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ORIGINAL RESEARCH

Lessons Learned from Older Adults Fusing of an Augmented Reality, Assisted Living and Social Interaction Platform

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Abstract

The aging population and the subsequent changing societal structures are foreseen to bring both opportunities and challenges for the economy, services and society at large. Digital exclusion among older people may become less of an issue in the future, as those who have used the Internet in their working and social lives continue to do so as they reach old age. However, given the rapid pace of technological advances, older adults, may still experience some degree of digital exclusion. Technological advances may offer benefits for older adults, such as maintaining their independence and connection to society. Nevertheless, adopting new technologies like augmented reality (AR) may be difficult for older adults commonly due to the decline of cognitive and physical abilities and/or their lack of familiarity, apprehension and understanding on these new technologies. In this study, the GUIDed system is presented, an AR-operated app developed in this work, aiming to support the independence and quality of life of older people. Finally, the paper discusses lessons learned from the co-creation process, including the evaluation methods, paper prototypes, focus groups and living labs, and the results on the acceptance of the AR functionality and for improving the GUIDed system.

Keywords Augmented reality · Ambient assisted living · Smart home · Social communication · Mobile application · Older adults

Introduction

The demographic trend predicts a rapidly aging population in advanced economies including the European Union (EU), which comes from advances in health care, higher incomes, shrinking fertility, improved education and increased gender equality. One consequence of the rapidly aging population for instance represents the rising pressure on health and care systems [1]. Therefore, the need for self-care of older people will continue rising. Information and communications technology (ICT) including smart home technology has the capability to decrease or in a few cases almost eliminate older people's dependency on caregivers [2]. However, some research [3–5] shows that older people tend to be fearful of adopting new technologies. Augmented reality (AR) is a technology that adds computer-generated objects to the real world and provides possibilities of designing user-friendly services with easier interaction capabilities. This may lead to a reduction of fear and usability issues, especially among older people, when adopting a new technology.

One research work examined the acceptability of an AR-based virtual coach for home-based balance training with older people. Their results suggest that the participants in their study find the AR system encouraging and stimulating [6]. In addition, Rosales and Fernández-Ardèvol describe that older people enjoy using mobile applications such as WhatsApp, a medium for exchanging messages, images, audio or video,[1] as they offer services that correspond to their needs while providing a good and intuitive user interface (UI). In conclusion, they summarize the older people's needs as follows: basic communication, security and safety,

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[1] WhatsApp—https://www.whatsapp.com/?lang=en.

support of personal interests including social interaction, personal management such as pill management and entertainment [7].

The GUIDed Active Assisted Living (AAL) EU project aims at supporting these needs by offering five services accessible through a mobile application, while also providing the AR interaction mode as an alternative UI layer for these services, in order to reduce usability issues. The first service represents the "Meds Planner" service that supports users with taking pills by scheduling intakes and receiving reminders. The second service, "Navigation", helps its users to navigate to places they select. The third and fourth services, "Home Control" and "Home Sensors", support older people's safety and devices control. In fact, a smart home service is established that facilitates the integration of many different smart home devices from different vendors. The fifth service, "Communication", helps the users stay connected to their family and friends offering a medium for video calls in order to counteract loneliness. Furthermore, the "Meet Others"-function of this service offers the capability to get to know other users from the GUIDed community that also use this system.

The contribution of this paper is twofold: i) to describe the development of the GUIDed system from the ICT perspective, which places AR as the key technological element that aims to reduce usability issues and ii) to present the evaluation methods and the evaluation results of the User-Centered Design (UCD) method, the co-development process and the evaluation feedback from the actual use of the GUIDed system. This includes the examination of challenges faced by dependent older adults with low ICT literacy skills and the consequent solutions provided by the system in order to improve usability and avoid system abandonment. Specifically, the evaluation aimed at examining end-user testing results, which provide valuable feedback primarily on the user acceptance of the AR element and secondarily for improving and delivering the final system to be tested at older adults' homes in the final field trials.

