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Mobile interfaces for caregivers and older adults: Iterative design of the LifeTomorrow Ecosystem with aesthetic and functional considerations

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Abstract: As the population of older adults increases, so does the demand for technology that supports caregiving and aging in place. Smart home technology, wearable health trackers, and mobile applications have all been identified as possible methods of support. Studies on the user interfaces of these technologies have predominantly explored how well their features and functions address the complex needs of older adults and caregivers. However, many of these applications lack adequate consideration of visual design principles and aesthetics. The present study aims to illustrate the iterative design process of the LifeTomorrow Ecosystem which includes two applications: one for caregivers and one for older adult care recipients. The results include high-fidelity screens from the applications that incorporate functional and visual design principles, as well as the feedback of older adults, caregivers, and designers. Finally, we provide recommendations for designers to consider when designing applications targeted at older adults and their caregivers.

Keywords: Caregiving; Aging in Place; User Interface Design; User Involvement

1. Introduction

Many older adults wish to age in place (i.e., stay in their homes as they age) and often require support from family members to do so (Davis, 2021). Some technologies exist to support the independence of older adults at home and their informal caregivers. Current research is focused on understanding the needs of caregivers and how emerging technologies can be utilized to address their challenges. Older adults and their true needs and wishes, conversely, are often underrepresented in digital technology research (Greenhalgh et al.,

2013), despite the rate of technology adoption by older adults increasing considerably over the past decade (Faverio, 2022). Applications that support care recipients and caregivers focus more on addressing functional demands and neglect expectations beyond basic needs. Therefore, this paper aims to outline the design of LifeTomorrow, a system comprised of a pair of applications for caregivers and care recipients that addresses the holistic needs of each user group, with an emphasis on visual and interaction design.

The needs of caregivers are often related to emotional health, physical health, receiving help from others, and information on their care recipient's condition (Quelez et al., 2020; MIT AgeLab, 2021; MIT AgeLab, 2022). Meanwhile, the needs of care recipients are associated with receiving support in accomplishing activities of daily living (ADLs), like eating, bathing, and mobility, as well as instrumental activities of daily living (IADLs), like transportation, shopping, and managing medications.

Mobile technologies and telehealth applications support caregivers and care recipients in addressing their care needs by providing access to social media, information, video conferencing, messaging, and an interface to smart home technologies (Quinn et al., 2018; Faieta et al., 2021). Several examples of caregiving applications aim to address the complex needs associated with caregiving (Brown et al., 2016; LaMonica et al., 2021). One study investigated the feasibility, use, utility, and areas for refinement of a web-based and Android™ app called CareHeroes, designed to support informal caregivers of loved ones with dementia (Brown et al., 2016). This study concerned itself with the application's possible features and related utility, emphasizing caregivers and primary care providers. The researchers followed design heuristics outlined by the National Institute on Aging and National Library of Medicine in a pamphlet called "Making Your Web Site Senior Friendly: A Checklist" (2002) to guide their visual design of the application. The literal translation of design guidelines, such as using white lettering on a black background, led to an interface that focuses heavily on legibility and simplicity with less attention to aesthetics and engagement (see figure 1.a). Smartphone applications with interfaces designed for older adults also demonstrate a lack of proper consideration and implementation of visual design principles (Petrovčič et al., 2018). Researchers conducted a heuristic analysis on 12 smartphone launchers with adapted user interfaces for older adults (Petrovčič et al., 2018) (see figure 1.b). They found that the heuristic of visual design was frequently violated due to using too many colors on one screen, lacking sufficient contrast for readability, and lacking simple and meaningful icons.

