Design for Older People: Improving the Usability of Mobile Apps through Targeted Design Recommendations

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With demographic change and advancing digitalisation, improving the usability of mobile apps for older people is becoming increasingly important. This study conducts a systematic literature review to identify the specific challenges of older users and develops six key design recommendations based on this. These recommendations aim to take cognitive, visual and motor impairments into account and improve the user experience. Through the prototypical adaptation of an existing app based on the derived design recommendations and their evaluation in a user study with 60 senior citizens, great improvements in usability were identified. The validation of design recommendations is an important step that is not carried out in most research projects. In our analysis, only 15% of the reviewed articles empirically validated their proposed guidelines, highlighting a gap in the research. This paper addresses this gap by not only proposing but also empirically validating design recommendations through a structured user study, showing that the validated recommendations provide real value and actionable insights for developers and designers aiming to create more inclusive mobile applications.

CCS Concepts: • **Human-centered computing → Accessibility design and evaluation methods**; *Accessibility systems and tools*; Empirical studies in ubiquitous and mobile computing.

Additional Key Words and Phrases: Usability, Older Adults, Elderly, Mobile Applications, Accessibility, User Experience, Google Maps

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1 INTRODUCTION

Demographic change in Germany and other industrialized countries is leading to an ageing society. The number of people over 65 in Germany has risen from 12 million in 1991 to 18.5 million in 2021, which now accounts for 22% of the German population. At the same time, the number of people over 85 has more than doubled in the same period, increasing from 1.2 million to 2.6 million [37]. According to forecasts, around 16% of the world's population will be

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aged 65 or over by 2050 [2]. This demographic group often faces barriers due to a lack of consideration for their specific needs in terms of usability and accessibility.

Technological applications, especially mobile apps, are often not tailored to the needs of older people, which leads to the exclusion of this demographic from the digital society. Older adults have specific needs that are often insufficiently considered in the design of digital applications [7, 14, 31, 21, 24, 20]. This neglect means that older people are more likely to have difficulties with digital technologies, making their use and acceptance more difficult and contributing to the widening of the digital divide [12, 24, 38, 18].

To create a more inclusive digital society, developers and designers need to be more responsive to the specific needs of this growing population and implement appropriate design principles [34, 13, 20]. The aim of this work is to develop and validate specific design recommendations for mobile apps that address the specific needs of older people. Based on a systematic literature search, we analysed 25 scientific articles and derived six central design recommendations, which were prepared for practical applicability.

Our research helps to raise awareness of the needs of older people and provides developers and designers with concrete guidelines that promote inclusive technology use and improve the digital participation of older people. Furthermore, we would like to validate the derived design recommendations, as this is an important step that is missing in many of the analysed works by Nurgalieva et al. [27] has been neglected. To test the effectiveness of the design recommendations, a user study was conducted with 60 older people aged 60 and over. The results show that the integration of the design guidelines can lead to improved and more intuitive usability. Intuitive usability refers to the degree to which a user can interact with an application in a natural and familiar way, requiring minimal cognitive effort or learning. This is particularly important for older adults, who may not be as familiar with modern interfaces and benefit from clear, recognizable elements that make navigation effortless.

In the following, the systematic literature review is first described and the design recommendations derived from it are presented. The implementation and evaluation of the user study is then explained. Finally, the results are discussed and implications for practice and future research are outlined.

2 RELATED WORK

The use of digital technologies by older adults is characterised by specific challenges that result from physical and cognitive limitations and must be taken into account in the design of digital applications. According to Nurgalieva et al.[27], this applies in particular to the design of touchscreen applications. Touchscreens require precise motor skills for interaction, such as tapping, swiping, and pinching, which can be challenging for older adults due to age-related declines in fine motor control. Additionally, touchscreens often lack the tactile feedback found in traditional physical interfaces, making it harder for older users to confirm their inputs. Combined with visual impairments, such as reduced contrast sensitivity, this can lead to frequent errors and a slower, more frustrating interaction experience [34, 9, 21, 20, 27].

The research by Nurgalieva et al. and our literature review have consistently shown that older users often have problems with user interfaces that younger users would not experience [7]. These problems result from motor, visual and cognitive limitations, among other things, or from unfamiliarity with modern technology [14, 31, 27].

The accessibility of applications is therefore an important area of research, especially when it comes to making them usable for older people. A literature review by Dodd et al. [8] identified physical problems such as impaired vision and haptic perception as well as cognitive problems that make use difficult and proposes solutions for the design of the user interface, input controls and natural language. Dodd et al. agree that future research should focus more on creating design guidelines for older people [8].

2.1 Physical problems

Design strategies and principles to make mobile apps senior-friendly include the increased use of visual elements such as images or icons and the use of large fonts and high contrasts [34, 13, 10]. Studies show that older adults prefer a minimum font size of 14 pt and sans serif fonts in mobile apps in order to be able to read texts better [20, 15, 40]. It was also found that older people spend less time reading texts with high text-background contrast than with low contrast [22]. The use of simple, easy-to-understand elements and contextual help is crucial for the intuitive use of apps [8]. Nurgalieva et al. [27] also recommend using simple and understandable elements and clear feedback mechanisms. Visual and motor impairments affect the ability of older users to use mobile apps effectively. High contrasts and sufficiently large buttons are therefore important design features to improve accessibility [3, 13, 22]. Voice interaction can be an alternative to physical interaction. This is also helpful for older people [8, 20].

2.2 Cognitive problems

Nurgalieva et al. emphasise the need to reduce memory load and confirm the importance of alternative interaction methods such as voice control [27]. Our literature review also shows that older people often need more time to complete tasks and have difficulty navigating applications due to cognitive limitations [3]. Design strategies such as reducing memory load and providing clear feedback mechanisms can help address these challenges [34, 8, 20].

2.3 Digital Divide

Like Nurgalieva et al. [27], we also see the digital divide as a big issue affecting older adults. Despite the increasing prevalence of mobile devices and apps, this population group often lags behind, leading to inequalities in the ability to use new information technologies [24, 38]. Reduced brain activity and weakened neuromodulatory control in old age lead to negative learning outcomes and exacerbate the digital divide [18]. The digital divide remains a great barrier to the inclusion of older adults in the digital world. Many older individuals struggle with access to and understanding of modern technologies, further exacerbating their exclusion from a digitally driven society.