The remainder of this article begins with describing related work examined in existing literature which provide recommendations that were followed in the design and development process. These include the engagement of older adults in the design and usability testing, and the consideration of best practices for design and development of mobile applications and web applications suitable for older adults. In the next section the UCD approach and the methods used, including paper prototypes, focus groups and living labs to support the co-design, co-creation and even the co-testing of the system with the involved stakeholders, i.e., older adults, family, friends and caregivers. Following, an overview of the GUIDed system's architecture is presented and the key GUIDed Assistant Service is presented. Next, each AR service is described in more detail. In the course of research, the names of some services were changed to more appropriate ones, reflecting the actual functions they offer.

First, the "Meds Planner" service shows the implementation of a medication planner for pill taking, as well as medication reminders. Second, the "Navigation" service is described. It includes the integration of the Mapbox Navigation APIs[2] for requesting navigation routes and the Mapbox Vision SDK[3] for displaying navigation instructions in AR mode. Thirdly, the "Communication" service is presented. It shows how a communication between two users can be established over a peer-to-peer network using the open-source WebRTC[4] system. Then, the last two services, "Home Control" and "Home Sensors", are presented that allow controlling actuator devices and collecting and receiving information from sensors, including notifications. Subsequently, the evaluations and results from the living labs are discussed, with emphasis on the acceptance of the AR interaction element for users. Finally, this article concludes with a summary of the work conducted for implementing and integrating the services and directions for future research.

Related Work

In this chapter, related literature that contributed to the input for this research and thereby the creation of the GUIDed services is shortly summarized. Related to each service at least one reference is described, whereby some references may also apply to other services, especially those that examine usability. Furthermore, previous research in the context of the GUIDed project is outlined. Finally, based on the issues and challenges identified from existing work, AR was incorporated as the integral part and the differentiating point of the GUIDed system compared to existing systems offering similar services. *The AR element is the distinct element offered as a result of this work with the aim to reduce usability issues and overcome the challenges faced. AR has become an increasingly integrated technology of everyday life, from entertainment to healthcare.* It bodes great potential as a technology-based intervention to promote and maintain overall well-being for older adults. In addition to considering this potential, this work will also contribute to ascertaining characteristics of older adults that influence the usability of AR development, which is a gap of current studies [19].

According to research in [15], older adults already use existing digital tools in the form of smartphone applications

2 Mapbox Navigation—https://docs.mapbox.com/android/navigation/guides/.

3 Mapbox Vision—https://docs.mapbox.com/android/vision/guides/.

4 WebRTC (Web Real-Time Communication)—https://webrtc.org/.

to combat the effects of isolation due to the COVID-19 pandemic. The research categorizes these apps into six categories: Social Networking, Medical: telemedicine, Medical: prescription management, Health and Fitness, Food and Drink, and Visual and Hearing impairment. In [16], the + Simple platform is discussed that groups content (news, procedures, social networks and pages of interest). Older adults were trained to use the tool through a 2-h course. The aim was to promote elderly adults' social inclusion through a digital literacy process [16]. The training involved 40 Digital online Classrooms. Moreover, 106,550 tablets with the + Simple platform were delivered to people over 60 years of age.

Age-related differences have been extensively examined within the HCI literature [17] and older adults' use of existing digital tools, including smartphone applications is also highlighted in the aforementioned [15], yet research focusing on older adults' responses to AR prompts remains largely unexplored [18]. Older adults have usually been excluded as a user group for AR development [19], further highlighting the need for new work in this area, contributing to increased understanding of how they interact with it.

Types of visual AR prompts were compared with older adults in [18] to determine which could be considered effective in enabling them to complete tasks in everyday, non-industrial contexts. This is deemed as a necessary step towards developing effective AR task prompts that can support older adults with daily living. Results indicated that older adults were less successful in completing actions when using ARROW and HIGHLIGHT augmentations in comparison to ghosted OBJECT or GHOSTHAND augmentations. Regarding user confidence when performing actions, these were affected by the actual action and augmentation type implemented. Overall, there was a preference in using combined AUDIO + TEXT prompts, while GHOSTHAND was shown to be the most preferred visual prompt. These are important insights for developers of AR content targeting older adults.