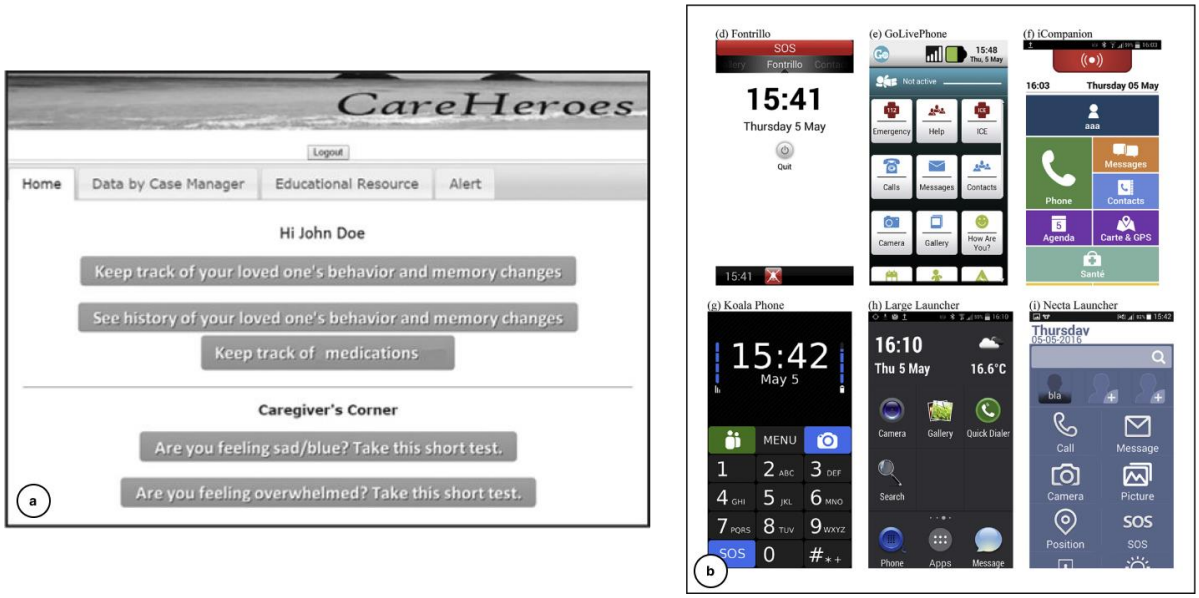

Figure 1 A screenshot of the CareHeroes web app (a), which demonstrates the various features and the elementary application of design heuristics for older adults (Brown et al., 2016) and several examples of user interfaces for older adults evaluated by Petrovčič et al. (2018) (b).

Several barriers to adopting caregiving support technologies have been identified in past studies. One systematic review examined 44 empirical studies and found that privacy, trust, functionality/added value, cost, ease of use, perception of "no need," suitability for daily use, stigma, fear of dependence and lack of training were all considered barriers to adoption of assistive technologies by older adults (Yusif et al., 2016). Another study sought to understand the facilitators and barriers to adopting health information technologies in older adults who identified as supportive others (e.g., a family member, a caregiver) (LaMonica et al., 2021). The researchers engaged these older adults in a participatory workshop to compile a list of facilitators and barriers that influenced the design of a care platform called the InnoWell Platform. Some participants indicated that "they were more likely to use a digital tool that had a good user experience and design" (p. 10).

In recent studies on technology acceptance, researchers have integrated "Perceived Enjoyment" as a determinant of a system's perceived ease of use (Venkatesh & Bala, 2008). "Perceived Enjoyment" is defined as "The extent to which the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use" (Venkatesh 2000, p. 351). Perceived ease of use has been hypothesized to be a fundamental source of user acceptance of systems (Davis, 1989). Similarly, research has demonstrated that the aesthetics of a user interface can influence its user's perceived usability ratings (Kurosu & Kashimura, 1995) and post-use usability ratings (Tractinsky, 2000). Schlatter and Levinson, in their book *Visual Usability: Principles and practices for designing digital applications* (2013), coin a meta-principle of interface design called "Personal-

ity," which incorporates the visual aspects affecting how a user perceives a system. Accordingly, the aesthetics of a system and how enjoyable it is to use is a valuable area of focus for designers to explore in the space of technologies that support caregiving and aging in place.

Standard interface design guidelines include recommendations on layout, scale, balance, contrast, color, type, imagery, and affordances (Watzman, 2002; Schlatter & Levinson, 2013; Gordon, 2020). More specific design guidelines have been compiled to support designers in creating technologies that address older adults' unique needs and abilities (Morris, 1994; Farage et al., 2012; Cho & Kim, 2014). These guidelines aim to supplement general interface design principles recommended for a design regardless of its target user demographic. Morris (1994) systematically translates older adults' physical, visual, and cognitive characteristics into visual design recommendations for computer interfaces. For example, this study notes that color sensitivity decreases in adults over 70 and recommends choosing color combinations that don't require the user to distinguish between colors of shorter wavelengths, like blue and green (Morris, 1994). Guidelines that extend beyond functionality and usability are outlined in Shneiderman's (2004) work, where it is written that designers should engage users with fun features that do not interfere with goal attainment, such as alluring metaphors, compelling content, and attractive graphics.

Research reveals that stakeholders agree on the necessity of prioritizing the needs and preferences of older adults in the development and deployment of new technologies that support aging in place (Peek et al., 2016). To select appropriate design guidelines and promote the adoption of new technologies, human-centered design (HCD) methodologies provide a deep understanding of users' preferences through their continued involvement in the design process. Utilizing this approach, researchers have employed qualitative methods such as user interviews and focus groups to develop novel financial planning services (Lee et al., 2023) and a comprehensive web-based tool that supports active aging—i.e., maintaining autonomy in health, social engagement, and security (Doménech et al., 2013).

Studies on application design for older adults, caregivers, and care recipients have been dominated by research questions related to usability and functionality. This means few studies explore themes of user experience (UX) and visual design and how these elements might interact with the applications' effectiveness or the users' satisfaction. In cases where user interface (UI) and visual design are considered, there is an exaggerated focus on simplicity and readability without proper attention to preferences and appeal. Many apps designed for caregiving or health-related functions are also intended to support situations where the care recipient experiences dementia. This results in a lack of research on the visual design preferences of older adults without dementia or other serious medical conditions, specifically for applications that support caregiving or aging in place. Similarly, there are few systems that enable older adults and caregivers to support themselves while also connecting the two groups together. There is an opportunity to provide support for older adults who wish to age in place and for informal caregivers via a single system which caters to both groups' functional and aesthetic preferences.