3 METHODOLOGY

In this study, a systematic literature review was conducted to identify the current challenges and needs of older users when using mobile applications. The research method comprised several steps, from data collection to the development and validation of design recommendations. The literature review was based on comprehensive database searches in SpringerLink, IEEE Xplore, and ACM Digital Library. To identify relevant articles, specific search strings were used, combining keywords such as "older adults," "usability," and "mobile apps." This search strategy aimed to capture a wide range of studies dealing with the interaction of older users with technological applications. For the systematic literature review, the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was applied to ensure a transparent and reproducible methodology for literature review and data analysis [23, 30]. Based on the results of the literature review, design recommendations were derived using a methodology described by Quiñones et al. [33]. This methodology involves eight systematic steps, starting with an exploratory phase, in which existing knowledge is collected and analyzed, through experimental and descriptive phases, to specification and validation. These steps allow for the step-by-step development and continuous refinement of design recommendations. The developed design recommendations were evaluated in a usability test with N=60 participants over the age of 60. This empirical validation is crucial to ensure the practicality and effectiveness of the recommendations and to verify that they indeed enhance usability for older users.

3.1 Search Strategy

To identify relevant studies, a search was conducted in the scientific databases SpringerLink, IEEE Xplore, and ACM Digital Library. SpringerLink provides access to scientific publications in the fields of computer science and engineering. Through IEEE Xplore, we were able to identify pertinent works in the areas of human-computer interaction, mobile technologies, and requirements engineering. Additionally, the ACM Digital Library enabled us to access publications in the fields of computer science and information systems with a particular focus on usability and user experience. The selection of these databases was based on their comprehensive coverage, quality, and relevance to our specific research topics.For the systematic literature review according to the PRISMA method, a specific search string was developed and applied in the respective databases. The keywords were divided into three categories: software, user group, and research type. The search was conducted for publications from the years 2018-2023. Furthermore, the keywords were specifically searched in the abstract. The search strings used across the databases were largely consistent, focusing on mobile applications for older adults and empirical studies. However, slight variations were necessary due to the specific search functionalities and filtering options of each platform. For example, in ACM, we applied an additional filter to limit the search to publications between 2018 and 2023, ensuring that we captured the most recent and relevant research. Such adjustments help to optimize the search results for each database while maintaining the overall search strategy.

The search string used for SpringerLink and IEEE Xplore was: ("Abstract":mobile application OR "Abstract":mobile app OR "Abstract":app) AND ("Abstract":older adults OR "Abstract":seniors OR "Abstract":elderly) AND ("Abstract":empirical study OR "Abstract":empirical research OR "Abstract":user study OR "Abstract":user evaluation)

The search string used for ACM was: [[Abstract: mobile application] OR [Abstract: mobile app] OR [Abstract: app]] AND [[Abstract: older adults] OR [Abstract: seniors] OR [Abstract: elderly]] AND [[Abstract: empirical study] OR [Abstract: empirical research] OR [Abstract: user study] OR [Abstract: user evaluation]] AND [E-Publication Date: (01/01/2018 TO 12/31/2023)].

Our search strategy aimed to capture a wide range of studies dealing with the interaction of older users with technological applications. The search results yielded 652 results in SpringerLink, 99 results in IEEE Xplore, and 233 results in the ACM Digital Library. In total, 984 sources were identified for the period 2018-2023.

3.2 Systematic Literature Selection with the PRISMA Method

The literature selection was conducted according to the PRISMA method to systematically identify, select, and evaluate relevant studies. A total of 984 sources were identified. In the first phase, titles and abstracts were analyzed based on exclusion criteria. Studies on technologies beyond traditional apps, with primary users outside the older population, or with inconsistent age definitions were excluded. This left 446 studies. In the second phase, the study contents were examined in more detail, and further studies were excluded if they did not focus on the evaluation of apps by seniors or did not include participants over 60 years old. A total of 25 studies were selected that met all inclusion criteria.