Focusing specifically on the use of AR technologies to promote and maintain the overall well-being of older adults', the following initiatives are highlighted in the literature [19]:

- *Nacodeal* project offers a guidance service, creating friendly guides, to enable older adults to be self-sufficient despite their memory diseases and access online services relevant to them [20].
- *Drinking Water* focused on the design of a system to remind older adults to drink water, using two wearable devices [21].
- *AR-3DH* training system is an innovative tool suitable for training the mental rotation skills of older adults [22].
- *ElderGames* project vision was to design and develop a unique application to explore how new and emerging advances in ICTs can be adapted, applied and combined with play/leisure activities to improve the health, welfare and quality of life for older adults [23].
- *Rehabilitation* system combines AR and gamification to support older adults' rehabilitation activities by collecting detailed movement data while augmenting the user's path by projections [24].
- *The 3D ARS* system improves lower extremity function and balance of older adults [25].
- *V-Time* was a multi-modal intervention solution (using a treadmill training program) for reducing fall risk for older adults [26].
- Aloha *VR program* helps older adults relax; it is an alternative to watching endless TV and offers a change of scenery for those who are not able to get out much [27].
- *CogARC* is a serious game for cognitive training and screening based on AR and the manipulation of tangible, physical objects (cubes) [28].
- *Assistive navigation* system uses points of interest or well-known places, in which user-friendly routes to a destination are generated based on the user context rather than conventional street names and quantitative distances [29].
- *Driver hazard perception* utilizes cues in improving driving safety among older adult drivers who are at increased crash risk because of cognitive impairments [30].

Digital Tools

Review of Medication Reminder Applications

Stuck et al. [8] examined some of the most downloaded medication reminder applications concerning their suitability for the usage by older people. Their findings reveal issues including unintuitive navigation, poor visibility and a lack of transparency. Furthermore, the authors inferred guidelines for application design from their findings. These include the inclusion of older people in the design and usability testing phases of the development process, as well as the compliance with standard age-specific design guidelines [8].

How Older People Struggle with Maps

In a recent research, Yu and Chattopadhyay examined the accessibility of current mobile maps from the perspective of older people. They classified the issues encountered by older people into motor issues and non-motor issues. In this context, motor issues represent interaction problems where a user failed to successfully execute an intentional action such as tapping or swiping. Non-motor issues include for instance the unwilling ignorance of UI components due to inadequate visual saliency, ambiguous affordances or low information scent. They concluded that non-motor issues were more critical as they more often resulted in frustration and resignation among users [9].

Social Needs of Older People

As loneliness tends to increase with age [10], communication applications such as WhatsApp or Viber have gained a strong popularity among older people. They enable them to stay connected to their family and friends that are not nearby. Bruggencate et al. [11] examined the social needs of older adults. These include active involvement, respect for individuality, stimulating social contacts including close and peripheral relationships, and the sharing of knowledge.

Smart Home for Older Adults

Yusif et al. [12] conducted a systematic review of empirical studies concerning the adoption of Assistive Technologies (AT) including smart home. Their findings suggest that older people are mostly concerned about privacy, costs of ATs, ease-of-use, suitability for daily use and the general benefit, which some older people assess to be low. However, their results also suggest that older people in general have a positive attitude towards ATs as they see it as a means to maintain independence [12].

GUIDed System, Related Work and Gaps

The GUIDed system was designed based on extensive literature review to tackle the aforementioned age-related ICT challenges. Specifically, the interface utilizes large targets (buttons), high contrast of elements and big fonts, all flagged as common violations in previous studies [34]. Furthermore, the interface provides only the minimum number of elements needed without overloading the user with information, uses universal approaches in terms of information presentation (e.g., placing of labels and menu) and has employed drop down menus or large sliding bars in selected places based on the user-centered design methodology to tackle both motor and non-motor usability issues. Finally, in respect to personalization, the interface allows users to customize the app based on their preferences (e.g., notifications). Common frameworks including the System Usability Scale, the Technology Acceptance Model and Human Computer Interaction principles that were utilized in this work to assess user experience and usability of the GUIDed system.