The present study aims to illustrate how an iterative design process with user involvement and an emphasis on UI design could inform the design of applications specific to older adults and their caregivers that combine established design guidelines with modern user preferences to create a more enjoyable user experience.

2. The LifeTomorrow Ecosystem and design framework

The LifeTomorrow Ecosystem comprises of two applications to support older adults and their informal caregivers. Each app interface targets one user group to better address their unique needs. The first application is intended for an iPhone and targets informal caregivers. The second application is designed for an iPad and targets older adults. The functions and features of the applications were determined based on the needs of each user group documented in previous research and the LifeTomorrow study at the MIT AgeLab.

The iPad application for older adult care recipients enables users to track and monitor personal health data recorded by an Apple Watch or entered manually. The app also allows users to monitor the status of smart home sensors selected to be part of the LifeTomorrow system. Lastly, the app enables users to share access to their health information with caregivers. Visual design elements supporting these functions include clear iconography, visual hierarchy of information, high-contrast color choice, and empowering imagery.

The iPhone application for informal caregivers enables users to connect and message other informal caregivers, find local resources, review educational content specific to caregiving, and monitor shared care recipient information. The visual design of this application sought to create a familiar experience for caregivers who use apps like Google Maps or messaging platforms like iMessage or WhatsApp. Other visual elements include a block system for content grouping reminiscent of iPhone widgets. All photos used in the interface designs were sourced from the free-to-use and open-source websites Unsplash.com and Pexels.com, and all icons were gathered from the free-to-use website Phosphoricons.com.

We followed the iterative design process defined by the Nielsen Norman Group (Gibbons, 2016) to design the LifeTomorrow applications. Accordingly, we ideated and prototyped the applications and conducted two rounds of usability tests and qualitative interviews with caregivers, care recipients, and designers (see figure 2).

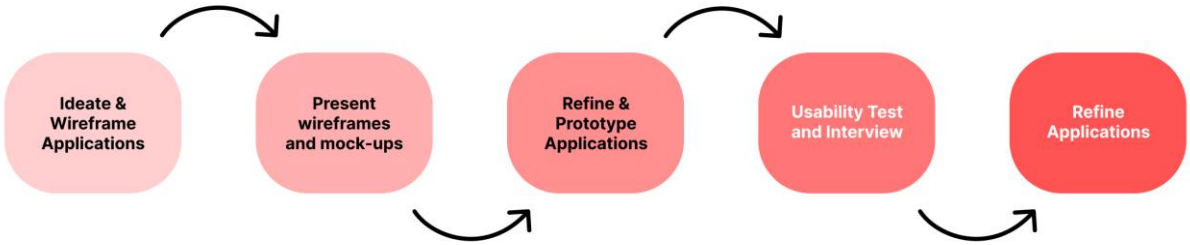

Figure 2 The high-level process followed during the study. The process included an initial design, two rounds of user testing, and two rounds of subsequent design refinement.

3. Initial interface design

The initial application designs aimed to translate functions and feature requirements into a user interface guided by established design heuristics, with particular emphasis on blending accessibility guidelines with visual design guidelines.

3.1 Design of the caregiver application

The initial interface for the caregiver application consists of mid-fidelity wireframes that represent each major function and feature (see figure 3). These wireframes aimed to illustrate how relevant information could be presented in a modern yet simplistic layout. Another intention for the design was to build on the mental model of other applications that smartphone users may be familiar with, such as the widgets page on iPhones with recent iOS and popular maps applications like Apple or Google Maps.

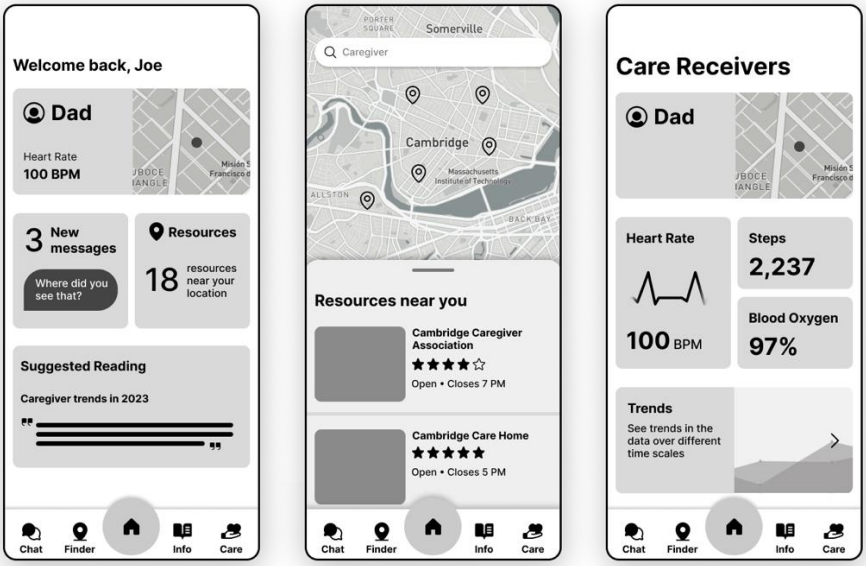

Figure 3 A subset of the interface screens including the caregiver application's homepage, resource finder, and care pages (left to right). The homepage highlights information such as the location of the care recipient, a shortcut to new messages, and a suggested reading.