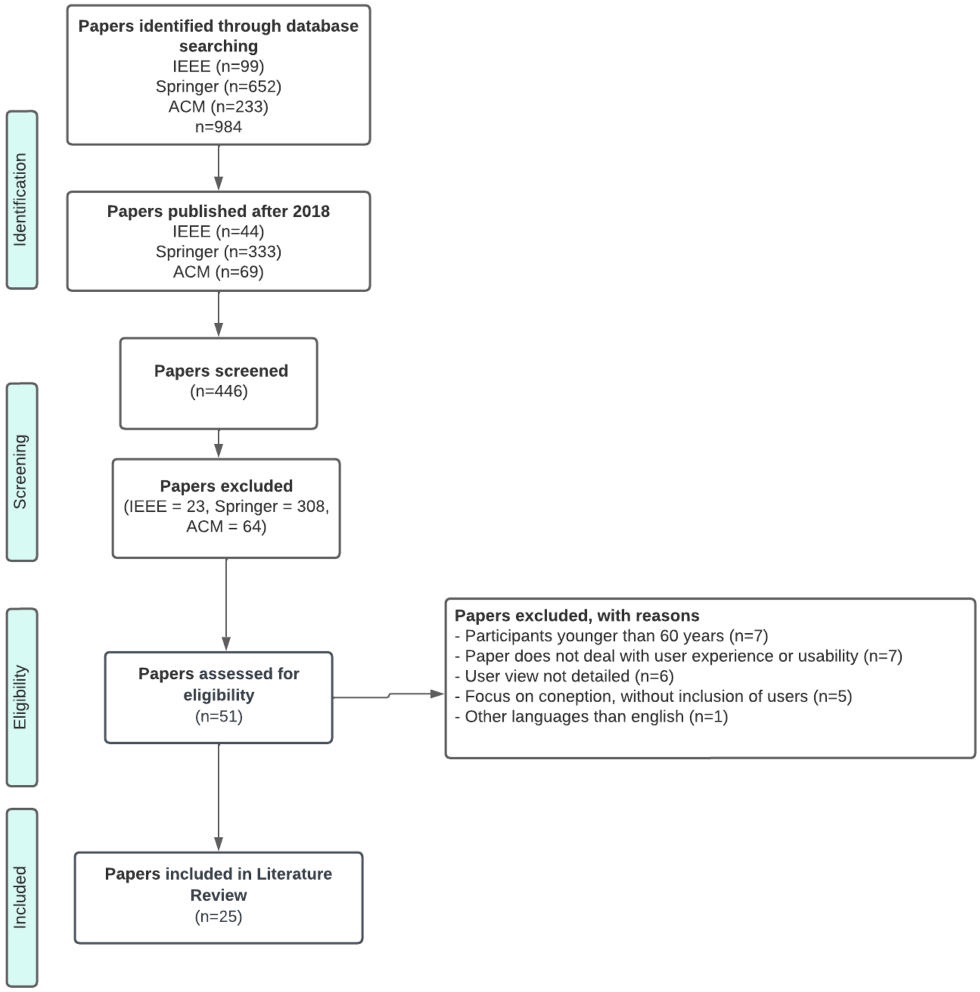

Fig. 1. PRISMA Method

3.3 Development of Design Recommendations

Based on the results of the literature review, design recommendations were developed using the methodology for creating heuristics described by Quiñones et al. [33]. This methodology consists of eight systematic steps, ranging from the exploration phase to the validation and improvement of the heuristics.

The need for a formal methodology for creating heuristics is emphasized in the study by D. Quiñones and R. Rusu [33], where they compare and evaluate various methods. The study shows that only about 25% of authors use a structured methodology, while others rely on existing heuristics, literature reviews, or usability issues. Among the seven compared methodologies, those by Rusu et al. [35] and Van Greunen et al. [16] are particularly highlighted. The methodologies by

Rusu et al. and Van Greunen et al. are particularly highlighted because they offer structured, empirically grounded approaches to developing usability heuristics. Rusu's approach emphasizes a detailed, multi-phase process that includes exploration, experimentation, and validation, ensuring that the heuristics are robust and well-tested. Van Greunen's methodology, with its three-phase model, integrates both theoretical and practical insights, making it highly adaptable to different usability contexts, including mobile applications. These methodologies provide a level of thoroughness and rigor that is often lacking in other approaches. For this paper, the updated methodology by Rusu and Quiñones [33] was chosen as it is the most current and comprehensive. The methodology includes the following steps:

(1) Exploration Phase: Conduct literature review
(2) Experimentation Phase: Analyze data
(3) Descriptive Phase: Summarize key information
(4) Correlation Phase: Compare results with existing heuristics
(5) Selection Phase: Retain, improve, or discard heuristics
(6) Specification Phase: Formulate new heuristics
(7) Validation Phase: Validate heuristics
(8) Improvement Phase: Refine recommendations based on results

The design recommendations derived from our literature review were methodically prepared according to the descriptive, correlation, selection, and specification phases to ensure standardized formulation and practical applicability. For the validation phase, an evaluation with 60 participants was conducted. The positive evaluation results allowed us to retain our recommendations in their formulation.

4 RESULTS

The analysis of the systematic literature review provided detailed insights into the specific challenges faced by older users when using mobile applications. Three areas were identified that affect the usability and accessibility of applications: cognitive challenges, visual challenges, and motor challenges. Cognitive challenges mainly concern the processing of information and the understanding of content. Complex menu structures and unclear instructions can present challenges for older adults, also unintelligible symbols and an overload of irrelevant information can also lead to confusion. Furthermore, a lack of feedback, as well as declining memory and learning abilities, impair the operation of the applications. As shown in Figure 2, the following points are considered.

- Complex menu structures and functions: These lead to slower information processing and uncertainties in operation. Older adults should instead be cognitively relieved and presented with a clear design without irrelevant information.
- Unclear instructions and unintelligible icons: Older adults need familiar symbols and instructions to navigate an app confidently. The design should adhere to known and accepted standards, use simple language, and provide unambiguous labels for icons. Icons should not be ambiguous.
- Too much irrelevant information: This can overwhelm users and cause confusion. Due to cognitive issues or reduced concentration, they can no longer quickly decide which information is most important and filter out unimportant information.
- Lack of feedback and support: This particularly impairs the learnability of apps and can lead to frustration. Especially at the beginning of using an app, attention should be paid to good onboarding or appropriate orientation aids.

- Impaired memory and learning ability: Older adults may require more time to process and learn new information.

Visual challenges affect the ability to perceive content on the screen. Older users may experience a reduced field of vision, focusing difficulties, and limited depth perception. Low contrast and small representations of text and symbols further complicate the use of mobile applications. The identified visual challenges include:

- Reduced field of vision and focusing problems: Older people perceive less light, which makes it difficult to recognize content. A slower adaptation to changes in lighting can also impair navigation in apps.
- Low contrast and small representations: Low contrast between text and background makes it difficult to read and recognize controls, reducing usage efficiency. Older adults also prefer a minimum font size of 14 pt and sans-serif fonts for mobile apps.
- Limited depth perception: This limitation can make interacting with touchscreens difficult, as users have trouble accurately judging depth and distances on the screen.

Motor challenges affect mobility and fine motor skills. Tremors or arthritis can make using touchscreens difficult, especially when touch areas are too small or too close together. Complex movements are often hard to perform, and poor hearing can further impair interaction. The motor challenges include:

- Reduced coordination and precision: These limitations often result from tremors and arthritis, making precise operation of touchscreens difficult and leading to incorrect inputs.
- Touch areas that are too small and too close together: Small touch areas require high precision, which is challenging for older users. Closely spaced touch areas increase the risk of accidental inputs.
- Complex movements: These are harder to execute and lead to frustration. Gestures such as swiping or multiple tapping can overwhelm older users if they are unsure when to use which gesture or if they have never used a particular gesture before.
- Poor hearing: Hearing impairments may make auditory feedback mechanisms less effective, impacting app interaction.