The testing of the system so far has provided encouraging results in terms of user experience. Mettouris et al. [13] describe the user-centered design approach with the focus on the co-creation aspect in the context of the GUIDed system. This includes the evaluation of high-fidelity (Hi-Fi) paper prototypes (i.e., the designs) for the GUIDed services. The Hi-Fi paper prototypes are based on the recommendations from the literature and the authors' goal was to validate them and the proposed augmented reality UI. The Hi-Fi prototypes were tested by older adults and their caregivers using focus groups in four European countries, namely Austria, Cyprus, Norway and Poland. The results show that the users found the GUIDed system understandable and easy to use [13]. Its intuitiveness was also appreciated, while the GUIDed system was seen as valuable, aspects that are expected to provide a great level of self-confidence, independence and convenience to older adults. These represent encouraging findings considering older participants' low technological literacy. Feedback that was also collected during this evaluation phase also led to a number of recommendations, modifications and additions to the design of the app and services, which will be evaluated in a second testing phase.

Methods

From a methodology perspective, a UCD approach is adopted, focusing heavily on a co-creation aspect. Considering this, three different categories of end-users were recruited in different phases of co-creation activities: Primary end-users (PUs): older adults living independently in their own homes with no or moderate need for assistance (regardless of their IT skills); Secondary end-users (SUs): family members and informal caregivers; Tertiary end-users (TUs): care organizations (day-care centers, hospitals, clinics, retirement homes, and nursery homes), technology product vendors, telecare service providers, policy makers and the like. To ensure that the end-users' demands are respected throughout the design and development of the GUIDed platform and its services, the following process was followed in sequence:

1. Older adults' recruitment process and an analysis of the respective needs.
2. National strategies and governmental recommendations for ATs were reviewed in Cyprus, Austria, Norway and Poland.
3. Based on 1 and 2, the GUIDed platform and its services were then defined and presented to the primary end-users via workshops in order to collect their initial impressions.
4. Based on 3, the platform and its services were defined and the specifications designed (see Section "GUIDed System").
5. Experimental evaluation and feedback activities commenced and continue (see Section "Evaluation Results and Lessons Learned").

Focusing on the experimental evaluation and feedback activities (i.e., step 5 in the aforementioned process), in

Table 1 Testing phases for the experimental evaluation and feedback activities

Testing phase	Evaluation tool	Method to collect feedback	Total no of PUs	Total no of SUs	Total no of TUs
1	Paper prototype	Focus groups	39	9	0
2	Mock-ups (semi-functioning)	Questionnaires	31	17	10
3	First functional prototype	Living Lab	22	21	4

order to adequately monitor, discuss, evaluate and collect feedback based on the design and development activities, it was decided to divide the testing phases (see Table 1).

In Section "Evaluation Results and Lessons Learned" of this paper, we present the results from the first testing phase that includes the design of Hi-Fi paper prototypes for the five services, as well as their evaluation with primary end-users utilizing focus groups. The feedback collected in phase 1 for each service was reviewed by the GUIDed team to determine which recommendations should be implemented and how to address specific considerations pointed out for the phase 2 testing, i.e., in the design of the mock-ups (semi-functioning). The testing phase 2 was then executed and the results were taken into consideration for designing and implementing the first functional prototype. Finally, the prototype was tested using the Living Lab method and the results of phase 3 are also reported in this work, which were used to improve the prototype that currently undergoes the first round of field trials testing at the homes of older adults.

Paper Prototypes

The first selected method for testing (whether the technical development of the GUIDed system meets the needs of the older adults) was paper prototypes. Paper prototyping is a widely used method in the UCD process and utilized in the early design stages in order to test the functionalities and layouts of a graphical interface before programming begins [31]. Paper prototypes (e.g., sheets of paper or in online format) consist of an easy method for the end-users to understand the functionalities of a system/platform and provide valuable feedback, insights and issues with regard to its usability [32]. More specifically, this is done by presenting the functionalities to the end-user using paper prototypes and encouraging her/him to comment on them ("talking aloud") while the researcher takes notes. Thus, paper prototyping assisted the project team pinpoint any design issues of the GUIDed platform for the end-users such as difficulties with navigating or comprehending the services and to identify potential points for alterations. While there are several techniques for conducting the paper prototyping method, the one utilized in this phase was wireframes. A wireframe is used to demonstrate the page layout of the interface. Figure 1 lists the set of rules for the design of the paper prototypes, to support the system prototypes' evaluation with the end-users and the focus groups activities. This resulted in the final GUIDed system mobile application UIs, whereas the main screen is also illustrated in Fig. 1.