3.2 Design of the care recipient application

The mid-fidelity mock-ups of the care recipient application demonstrate an initial attempt to apply interface design guidelines for older adults to a novel application that blends health and smart home information (see figure 4). The design includes clear iconography, large buttons, linear navigation, and contrasting call-to-action buttons. Together with principles of visual design such as balance and hierarchy, the pages represent a concise yet modern look while maintaining the function and essential features.

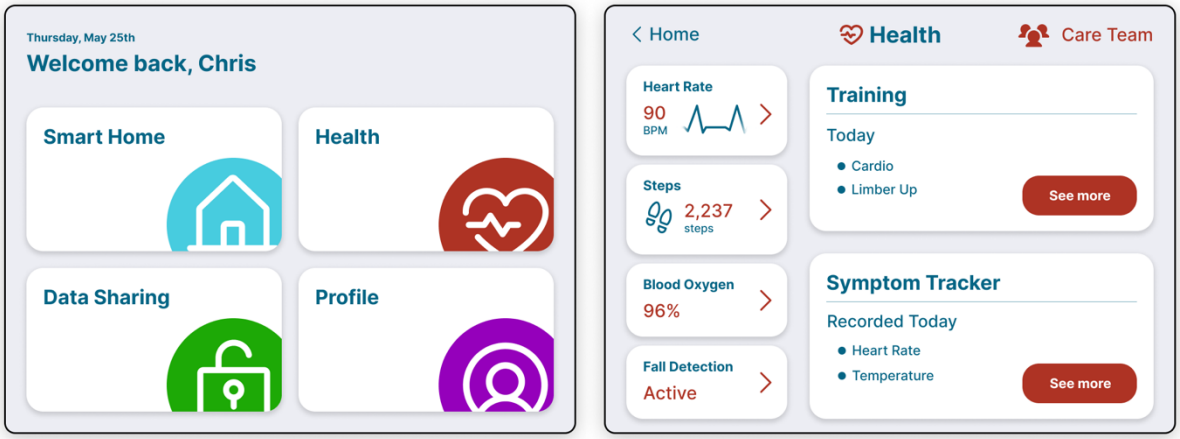

Figure 4 A representative subset of the initial mock-ups for the care recipient application home page and health page (left to right).

4. Gathering user feedback and refining the prototype

For the first round of user testing, we recruited 19 participants: two female and two male older adults (80-92 years old), four female and four male caregivers, and five female and two male designers (23-35 years old). The caregivers were not asked to provide their age during this round of user interviews. The older adults were only required to provide feedback on the care recipient interface, while the caregivers were only asked to give feedback on the caregiver application. The designers provided feedback on both applications. The goal of this round of user testing was to explore preliminary thoughts on the visual design of the applications. To accomplish this goal, we presented the screens to participants on the relevant device and asked open-ended questions regarding the visual design, usefulness, and available features. Open-ended questions pertained to the perceived usability of the system and then transitioned into more detailed questions on the interfaces' iconography, color, layout, and text.

4.1 User feedback and changes to the care recipient application

Interview results revealed that older adults were pleased with the clear presentation of information on each page. Some participants also noted that important information was highlighted and easily visible. Others shared that they felt the system was simple and easy to use. In contrast, participants expressed concerns about the color palette of the application. Some reported that colors were harsh on the eyes or did not provide enough contrast with the text on top. Additionally, some buttons were thought to have an ambiguous function due to their placement on the screen or their associated label. Interview results from our conversations with designers revealed that the interface felt playful, and that information was direct, clearly presented, and thoughtfully laid out. Designers also noted that the font size and weight were appropriate for an older user group. In addition, one designer ex-

pressed that the overall design was familiar and intuitive. One repeated concern among designers was the low contrast of words on some background colors and the small size of several icons.

Several changes were made to the care recipient application to address the comments made during the interviews. For example, the home screen was reworked so that the buttons for the primary features were resized in accordance with a more accurate hierarchy of importance (see figure 5). This also reduced the color palette on the homepage. In addition, photos were added to provide friendly and empowering visuals to the interface. The Data Sharing page was consolidated so that users could access data sharing privileges and contact information from one screen instead of navigating back and forth across different screens to access the same information.