Additionally, various wishes, needs, and obstacles were identified.

- Larger icons and voice interaction: Larger icons facilitate visual recognition and operation. Voice interactions are often desired by older adults with motor impairments as an alternative input method.
- Personalized settings: Since not all older users have the same limitations, they want to be able to customize features such as font size or screen brightness. A fixed senior mode that imposes the same settings on all older adults is not ideal.
- Simple functions and labeled icons: Clear labels and simple functions improve understanding and navigation, helping users perform desired actions efficiently. Icons, in particular, can be ambiguous and should clearly indicate their functionality through labeling.
- Simple menu structures: These reduce cognitive load by simplifying navigation within the app and avoiding unnecessary complexity, which is especially beneficial for older users.
- Increase in font size to at least 12pt: This was positively received and improves readability.
- Visual effects of buttons are often not recognized: Older users have difficulty perceiving subtle visual effects, which can lead to uncertainty. Clear and distinct visual feedback is important to strengthen confidence in operation.

- Changes in operation cause uncertainty: Older users are often accustomed to existing operation patterns. Changes can cause confusion and reduce acceptance. A gradual introduction of new features with adequate explanation should be pursued.
- The "senior mode" is perceived as boring: While simple user interfaces are important, they can be seen as too functional. An appealing design with versatile features that remains clear could improve the user experience. Additionally, customizability should be maintained.

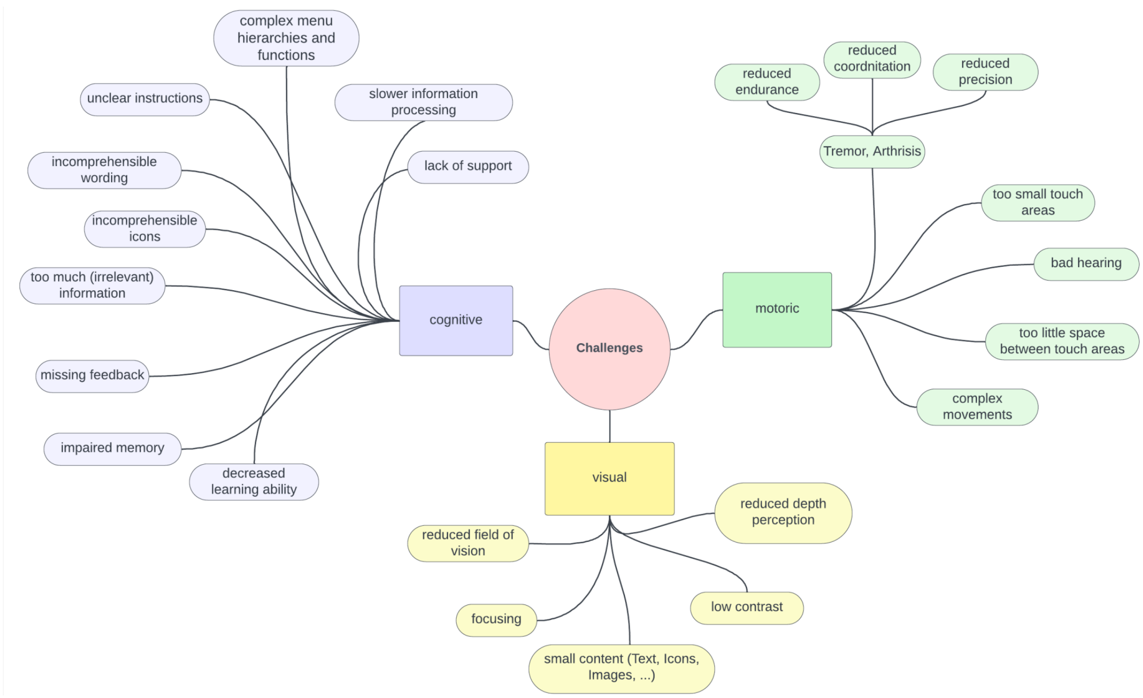

Fig. 2. Challenges

Problems	**Sources**
Complex Functions/Menus	[17, 11, 41, 6]
Too Much Content	[5, 29]
Difficult Movements	[17, 5, 11]
Color Choice and Contrast	[3, 5, 29, 19]
Lack of Help	[11, 1]
Complex Language	[1, 19]
Incomprehensible Icons	[11, 29, 42]

Table 1. Problems and Sources

Table 1 shows the identified issues, which were categorized accordingly. These categories form the basis for creating design recommendations. Main obstacles included complex functions and menus, followed by an overload of content, difficulties with (gesture) movements, color choice and contrast, lack of help, complex language, and incomprehensible icons.

The categories of the following table 2 were supplemented by usability and user experience attributes and assigned to existing heuristics where possible. Usability refers to how effectively, efficiently, and satisfactorily a user can complete tasks within a system or application. Its attributes often include ease of learning (learnability), error tolerance, and user satisfaction. In contrast, user experience (UX) extends beyond usability to encompass the user's overall perceptions and feelings when interacting with a product. UX attributes can include accessibility, desirability, and the perceived value of the interaction. While usability is a crucial component of UX, the latter also considers the user's emotional journey and broader contextual factors. The table 2 shows the corresponding assignments. Additionally, voice control was added as a feature during the correlation phase. The existing heuristics used were those by Al-Ragzan et al. [34] and Nielsen [26]. Nielsen's ten usability heuristics were chosen because they are well-known and widely used to create user-friendly designs. However, they are tailored to people without limitations and overlook the needs of older users. In this regard, we additionally consider the guidelines by Al-Ragzan et al., as they also take into account the needs of older people. Subsequently, following the template by Quiñones et al., the design recommendations were specified and formulated. The template stipulates that each design recommendation is clearly identified and rated by its priority, with importance divided into three categories: (3) critical, (2) important, and (1) useful. The design recommendations were prioritized based on their impact on usability and user experience, particularly for older users, following the methodology proposed by Rusu et al. Heuristics addressing critical aspects were given a priority level of 3 (crucial), those assessing relevant aspects were assigned a priority level of 2 (important), and heuristics contributing to overall usability were categorized as priority level 1 (useful). For example, the heuristic 'Use only simple, short movements' was considered crucial (3) due to its significant role in addressing motor difficulties faced by seniors, thereby enhancing accessibility and reducing frustration. In contrast, 'Use warm colors and high contrasts' was categorized as useful (1) as it primarily improves aesthetic preferences and user satisfaction without being essential for usability. The complete prioritization process ensured that the most impactful design recommendations were given appropriate attention based on their expected contribution to a positive and efficient user experience for older adults. Each design recommendation includes a name, a brief definition, and a detailed explanation. The specific application feature evaluated by the design recommendation is also described. To increase understanding, examples of violations and adherence to the design recommendation are defined. The expected benefits for usability and user experience upon fulfilling the design recommendation are also described. Additionally, issues related to misunderstandings of the design recommendation are anticipated. Table 3 shows the design recommendations along with their respective priorities.

