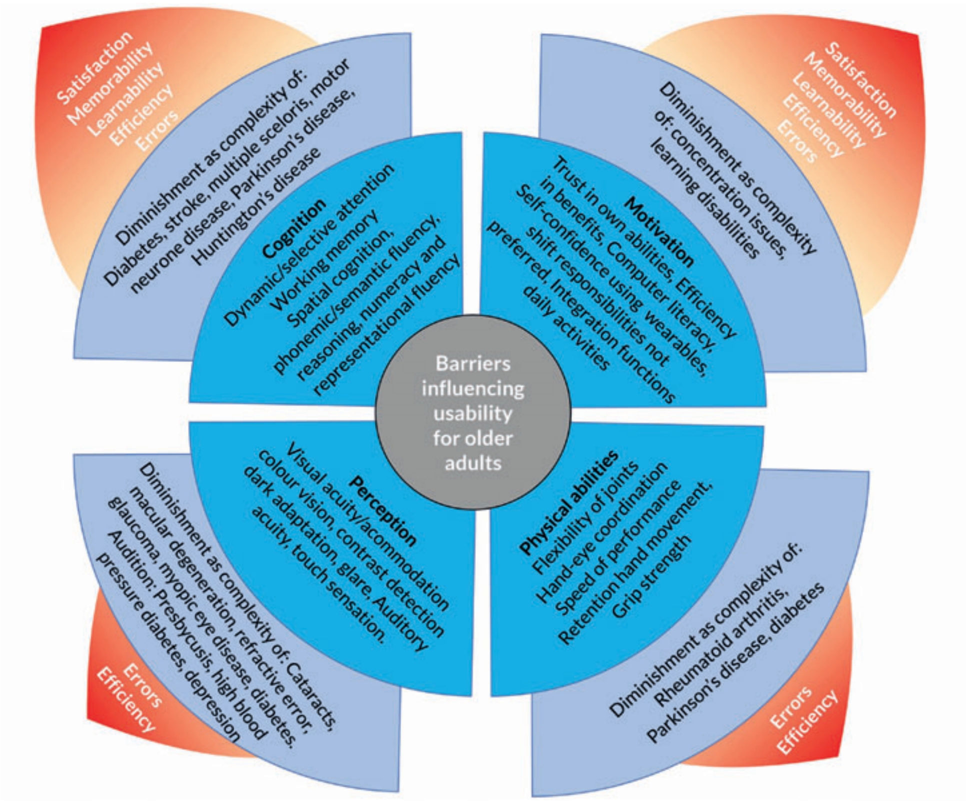

Figure 1: MOLD-US framework, barriers of older adults influencing usability of mHealth

The MOLD-US framework is unique, because it integrates acknowledged aging barriers impeding digital user experience, aging barriers identified in empirical studies on digital (mobile) health applications usability and complexities of medical conditions possibly influencing mHealth usability. The strength of the MOLD-US framework is that it enables (future) usability testing results of mHealth aimed at older adults to be classified and interpreted based on impediments intrinsic to encountered issues. It thus allows for improved analysis of results in systematic usability evaluations of mHealth aimed at older adults. Finally, MOLD-US informs more robust design of mHealth tools by providing insights that allow better attunement of technology design to the impairments of older adults.

4. Discussion

In this research a synthesis of the literature was performed in order to map, centralize and explain aging barriers in relation to usability of mHealth; and visualize this by means of a framework, MOLD-US. Age related physical function and perception limitations, for example arthritis and other rheumatic conditions as well as hearing or vision loss, may limit usefulness and usability of mHealth as experienced by older adults. While interacting with mHealth these aging barriers can lead to difficulties, such as holding a smart device in one hand, attempting to click buttons which are close together (as is often the case in smartphone interfaces), making certain gestures (such as pinches and swiping) or visually distinguishing between similarly shaped software icons used on screens. This hampers efficient use of mHealth and increases the risk of user errors and failure to notice important user interaction tasks, resulting in either hazardous use or non-adoption of mHealth by older adults. Prominent cognitive barriers such as a decline in working memory may further impede older adult patients in fully benefiting from mHealth apps. If an interface is cluttered and complex, older adults experience difficulties in navigating through the application and in interpreting the subsequent system feedback. MHealth apps may therefore be difficult to understand and learn, inefficient to use, induce user errors, and frustrate the older adult user. Motivational barriers, such as trust in one's own ability to use mHealth, likewise may limit effective and satisfying use of mHealth. For example, older adults tend to be afraid to experiment with a mobile device and an app's navigation, because they fear they might 'break something'. Many older adults further suffer from complexities of medical conditions, such as eye sight problems related to diabetes or a decline in cognitive skills due to a stroke. When developing mHealth - especially if the mHealth intervention is targeted at a specific patient population such as diabetic patients or heart failure patients -it is thus important to be aware of these complexities, since they further affect the cognitive, physical, perception and motivation abilities of older adults negatively, thereby hampering their use of mHealth.