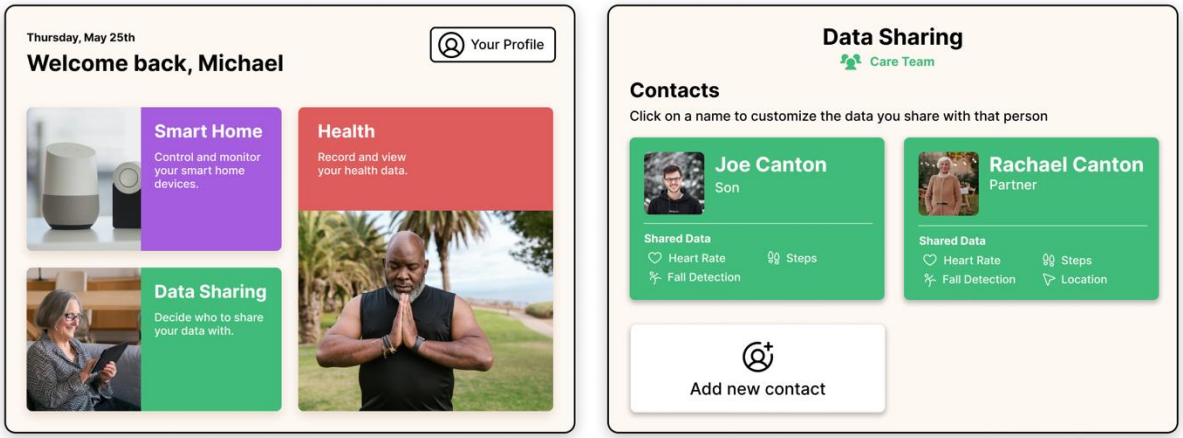

Figure 5 Screenshots of the home page (left) and data sharing page (right) from the second iteration of the care recipient application. These screens feature a warmer background, straightforward text that illustrates the functionality, and empowering imagery.

4.2 User feedback and changes to the caregiver application

Interview results for the caregiver application reveal that participants found the app's design familiar. Multiple caregivers noted that elements such as the interface's iconography and the finder page's layout were like other applications they had experience with. One caregiver said, "It reminds me a lot of the iPhone app design… It wouldn't require me to learn anything new." Issues with the visual design raised by caregivers were mainly related to the lack of color in the grey-scaled wireframes presented to them. These would be addressed in further iterations. One designer suggested larger profile images to support faster recognition of familiar faces. Another designer recommended that we ensure the white space between visual elements is uniform.

Changes to the visual design of the caregiver application included adding color, increasing the size of profile images, and introducing more information about the care recipient di-

rectly on the home screen (see figure 6). In addition, we made the white space between visual elements more standard so that the screens appear less crowded with information and the visual hierarchy is directed more by the size of the elements.

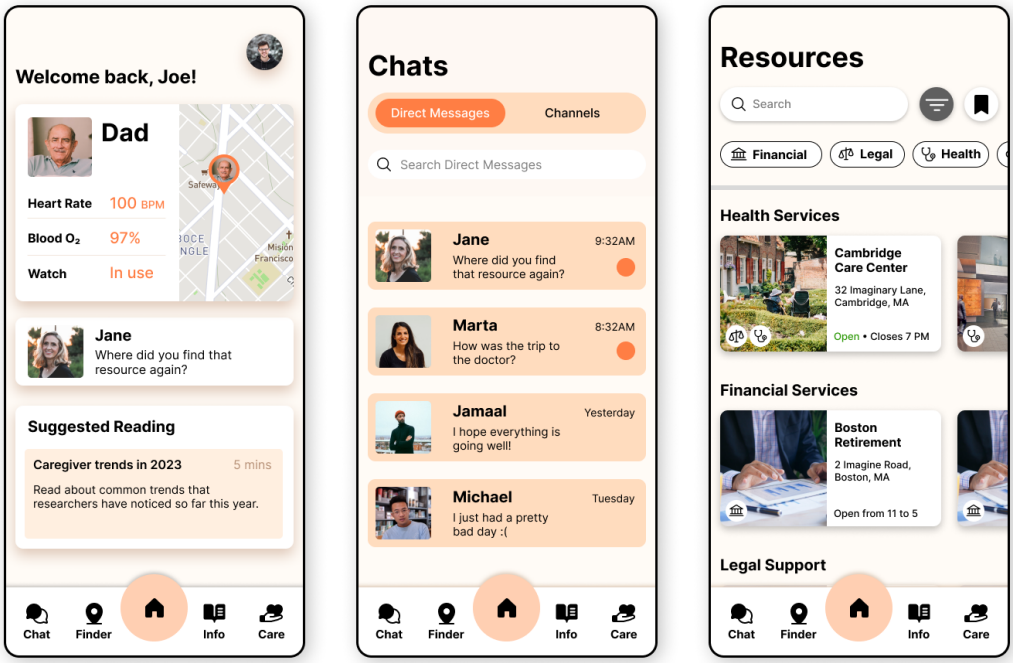

Figure 6 The refined home screen (left), chat page (middle), and resources page (right).

5. Evaluating the improved interface

For the second round of interviews, we prototyped the refined screen designs so that the users could interact with the interface while also answering our questions. We interviewed 18 participants, including eight female and one male older adult (68-92 years old), five female and one male caregiver (24-60 years old), and two female and one male designer (25-34 years old). The procedure for the interview included starting with a description of the application, which was followed by a set of tasks for the participants to complete. These tasks required navigating the application to find specific information, such as finding health data and sharing it with a caregiver. Participants were asked to fill out the System Usability Scale (SUS; Brooke, 1996) immediately after exposure to the application screens. This questionnaire requires participants to assess statements about the system and rate how strongly they agree or disagree with each. Statements they were asked to rate included “I think that I would like to use this system frequently,” “I thought the system was easy to use,” and “I found the various functions in this system were well integrated.” We then asked participants to explain their thoughts on each rating.