Difficulty / Problem / Need	**Usability Attribute [25]**	**UX Attribute [39]**	**Related Guidelines**
Voice Interaction	Efficiency, Learnability, Memorability	accessible, usable, desirable, useful, valuable	Only senior-friendly gestures should be used [34]
Complex Functions and Menus	Errors, Learnability, Memorability	usable, useful	1) Main functions should be displayed on one page [26] 2) The app structure should be simple and consistent [34]
Too Much Content	Memorability, Satisfaction	valuable	The memory of the elderly should be utilized as little as possible [34]
Lack of Help	Learnability	accessible, usable, useful, findable, valuable	Help and Documentation [26]
Complex Language	Errors, Memorability	usable	1) The language and culture of the elderly should be used, technical terms should be avoided, use simple language [34] 2) The memory of the elderly should be utilized as little as possible [34]
Incomprehensible Icons	Errors, Learnability, Memorability	usable	Assistance in identifying, evaluating and correcting errors [26]
Complex Gestures	Efficiency, Errors	accessible, usable	Only senior-friendly gestures should be used [34]
Color and Contrast	Satisfaction	accessible	Elements should be easy to recognize [34]

Table 2. Identified Problems matching Related Guidelines. This table maps specific difficulties encountered by older adults when using mobile applications to relevant usability and UX attributes, as well as design guidelines that can help address these issues.

ID	Priority	Name
RE01	Useful (1)	Use high contrasts.
RE02	Critical (3)	Provide voice control as a complement to gesture control.
RE03	Critical (3)	Functions should be simple and clear.
RE04	Important (2)	Hide irrelevant information.
RE05	Important (2)	Offer help options on every page.
RE06	Critical (3)	Label icons.

Table 3. Design Recommendations

5 CREATION OF THE PROTOTYPES

To verify the practical applicability of the derived design recommendations, a well-known app with high design standards was selected. The mobile app Google Maps[1] in Dark Mode was chosen. With more than one billion users per month, Google Maps is the world's most popular navigation app, used in over 220 countries and territories. At least half of these users access the app via mobile devices [4].

We chose the app's Dark Mode because it has specific weaknesses in UI design that can be particularly problematic for seniors with impaired vision. For example, in Dark Mode, certain colors and shades of buttons, such as the category buttons, are less prominent than in Light Mode. This is primarily due to insufficient contrast against the dark background, making these buttons less visible and harder to use for older users. Additionally, elements that are clearly visible in Light Mode can be easily overlooked in Dark Mode. By selecting Dark Mode, we aim to identify these weaknesses and evaluate specific solutions based on our design recommendations to enhance the usability of Dark Mode for older users.

Due to its high level of recognition and the design standards of Google Material Design 3[2], this app is suitable for both evaluation and verification of practical applicability. Our analysis of the app showed that four out of the six derived guidelines are not or only partially integrated into the main view of the app. This indicates great potential for improvement regarding senior-friendly design. It can be assumed that the app's usability for older people might be reduced, leading to various usability and accessibility issues. The original app was implemented as an online prototype, and another prototype was revised with the derived design recommendations. The prototypes were created using the online tool Figma[3]. The following measures were implemented:

- **RE01:** The contrast and visibility of buttons on the home page were increased to improve visibility and usability.
- **RE03:** Buttons were given clear labels to their function to make them immediately recognizable. Unclear gesture elements (e.g., swipe gestures) were replaced with clear elements like buttons.
- **RE04:** Non-essential information was hidden by default to create a more streamlined user interface. This reduces cognitive load and makes navigation easier.
- **RE06:** All icons were provided with text labels to make their meaning understandable without additional explanations. This is particularly helpful for users who are less familiar with the symbols.

Addressing the identified challenges in the mobile app Google Maps in Dark Mode highlights the need to revise and adapt existing usability and UX attributes. Our measures aim to rectify these weaknesses. Another important aspect is considering cognitive load. Older users often struggle to process large amounts of information, especially if it is

[1] https://play.google.com/store/apps/details?id=com.google.android.apps.maps&hl=de
[2] https://m3.material.io/get-started
[3] Figma.com

not clearly structured or visually appealing. As shown in Figure 3, we standardized the buttons of the original app and did not allow dark buttons for the functions "Show location", "Adjust view", and "Plan route". The buttons were also grouped and placed together on the right side of the screen. Weather information was displayed larger to make it more recognizable. These interventions aim to simplify navigation and the visibility of information. Additionally, cognitive load is reduced, allowing users to focus on the essential functions of the app. Introducing text labels for all icons was a particularly important step, as many older users are not familiar with the symbols and their meanings. In the app, many buttons and functionalities were not recognizable, limiting usability for older people. Additionally, areas requiring horizontal or vertical swipe gestures were replaced with a button solution. Our measures demonstrate that even well-known designs can be revised through targeted adjustments and consideration of the specific needs of older users. The next pictures show two of the six original clickable german prototype Screens. The version is german because the designing and evaluation was progressed in germany.