Focus Groups

The paper prototype evaluation tool was used to conduct 1-h long focus groups, with participants. The number of participants for each focus group was influenced by the national social distancing measures against COVID-19 (see Section "Evaluation Results and Lessons Learned"). Focus groups consist of a valuable qualitative research technique in an interactive interview setting, where end-users have interactive and directed discussions and can freely express their opinions, perceptions and beliefs towards a product/ service/ system. During this process, end-users together with other participants can freely interact and share ideas and opinions which in turn assists the researchers in data collection [16]. Due to the group setting, for many end-users, focus groups constitute a more pleasant and stress-free process compared to one-to-one interviews [33]. Furthermore, the group dynamic as a process facilitates discussion and can lead to more in-depth and spontaneous conversations, debates and ideas regarding the service/system. As such, this technique assisted the GUIDed project team to acquire valuable feedback in these early design and developmental stages of the platform with regard to its services. Before the focus groups, participants were briefed on the scope of the project and the study and were asked to participate in a free discussion covering their first impressions on the GUIDed system, the design of the interface (colors, placing of elements, etc.), utility of the services in their everyday life, any identified risks-dangers and possible mitigation actions, user experience and journey through the app, ethics issues and aspects missing and finally, the needs for support (e.g., training and helpdesk). The responses were recorded on paper by the researchers and analyzed via thematic analysis using the QDA miner lite software.[5]

[5] QDA Miner Lite—https://guides.library.wheaton.edu/QualResearch/QDAMiner.

"Rules" (ref. editable template beside):

1. Simple, elegant colour scheme, the same one in all 5 service paper prototypes. Distribute colour codes to the project team.
2. No red against green, or the other way around.
3. Screen font Calibri or similar (i.e. sans serif – no small "feet" as e.g. in Times).
4. Large text, short expressions.
5. High contrasts between text colour and background.
6. No all-caps words, and no ordninary words with a single capitalised letter. Use first capital letter only in a sentence or a button, or names of persons, cities etc. when grammatically correct prose).
7. Left-adjusted text (no centre-adjusted except in buttons and the like).
8. No abbreviations, at least without explanation.
9. GUIDed set of navigation application specific icons – in-house design.
10. Same main basic action buttons in all 5 service paper prototypes (Start, Quit, Exit, Save, Home, Back, Reload, etc.).
11. Always a short way “home”, possible to go “back” and Exit without any disaster.
12. Suitable illustration icons in "one family of expression", with transparent background to avoid ugly white square backgrounds (icons "borrowed" before final purchase).
13. Short guidance texts when assumed necessary.
14. Easy-to-read “normal” language. Short sentences
15. Error messages in clear everyday-language. No "techie phrases".
14. If possible, no horizontal scrolling, minimal vertical scrolling.
15. No unnecessary decorations or disturbing animations
16. Identical example branding in all 5 service paper prototypes (GUIDed logo).
17. No "bells and whistles", such as decoration elements, childish animations, clip art humour / cartoon style, smileys etc.
18. Avoid over-loading the app screens.
19. All text in native languages.
20. Enable for native ways of expressing time, date, day as well as order and decimal figures.

Consistency between features and functionalities.
Minimalistic clean design and functionality.
Prepare for responsive design.

Tool and format:

- PowerPoint.
- One screen pr. page (vertical), to allow printing to larger posters for co-creation.
- Page size A3 or A2 to provide group-work posters.