Further, we questioned them on how the application's visual design may have influenced their decisions if they discussed visual elements like color, layout, text, and aesthetics. To

support the discussion, we revisited each screen individually. We asked questions that allowed participants to discuss what they liked and disliked about the improved interface, if they would use it themselves, and if they would recommend the application to a friend.

5.1 User feedback to the improved care recipient application

In general, older adults reported that they liked how the use of color denoted which function or page they viewed in the application. One older adult, referring to the entire experience of using the prototype, said, "It's very clean, pleasing on the eye." One suggestion was to add icons to all health data categories on the health page to support easier scanning of the available information. Another suggestion was to make the function of some buttons more straightforward. For instance, some participants were unaware that they could view the historical data associated with a health data category, like heart rate, by simply tapping the button that displayed the current information. The mean SUS score across our nine older adult participants was 90.3 out of 100 (n=9). This score suggests a high degree of usability, which was further supported by participant's comments.

Results of the interviews with designers revealed that the large buttons, bold font, and large blocks of content were considered strengths of the design. In general, designers liked the overall design of the caregiver application. One suggestion was to utilize color to signal the status of the sensors on the Smart Home page. Another suggestion was to reduce the prevalence of primary theme colors on each page because it was believed that they might overwhelm users, particularly on the Health Page.

5.2 User feedback to the improved caregiver application

Caregivers reported finding the interface familiar even after adding details like color and imagery. They also liked the clarity of information, with some describing the interface as "clean." Some participants noted that the information layout and navigation were easy to understand and not overly complex. In addition, one caregiver and designer shared that they appreciated the static and constantly present search bars at the top of many pages. Specifically, they believed this would eliminate a barrier to searching for content for some users, given that they won't need to navigate to a separate search feature. Across the 6 caregivers, the mean SUS score was 79.2 out of 100 (n=6). This reveals that the caregiver app was perceived to have acceptable usability but that there is still room for meaningful improvement. For instance, one suggestion was to rename the Resources page to more closely match the meaning evoked by the associated icon in the menu bar.

Similarly, one participant expressed that they associated the Resources page menu icon with a map, but the first screen of the Resources page does not look like a map feature. Only after a user taps on a particular resource can they view a map visualization of that resource's location. Another suggestion was to clarify the distinction between direct messages and channels on the Chat page. Some participants were unsure what the channels tab would represent until they explored that subpage.

Results from interviews with designers revealed that the application utilized color, text, and layout effectively. One designer shared that the warm orange tones in the color palette created a welcoming feeling and that the app appeared free of visual and informational clutter. Another designer shared that page headers were large and clear. One suggestion for improvement was to ensure the contrast of the text in relation to the background color was sufficient for caregivers who may have poor visual acuity. Another designer suggested that the Resources page and the Information page could be condensed into one page, indicating that the distinction between the content needed to be clarified.

6. The final interface designs

After the second round of interviews, changes were made to both application interfaces based on the user and designer feedback.

6.1 The care recipient interface

The final design of the care recipient application sought to address the concerns of older adults and designers, specifically to make all buttons and functions clearer through iconography and text and to use theme colors sparingly to support visual hierarchy and reduce visual complexity. The final design presented in this paper reveals changes to the layout of pages like the Health page and larger, color-coded icons on the Smart Home page (see figure 7). The Health page now dedicates more visual space to the four key health indicators and reduces complexity by minimizing the shortcut functionality of the Training and Symptoms features. These changes improve the visual balance and white space of the page. The size of the icons on the Smart Home page was increased, and their colors were selected to indicate the status of each sensor quickly. The design also includes consistent block-style layouts, which act as large touchpoints for older adults who may experience poor fine motor skills. Finally, the color palette for the entire interface was modified to better support colorblind users.