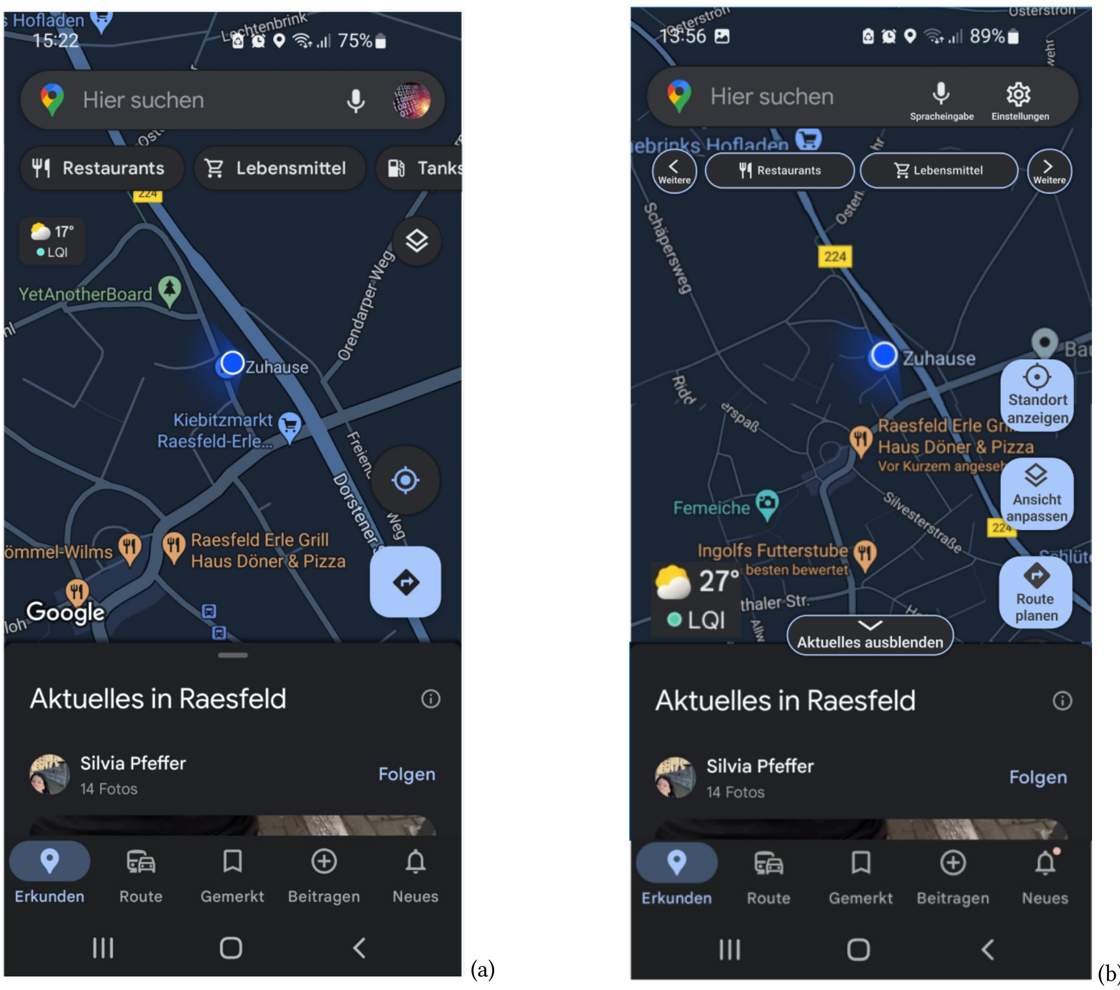

Fig. 3. Startscreens of the two prototypes which were shown to the participants. (a) Original mobile app design, (b) App with design for older people

A total of six different screens with various app states were created. The prototypes were implemented as clickable variants, but a pretest showed that switching between the online questionnaire and the clickable prototype could lead to problems. In particular, issues arose when participants misclicked and then, due to frustration, abandoned the study. To avoid this problem, we integrated the screens as image files in the online questionnaire. Participants were instructed to imagine themselves using the app live for each task and to consider which element they would tap. This approach proved to be much more suitable for our study. The next step is to verify whether there are differences in the usability of both prototypes for older people.

6 EVALUATION AND VALIDATION OF THE RECOMMENDATIONS

The evaluation was conducted as an online study with a between-subjects design, where each participant tested one of the two prototypes. Participants aged 60 and above were surveyed over a period of 14 days. Participants were recruited by distributing the online study link, for example, through advertisements in senior homes, fitness centers for older adults, or community centers. When a participant clicked on the online link, they were randomly assigned to either the original or the revised prototype. The random generator ensured an equal distribution, creating two equally sized groups.

Ten tasks were defined and formulated for the test (e.g., Hide information, Navigate to the app settings). Participants then rated on a Likert scale from 1-7 how easy or difficult they found the task (1 = very difficult, 7 = very easy). Additionally, for each task, participants were asked whether they believed they knew the correct solution (I know exactly what to do, I am not sure, I need help). Subsequently, the correct solution was shown, and participants were asked if their solution matched the correct one (Yes, No). At the end of the evaluation, a series of questions about visual clarity, information presentation, user-friendliness, and overall impression were asked. The study was conducted with (N = 60) participants, of whom 40% were male, 48% were female, and 12% did not specify their gender. The average age of the participants was 65.7 years, with 55% being 60-64 years old, 40% being 65-74 years old, and 5% being 75 and older. Tables 4 and 5 provide an overview of this data.