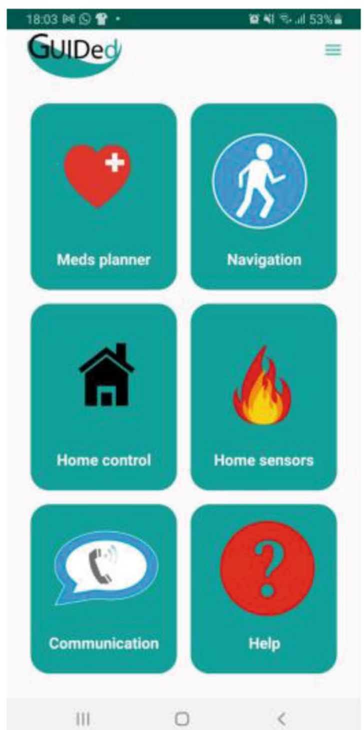


Fig. 1 Design guidelines adopted for the Hi-Fi prototype designs instructions for the format of the evaluation tool format and the final UI of the GUIDed system

Living Labs

The concept of Living Labs involves a UCD process that is tested in real-world scenarios. During the Living Lab stage, a variety of relevant stakeholders included and impacted on the iterative design and development process.

The Living Lab approach provided the time and space to participants to test the application in a controlled environment that simulated real-world settings. This was the participants’ first opportunity to really try out the product. The feedback provided at this stage was crucial to really understand how the product could be used to make the everyday

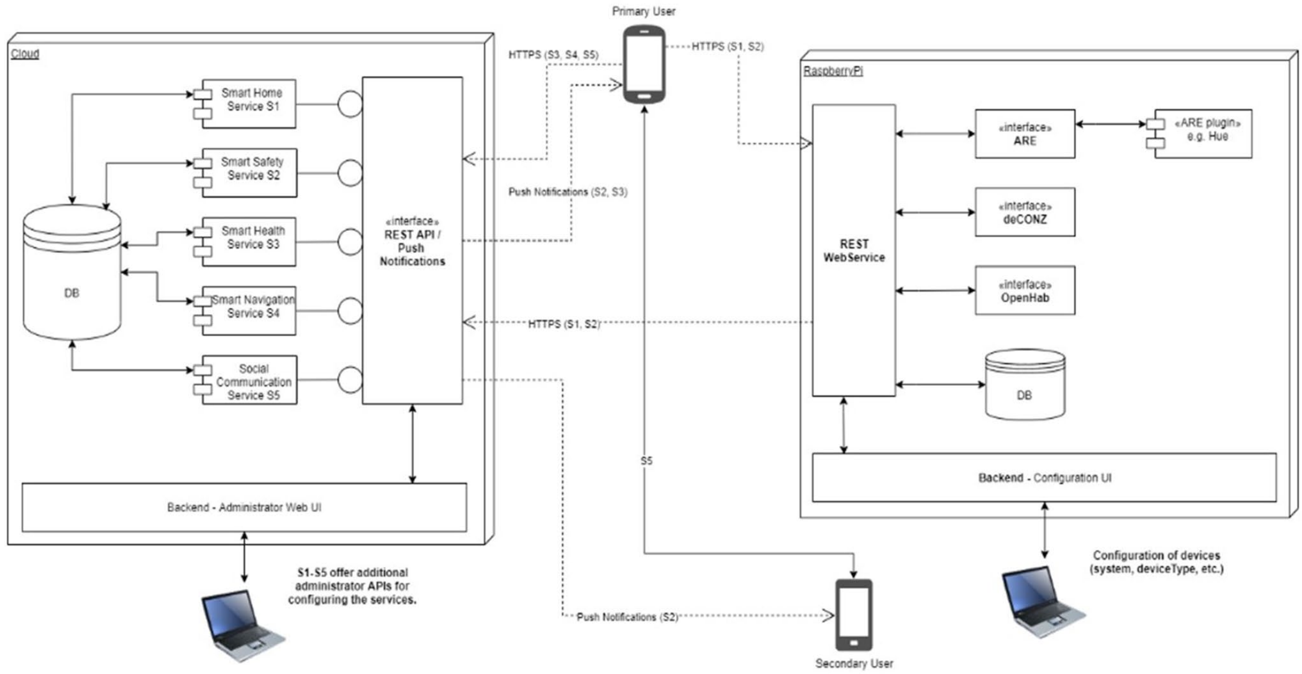


Fig. 2 High-level architecture for the GUIDed system

life of its users much more productive and easier. It was also used to fine-tune the prototype prior to its testing in real-life environments. The Living Lab approach, in contrast to the previous stages (1 and 2), introduces this element of practicality, by giving the participants control over the device and observing its results. As such, it helped users really understand their needs and wishes.