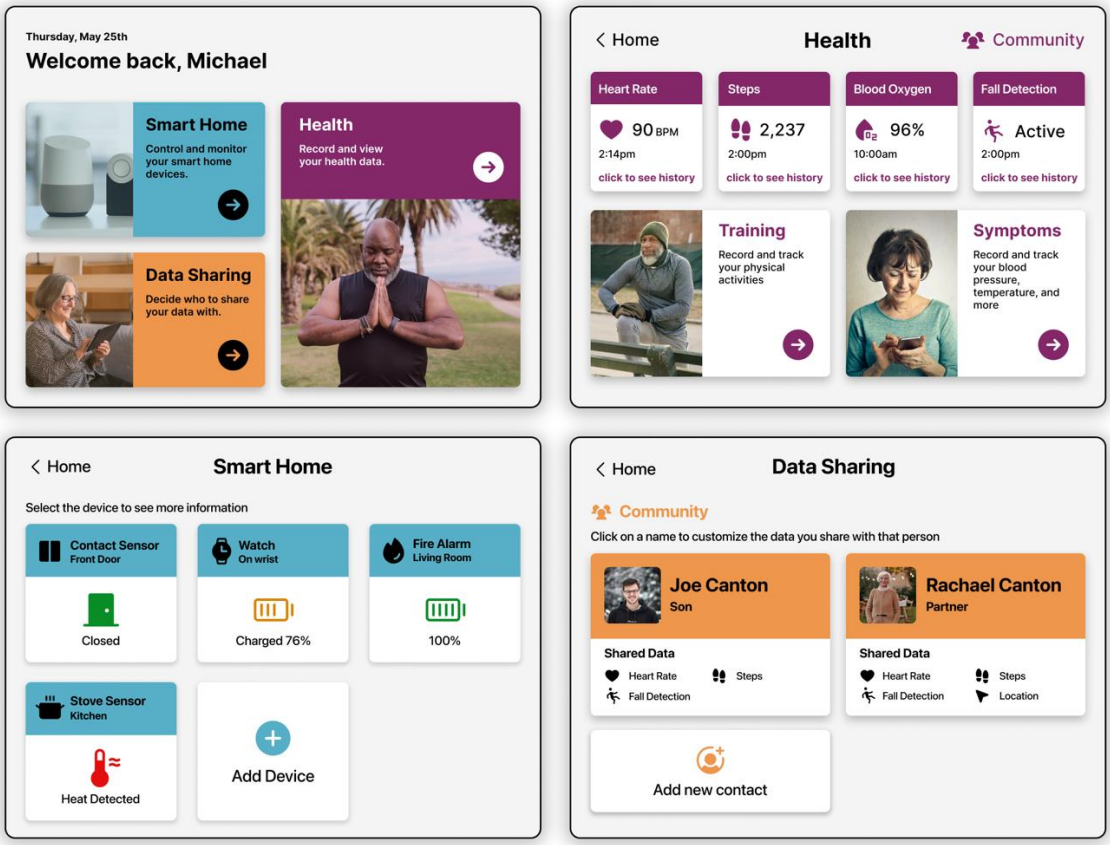

Figure 7 The latest version of the Home Page (Top left), the Health Page (Top right), the Smart Home Page (Bottom left), and the Data Sharing Page (Bottom right). These pages demonstrate an improved use of color and iconography that supports visual hierarchy.

6.2 The caregiver interface

The final presented design of the caregiver application seeks to address confusion regarding the functions of pages and features while effectively using layout, color, and text (see figure 8). We changed the title of the Finder page to Discover. To help avoid confusion with a map feature, we also changed the menu icon from a map location marker to a pair of binoculars. We also changed the name of the Information page to the Learn page to further distinguish this feature from the Discover feature. Lastly, the color palette was adapted to maintain contrast and appear more cohesive with the interface of the care recipient application.

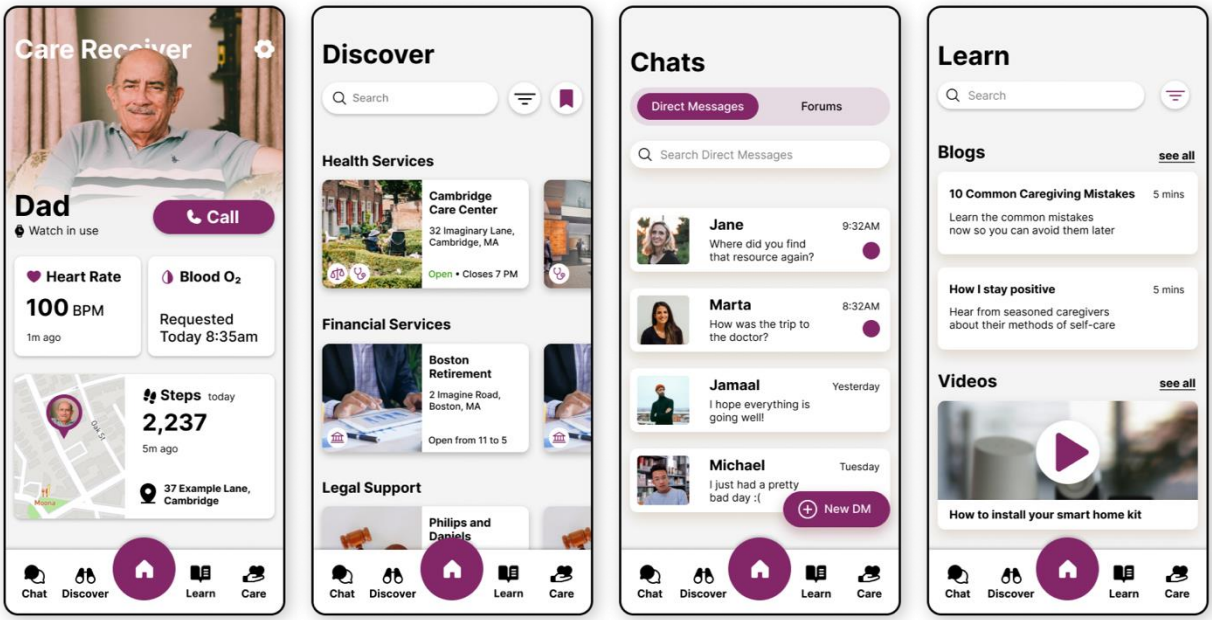

Figure 8 The Care Recipient page, the Discover page, the Chats page, and the Learn page (from left to right).