Gender	**Percentage**
Male	40%
Female	48%
No Information	12%

Table 4. Gender

Age Distribution	**Percentage**
60-64 years	55%
65-74 years	40%
75 and older	5%

Table 5. Age Distribution

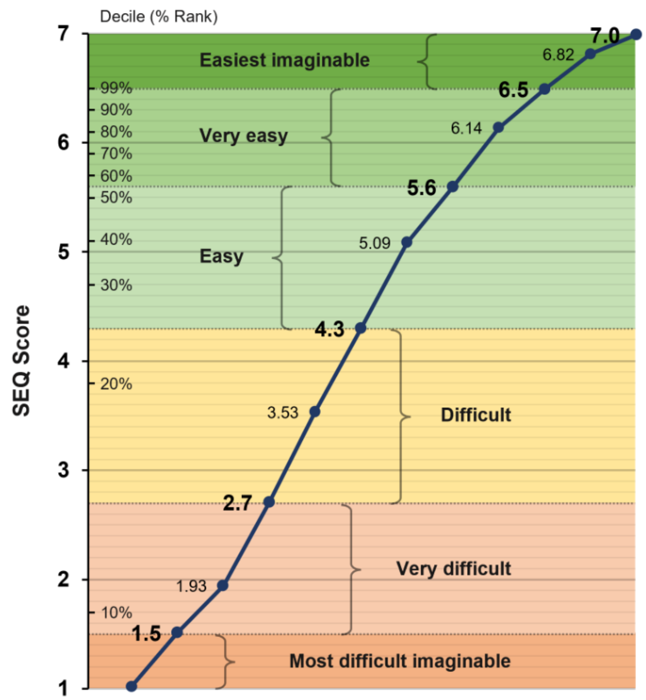

Fig. 4. SEQ Score Ranks [36]

To determine usability, the SEQ Score was used. The Single Ease Question (SEQ) is a measure of perceived usability, used to evaluate the user-friendliness of a website, application, or system [28]. Figure 4 illustrates the different levels of perceived usability. The diagram shows SEQ scores from 1 to 7, divided into six categories ranging from "Most difficult imaginable" to "Easiest imaginable." These categories provide an intuitive assessment of usability by helping users to easily categorize their experiences. The scale is divided into various sections that reflect the perceived difficulties or ease of the user experience. This representation helps to quickly identify the usability level of an application from the users' perspective, thereby facilitating the identification of optimization potential.

The statistical analysis of the SEQ Score, which can also be found in the following table 6, shows that the revised prototype was superior to the original. In particular, the display of information, navigation to the app settings, and finding the "center location" and "adjust map view" functions showed differences in usability ratings. This was mainly due to the fact that the buttons and icons in the original app were not labeled and important functionalities were not adequately recognizable. The revised prototype had all important functionalities uniformly placed and labeled. Additionally, the buttons had increased contrast as they were standardized in the bright primary color, making them easier to find.

Task	Original	Revised
Display information	4.29	5.22
Hide information	3.82	6.34
Navigate to voice control	4.71	5.53
Navigate to keyword "coffee"	5.43	5.94
Start route search	5.14	5.94
Set pedestrian mode	6.68	6.63
Navigate back to the main page	6.46	6.47
Function: Center location	4.64	6.09
Function: Adjust map view	4.57	6.06
Navigate to app settings	3.61	6.47

Table 6. Comparison of Usability Ratings

Table 7 provides an overview of the final questions. The evaluation of the final questions was also conducted on a 7-point Likert scale (1 = very poor, 7 = very good). It was found that visual aspects (e.g., visibility of information, comprehensibility of icons) were rated better on the revised prototype (*M* = 5.51; *SD* = 1.32) than on the prototype with the original design (*M* = 4.87; *SD* = 1.15). The presentation of information (e.g., recognizability of information) was rated slightly better on the revised prototype (*M* = 5.62; *SD* = 1.33) than on the prototype with the original design (*M* = 5.21; *SD* = 1.31). Usability (e.g., intuitiveness, satisfaction, recognizability of functions) was rated better on the revised prototype (*M* = 5.4; *SD* = 2.1) than on the prototype with the original design (*M* = 4.7; *SD* = 1.1). The overall impression showed that users had a better impression of the revised prototype (*M* = 5.7; *SD* = 1.3) than of the prototype with the original design (*M* = 5.0; *SD* = 1.2). These results suggest that the design changes made had a positive impact on the user experience.

Parameter	Original	Updated
Visual Clarity	4.87	5.51
Information Presentation	5.21	5.62
Usability	4.7	5.4
Overall Impression	5.0	5.7

Table 7. Ratings of the Final Questions

The statistical analysis also showed that 80.3% of the participants in the revised prototype assumed that they definitely knew the solution to the tasks set, 15.6% were sometimes a little unsure and only 4.1% needed help with a task. In the prototype with the original app, only 53.2% were sure they knew the solution, 33.6% were partially unsure and 13.2% could not get any further without help. This shows that older people would need up to 3 times more help with the original app than with the app with the integrated design recommendations. The following table 8 shows the data.

Category	Prototype 1 (Original)	Prototype 2 (Updated)
I know exactly what to do	53.2%	80.3%
I am unsure	33.6%	15.6%
I need help	13.2%	4.1%

Table 8. Comparison of Solution Confidence between Prototype 1 (Original) and Prototype 2 (Updated)

In addition to these findings, we investigated how often the planned behavior of the users actually corresponded to the correct solution. It turned out that only 66.1% of participants had planned the correct solution in the original prototype. In the revised prototype, a full 93.1% of the planned solutions also corresponded to the actual solution. It can therefore be assumed that the operation of the revised prototype is way more intuitive, which should have a positive effect on learnability and usability, but this would have to be investigated in a further study.

Parameter	Prototype 1 (Original)	Prototype 2 (Updated)
Planned correct solution	66.1%	93.1%

Table 9. Comparison of Planned Correct Solutions between Prototype 1 (Original) and Prototype 2 (Updated)

The conducted evaluation demonstrates the effectiveness of the design recommendations regarding usability. The choice of a between-subjects design, where each participant tests one of the two prototypes, ensures a robust data foundation for assessing usability and user experience. Recruiting participants through targeted advertising in senior homes, fitness centers, and community centers for older adults ensured that the study included a representative sample of the target group aged 60 and above. The study methodology, including ten specific tasks and the use of a Likert scale to assess the SEQ Score, highlighted where older adults faced any challenges with the app and how these issues could be resolved through design recommendations. The high agreement between the planned solutions and the actual solutions in using the revised prototype indicates improved intuitiveness and usability. The statistical analysis, which revealed that 93.1% of participants correctly completed tasks with the revised prototype (compared to 66.1% with the original version), confirms an improvement in the revised prototype. This supports the assumption that the design recommendations enhanced the app's operability and learnability. These findings indicate a clear positive impact on usability for older adults, as demonstrated by the increased task success rate, higher confidence levels, and reduced need for assistance.