Primary and secondary users were able to test all the services offered by the application and the web portal in a control environment. Tertiary users received a demonstration of both the services in the application and the web portal while also testing them though, to a much lesser extent than primary and secondary users so as to get a feel for the product as a whole. One room is sufficient but it was preferable to conduct the experiment in two to three different rooms, in order for the participant to test the application and provide individualized and diverse feedback. All the devices meant to be operated by the application, such as smart lights and sensors ought to be installed and tested by the researchers prior to conducting the experiment.

The main instrument for the testing is the GUIDed app prototype that was installed on smartphones. These smartphones were given to participants and an orientation of the space testing area where the devices were located was provided before the Living Lab initiated.

A combination of quantitative (standardized and non-standardized tools) and qualitative methods was used to collect participants' feedback, including the System Usability Scale (SUS) [35], a set of open questions constructed based on the Technology Acceptance Model (TAM) [36] and business-oriented questions assessing intentions to purchase, use or recommend to others in the future. The results of this phase were recorded on paper by the researchers and analyzed using descriptive statistics and frequencies for quantitative and thematic analysis for qualitative data, using SPSS Version 22 and QDA miner lite, respectively.

GUIDed System

Architecture

The architecture of the GUIDed system is depicted in Fig. 2, which is described shortly as follows, whereas more details are described in the report from the GUIDed EU AAL Project [14]. The architecture of the GUIDed system consists of three entities: the Android client for the users, the cloud instance for configuring, relaying and processing data and the Raspberry Pi 3B + for the smart home services at the user's home. The cloud hosts a Drupal content management system instance, which is actually the web portal for configuration of the five services and the creation and management of user data (Services 1–5). The cloud includes also a spring boot application for handling home control and home sensors functions (S1, S2), such as sending push notifications to specific users when an alarm is triggered, as well as a WebRTC signaling server to keep track of all connected and available GUIDed users and for establishing

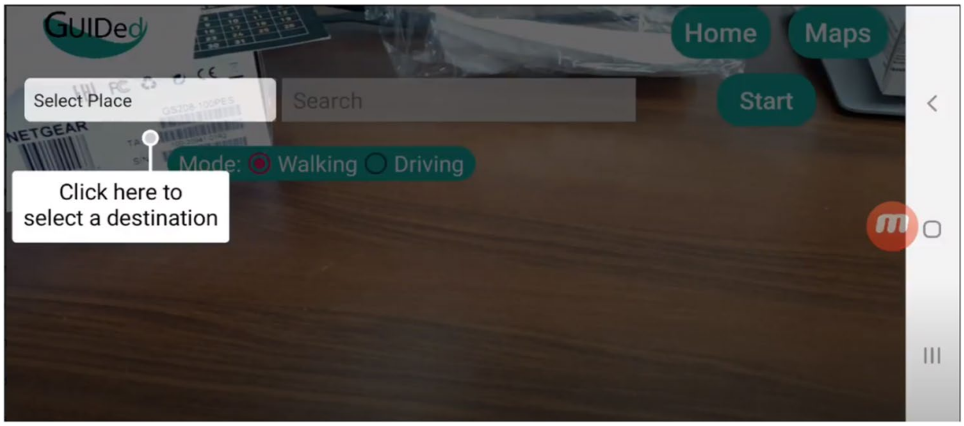


Fig. 3 GUIDed assistant service

a communication channel between two users within the "Communication" service (S5). The web portal, which is accessed over a web browser, allows users including older people to use a mouse, a keyboard, bigger user interfaces and clearer navigation structures that simplify the services configuration process and adding relevant data for the services, in contrast to using a mobile device and application with limited screen sizes. Specifically, the web portal is also used to enter medication information that can be viewed on the mobile application by the older adult, as well as provide medication reminders. This functionality is provided by the Meds Planner service (S3). Finally, the navigation service (S4) operates in two modes and can provide AR-based or conventional map-based navigation instructions to the older adult, in order to server each older adult based on his/her preferred HCI mode.