7. Discussion

The final interface design represents a step towards balancing function with form within technologies for older adults and caregivers. Research has revealed that older adults value the aesthetics of assistive technologies, particularly as it relates to stigma associated with devices like mobility devices (Kabacińska et al., 2022). Accordingly, we sought to combine established design guidelines for older adults with aesthetic visual design principles to create an inviting digital experience. The result of our work includes two interfaces specific to caregiving and older adults that utilize consistent visual design, thoughtful use of color, and compelling visuals. Participants found the visual design of the applications to be clear, familiar, and pleasant. Participants also expressed many ideas for improving the visual design including changes to the color schemes, iconography, and interaction cues. Overall, our work demonstrates how a holistic and iterative approach to interface design can support the development of technologies that aim to improve multi-generational societies and well-being.

Based on our experience designing the early iterations of the LifeTomorrow Ecosystem, we present three guiding principles relevant to designing care-related interfaces for older adults and caregivers:

7.1 Understand the function, then explore the form

The lives of caregivers and older adult care recipients are well studied. They have complex and challenging needs that must be addressed through carefully crafted solutions. Thus, designing for these target groups should first focus on their functional needs and then explore how to create a more enjoyable experience through form and aesthetic exploration.

7.2 Investigate the intersection of age-related design guidelines and aesthetics

Interface design for older adults often lacks consideration of aesthetics and beauty. This results from designers and researchers implementing age-related design guidelines such as high-contrast text, accessible color palettes, and large buttons. However, it is possible to fulfill these guidelines while creating pleasing visual designs, clean interfaces, and enjoyable experiences. To accomplish this, designers must spend time translating age-related design guidelines into aesthetic visuals through an iterative process.

7.3 Gather detailed user feedback often through varied questions

Gathering user feedback throughout an iterative process can help direct a designer's efforts. Feedback is essential for accurately incorporating what the target audience likes and dislikes about a design. This is particularly important in caregiving technologies, which often focus on the feedback of caregivers and less on older adults without severe cognitive decline. User feedback is also often elicited through questions that pertain to the functionality of a solution and neglect questions that investigate the aesthetics. Prompting users on their enjoyment and perceived beauty of a system is essential.

8. Challenges, limitations, & conclusion

While all participants provided feedback throughout their interviews, it is possible that some exhibited a courtesy bias. This bias occurs when participants feel reluctant to provide negative feedback to be polite. To reduce this bias and preserve the validity of our results, we stated to participants that there are no correct answers to our questions and that all feedback would serve to improve our system. Another challenge was related to the fidelity of our prototype applications. One minor source of participant confusion or line of questioning arose from the inability to interact with specific app sub-features. One aim of this study was to validate the concept and primary features of the system; thus, it was not deemed necessary to present a fully functional prototype. To mitigate this challenge, we discussed the functional limitations of the prototype before and during the interviews as needed.

The limitations of this study are highlighted by concerns regarding whether the caregiver application's design elements, such as font size, color scheme, and interaction patterns, are suitable for older caregivers. Furthermore, participants expressed a need for an onboarding experience to familiarize users with the app's concepts and functionality before actual use. Additionally, the study acknowledges the necessity to explore and evaluate alternative interaction methods, like voice control, to accommodate older adults and caregivers facing fine motor control challenges.

Further questions we wish to explore relate to the use and perception of the LifeTomorrow system in the field. Do the aesthetic elements of the designs support or hinder the use of the applications? How do perceptions of aesthetics change over time, if at all? How do older adults and caregivers value the balance of form and function when repeatedly using applications to complete specific tasks? We would propose a field study with caregiver and care recipient dyads to address these and similar questions. The study would observe how these

target audiences use their respective applications to manage their daily needs over a more extended period and in their everyday environment. The feedback from a study like this would be used to further iterate and validate the design of the LifeTomorrow Ecosystem. One foreseeable challenge to this study would be onboarding the dyads to the new technologies if they are unfamiliar with smart watches, tablets, or smart home sensors. This process would require detailed instructions and we would need to ensure sensors are attached correctly. It is also likely that introducing a new technology into a caregiver or older adults' routine would require forming a new habit that compliments or replaces parts of an established care routine. Thus, another challenge would be ensuring the dyads consistently use the applications over time instead of reverting back to previous workflows.

For decades, technology products and interfaces have been developed to address the complex functional needs associated with aging and caregiving. Needs and expectations beyond functionality – such as preferences, visual appeal, and personality of interactions and engagement – were often compromised or neglected. However, as more older adults seek to age in place and increasingly adopt new technologies, there is an opportunity to incorporate established visual design guidelines into care applications to make the experience pleasing and engaging. Our design process for the LifeTomorrow system demonstrates interest and appreciation for good visual design in critical applications that support aging in place and caregiving. Our results suggest that careful application of visual design guidelines in combination with iterative user-involvement can improve the overall user experience of care-related digital interfaces.

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