7 DISCUSSION

The findings of this study highlight the urgency of adapting mobile applications to the specific needs of older users. This necessity is underscored by the identified cognitive, visual, and motor challenges, which are frequently mentioned in the literature [27, 8, 34]. The derived design recommendations specifically address the highlighted issues and were practically transferable to an app with high design standards. Notably, the measures RE01 (use of high contrasts), RE03 (Functions should be simple and clear.), RE04 (hide irrelevant information), and RE06 (label icons), which we tested, were validated and achieved a more senior-friendly design. It is noteworthy that many participants were already familiar with the original interface of the application. Despite this familiarity, our results demonstrated that the revised prototype still led to considerable improvements in usability and user experience. This finding underscores the value of targeted design recommendations that can enhance even well-established interfaces, making them more accessible and user-friendly for older adults. Our results support the research by Nurgalieva et al. [27], which also emphasizes the importance of high contrast, clear function recognition, and the avoidance of irrelevant information. These interventions mainly improved the user experience for older adults. Our investigation shows that the labeling of icons and buttons was the least considered in the app we selected, Google Maps. The measures RE02 and RE05, which were already integrated into the original app, showed no separate effect in the revised prototype, highlighting the importance of further research to validate these measures. The necessity of these measures is also supported by Al-Razgan et al. [34], who emphasize the relevance of understandable language and clear user guidance. The post-hoc analysis of our results showed that the identified effects are very likely (Total Power 0.97 = 97%) to be true effects. Building on these findings, it is still recommended to investigate the long-term effects of the implemented design changes in general and also for the light mode, and to evaluate the applicability of the recommendations in different cultural and technological contexts. Additionally, it is important to develop and use advanced methods for the empirical validation of the effectiveness of usability and accessibility improvements [38]. Future studies should include a broader and more diverse participant base to increase the robustness and transferability of the developed recommendations. Overall, we emphasize the importance of a conscious and needs-oriented design of mobile applications, which can contribute to improving the digital inclusion of older adults. Through targeted design adjustments, developers can create more effective and inclusive technologies that enhance the quality of life for an important user group [32]. This confirms the assumption that the revised design recommendations enhance the app's operability and learnability. Thus, it is evident that the well-known and widely accepted mobile app Google Maps in its Dark Mode version cannot automatically be considered senior-friendly through the Material Design 3 standard alone, but improvements were achieved through additional design guidelines. Our results support the thesis that senior-friendly adaptations can enhance usability and the user experience for older adults. A standard design approach is insufficient to meet the unique needs of older users. Tailoring mobile applications specifically for this demographic is essential to ensure their digital inclusion and enhance overall usability. Our independent findings and the results of the research by Nurgalieva et al. overlap in many areas, which emphasises the relevance and topicality of these issues. This further underlines the importance of considering the specific needs of older adults when designing mobile applications. In addition to the improvements demonstrated in our prototype, other widely used apps like WhatsApp, Facebook, YouTube, and PayPal also display potential for enhancing usability for older users. A common usability issue across these platforms is the lack of labeled icons in the header bar. Without descriptive labels, older users may struggle to recognize the functionality of these icons, leading to confusion or hesitancy in using certain features. Applying our design recommendations, such as RE03 (Functions should be simple and clear) and RE06 (labeling icons), could significantly enhance the user experience on these apps by making functionalities more easily recognizable and reducing the learning curve for older adults.

7.1 Limitations

Despite the positive results, this study has some limitations. First, the sample size was relatively small, with 60 participants, which limits the generalizability of the results. Second, the study was conducted as an online survey, meaning that the actual interaction with the app could not be fully simulated. Third, the selection of the Google Maps app and the focus on the Dark Mode may limit the transferability of the results to other apps and usage contexts. Finally, the design recommendations were tested in a controlled environment, meaning that further studies in real-world usage scenarios are necessary to confirm practical applicability.

8 CONCLUSION

This study has shown that targeted adjustments in the design of mobile applications can achieve great improvements in the usability and satisfaction of older users. Notably, the recommendations for using high contrast, clear and simple functions, hiding irrelevant information, and labeling icons stand out. These measures influence the operability and user experience. The evaluation of the revised prototypes demonstrated that the implemented design recommendations led to a more intuitive and user-friendly interaction that allows users to complete tasks naturally and without confusion. The higher visibility and comprehensibility of the elements contributed to older users completing tasks with less uncertainty. Specifically, the clear labeling and reduction of cognitive load through clear and relevant information led to an improved user experience. An important finding of the study is the recognition that even applications with high design standards like Google Maps can be further improved through targeted adjustments. This underscores the necessity of continuously evaluating and adapting existing applications to the specific needs of older users. Moreover, these recommendations are not limited to a single application. they can also be applied to other popular apps used by older adults, such as WhatsApp, Facebook, YouTube, and PayPal. A key area of potential improvement across these platforms is the lack of labeled icons in header bars, which can hinder ease of use for older users. Overall, future research should continue to explore the implementation of these design recommendations across different applications and cultural contexts, ensuring that the digital world becomes more inclusive and accessible for all users.

9 OUTLOOK

Several important aspects arise for future research and development. First, the developed design recommendations should be tested in various application contexts and with a broader demographic base to ensure their general applicability and robustness. The long-term effects of the implemented design changes should be investigated to ensure sustainable improvements in the user experience. We also recommend considering not only quantitative but also qualitative aspects of the user experience in the future to obtain a comprehensive picture of interaction quality. Finally, it is important to promote collaboration between developers, designers, and older users to ensure that the developed technologies truly meet the needs of this growing user group. In conclusion, the conscious and needs-oriented design of mobile applications can contribute to influence the digital inclusion of older adults. Developers are encouraged to integrate these findings into their practice, thereby creating more inclusive technologies that enhance the quality of life for a growing and often neglected user group.

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