4.1 Inclusive design accommodating aging barriers

The aim of designers, programmers and developers should be to create mHealth interventions that accommodate aging barriers [28] and possible multimorbidity issues [7]. A design effort that minimizes demands on as many users as possible is known as inclusive design; a design that is flexible enough to be usable by people with no limitations as well as by people with functional limitations related to disabilities or old age [31]. The MOLD-US framework can be of value to mHealth designers in inclusive design efforts. The visual overview of MOLD-US enables a quick assessment of aging barriers and medical conditions that involve deterioration in capacities related to these barriers to take into account while designing an mHealth app for older adults.

4.2 Possible correlation between aging barriers

The results from this scoping review show that older adults can be unmotivated to use an mHealth tool if the benefits of app usage cannot be quickly determined by them in the first phases of use [30, 39, 52]. However, what is not yet clear from the current literature is whether the cognitive, physical and perception barriers are correlated to the demotivation of older adults to use mHealth. We hypothesize that it may be more difficult for older adults to determine the benefits of mHealth due to the variety of utilities of mHealth - which require more cognitive, physical and perception skills compared to traditional computer-based digital health interventions for patients. Digital health interventions preceding mHealth apps mostly focused on providing medical information to patients via websites and pioneering with patient portals use. MHealth apps have vastly more options for use: gathering patient data via sensors, using decision-making algorithms to assist patients in health monitoring and presenting real-time medical data visually. Older adults need to perform many interaction tasks related to this variety of utilities of mHealth, such as interpreting numeracy and graphical data, activating the application to perform measurements or manual input of blood pressure levels; many of which are difficult for them due to normal physical and functional decline.

To gain insight into whether aging barriers correlate in influencing usability of mHealth experienced by older adults, priorities for future research are to examine possible associations between the four aging barriers and encountered usability issues in user testing. Study designs and methodologies used in usability evaluations of mHealth should therefore accommodate the assessment of how aging barriers of older adults relate to usability issues. The MOLD-US framework provides a reference model for this type of research. Firstly, the overview of older adults' (medical conditions related to) degradation of sensory, physical and cognitive abilities can assist researchers in setting inclusion criteria of study participants, assuring representativeness of the overall user population, and selecting specific usability metrics relevant to user-based usability testing by the user population. Secondly, since the framework addresses the impediments intrinsic to usability issues of mHealth that may be encountered by older user populations, it can be used as a classification tool to interpret usability testing results. MOLD-US adds value to current classification tools, such as the Usability Problem Taxonomy (UPT) and User Action Framework (UAF) [55-56], because it is unique in integrating aging barriers and categories of usability aspects that influence user experience. By using MOLD-US in assessing which age barriers are intrinsic to experienced usability issues of mHealth by older adults, multiple snapshots of aging barriers influencing usability can be taken over time and compared to gain insights in the evolution of the framework.

4.3 Limitations

A drawback of the scoping review methodology is that we might have missed relevant publications. However, key literature on older adults' barriers was detected in our review approach. Though the scoping review is also limited in the exclusion of grey literature and studies published in a non-English language, the proposed MOLD-US framework provides a first basis that can evolve by means of including more and future research on aging barriers related to mHealth usability. True to the scoping review method, we did not asses the quality of the included studies by means of a formal measurement tool. Hence, this review might include a greater range of study designs and methodologies than a systematic review. Yet, this scoping review aimed to synthesize the reported evidence on aging barriers related to digital user experience in order to provide new directions of future research based on the variety of studies on this topic.

5. Conclusion

The potential of mobile health to facilitate patients' self-management of diseases is high, yet use of mHealth by older adult patients aged 50 years and above is prone to Human Factor design problems related to aging barriers. This study identified four aging barriers, cognition, physical ability, perception and motivation, which may be reinforced by certain medical conditions of patients. This research will serve as a base for future studies as it enables new systematic analysis of mHealth usability issues encountered by older user populations by means of the MOLD-US framework. The framework can be used to classify and interpret results based on older adults' impediments intrinsic to usability issues. MOLD-US also contributes to creating awareness on aging barriers and disease complexities of older adults amongst stakeholders involved in mHealth development. Further studies could investigate whether the cognitive, physical and perception barriers are correlated to the demotivation of older adults to use mHealth, and thereby evolve the framework.

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Supplementary file A

The table shows the included studies informing on aging barriers related to usability of digital health technologies. Studies informing on the prevalence of physical and functional decline of older adults, as well as on which medical conditions involve such a decline as a complexity of the disease, are not included.

Supplementary file B

The prototype of the framework 'mHealth for Older Users' as presented at a 2015 conference on 'Digital Healthcare Empowering Europeans', organized by European Federation for Medical Informatics, shown in appendix 1 [17].

Supplementary file A – Table 1

Author, year, ref.nr.	**Type of article/ Study design**	**Technology / Innovation**	**Age participants (years)**	**Type of barrier and age dependent ability mentioned**			
				Cognitive	Perception	Physical	Motivational
Athilingam, 2016 [53]	Case study (usability)	Mobile application	Mean age: 58				Self confidence in using wearables
Bolle, 2016 [29]	Case study (usability)	Website (internet skills)	Mean age: 73	Working memory	Visual acuity/ accommodation Color vision Contrast detection	Retention in hand movement	Shift in responsibilities from provider to patient not preferred
Cjaza, 2013 [27]	Case study (usability)	Website (internet skills)	Mean age: 70	Cognitive abilities			Computer literacy
Farage, 2012 [28]	Literature review	Computer (use)	65+	Dynamic / selective attention Working memory Phonemic/ semantic fluency Spatial cognition Reasoning	Visual acuity/ accommodation Color vision Contrast detection Dark adaptation Auditory acuity Touch sensation	Grip strength	
Fisher, 2014 [36]	Literature review	Health Information Technology	Older adults (age not specified)	Cognitive issues Memory issues	Vision loss Hearing loss	Physical issues	Trust in own abilities Computer literacy
Foster, 2014 [41]	Literature review	Telemedicine applications	65+	Working memory	Visual acuity/ accommodation Color vision	Flexibility of joints Hand-eye coordination Grip strength	Computer literacy

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Author, year, ref.nr.	Type of article/ Study design	Technology / Innovation	Age participants (years)	Type of barrier and age dependent ability mentioned			
Grindrod, 2014 [30]	Case study (usability)	Mobile application (medication management)	Mean age: 67	Dynamic / selective attention Working memory	Visual acuity/ accommodation Color vision Contrast detection Auditory acuity		Trust in own abilities Efficiency in seeing benefits Integration of functionalities during daily activities Shift in responsibilities from provider to patient not preferred
Harte, 2014 [31]	Descriptive	Connected health devices	60+	Working memory Phonemic/ semantic fluency Reasoning	Visual acuity/ accommodation Color vision Contrast detection Glare Auditory acuity Touch sensation	Flexibility of joints Hand-eye coordination Speed of performance Retention in hand movement Grip strength	Trust in own abilities Computer literacy Integration of functionalities during daily activities
Hawley-Hague, 2014 [51]	Literature review (systematic)	Fall detection, prevention and monitoring technology	50+		Color vision		Efficiency in seeing benefits Self confidence in using wearables
Hendrix, 2000 [42]	Literature review	Computer (use)	65+	Working memory	Visual acuity / accommodation Hearing loss	Mobility impairments	Trust in own abilities
Henshaw, 2012 [47]	Descriptive	Computer (use), website(internet skills)	Mean: 62		Auditory acuity		

Author, year, ref.nr.	Type of article/ Study design	Technology / Innovation	Age participants (years)	Type of barrier and age dependent ability mentioned			
Holzinger, 2007 [24]	Descriptive	Computer (use)	Elderly (age not specified)	Dynamic/ selective attention Working memory	Visual acuity/ accommodation Color vision Contrast detection Dark adaptation Glare Auditory acuity	Flexibility of joints Speed of performance	Trust in own abilities Computer literacy Efficiency in seeing benefits
Isakoviç, 2015 [33]	Case study (usability(	Mobile application (diabetes)	Mean age: 64	Working memory Phonemic/ semantic fluency Numeracy and representational fluency	Visual acuity/ accommodation Color vision		Trust in own abilities Efficiency in seeing benefits
Kaufman, 2003 [38]	Case study (usability)	Telemedicine application (diabetes)	Mean age: 70 (NYC) 74 (upst.)	Working memory Numeracy and representational fluency			
Ligon, 2014 [40]	Case study (usability)	Electronic medication delivery unit	Mean age: 87	Cognitive impairment			
Lober 2016 [35]	Descriptive	Personal Health Record	Mean age: 69	Cognitive impairment	Visual impairment	Physical impairment	Trust in own abilities Computer literacy
Matthew-Maich, 2016 [32]	Literature review	Mobile applications and technologies		Working memory	Visual acuity/ accommodation		Efficiency in seeing benefits Integration of functionalities during daily activities

Author, year, ref.nr.	Type of article/ Study design	Technology / Innovation	Age participants (years)	Type of barrier and age dependent ability mentioned			
Morey, 2017 [39]	Case study (usability)	Mobile applications	Mean age: 72	Working memory Numeracy and representational fluency	Color vision		Efficiency in seeing benefits
Or, 2012 [34]	Case study	Computer based self- management system	Mean age: 72	Working memory Numeracy and representational fluency	Visual acuity/ accommodation Color vision Contrast detection		
Pak, 2008 [37]	Clinical trial	Interactive Voice Respond System	Mean age: 71	Dynamic / selective attention Working memory Spatial cognition			
Rogers, 2010 [25]	Descriptive	Technology (general)	Older adults (age not specified)	Dynamic / selective attention Working memory	Visual impairments Hearing impairments		Efficiency in seeing benefits
Timmerman, 2016 [52]	Case study (usability)	Telemedicine application	Mean age: 62				Efficiency in seeing benefits
W3C, 2008 [44]	Descriptive	Technology (general)	Older adults (age not specified)	Working memory	Visual acuity/ accommodation Color vision Contrast detection	Motor skill diminishment	

Supplementary file B