The GUIDed system exposes the services through Web APIs, which enable the use and manipulation of data via the mobile application.

GUIDed Assistant Service

The GUIDed Assistant service (see Fig. 3) is a horizontal feature provided across all services in the system. The assistant service can be turned on/off from the settings of the GUIDed mobile application. In the case the assistant service is enabled, then for any service the user selects to use, the assistant service augments digital information in the screen of the end-user. When the user taps the screen, the assistant service continues with the next instruction augmented on the camera view, in order to provide guidance to the user on how to use the individual services.

The One-Click Interaction Method

The initial implementation of the mobile application combined the Android ARCore Framework and the Tensorflow Machine Learning (ML) for detecting the physical devices (e.g., pillbox, WiFi plug) as 3D objects. This enabled the "one-click" interaction method by scanning devices and presenting directly the appropriate UIs for controlling the actuator device or receiving information for the detected sensor device. The co-creation process revealed though usability issues, e.g., scanning the device at distance, scanning the device at a peculiar angle, lighting conditions, false positive detections.

Based on the results, the detection method was modified and implemented using the ARCore platform's Augmented Images API that allows detecting a 2D image (i.e., smart tag) that is associated with each device. The AR Core Augmented Images API allows creating an images database that allows recognition of the tags. The smart tags can be strategically positioned within the house, e.g., as a sticker or in laminated form. For instance, a smart tag can be added on the coffee table in the living room or on the fridge, so that it allows scanning and controlling the devices with one-click without having to undergo multiple interactions over several screens. Thus, the new AR detection mode is based on the smart tags' recognition instead of real devices (see Fig. 4), since it aims to resolve usability issues identified in the initial phases of testing, i.e., Living Labs. It will be tested as part of the end-user field trials during the next testing phase of the project.

Meds Planner Service

Compared to existing medication planner mobile applications that in almost all cases perform data management and data access on the mobile application and interaction through restrictive user interfaces, the "Meds Planner" service enables data management via the web portal. Specifically, the primary user (i.e., older adult) or secondary user (e.g., family, caregiver) assisting the older adult can use the web portal over a web browser to manage medication data using larger user interfaces, with clearer navigation and easier interaction, rather than administering data on the mobile

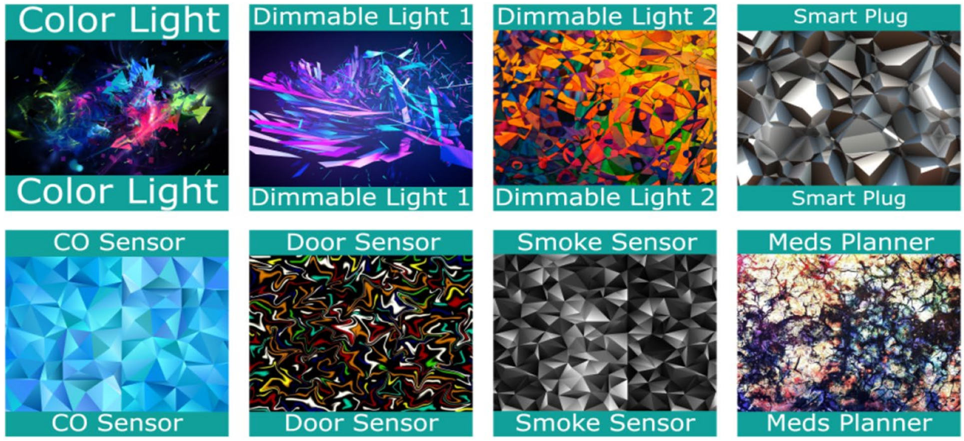


Fig. 4 Using the ARCore platform's augmented images API: Smart Tags

Fig. 5 AR Medication Planner—Pillbox Smart Tag Detection (expanded view)

application. Moreover, Headless Drupal enables data access for the mobile application via the exposed REST Web APIs and allows user interaction using intuitive AR interfaces or standard UIs to serve different older adults' requirements and needs.

As defined in Section "The One-Click Interaction Method", the Android ARCore framework allows detecting a 2D image (i.e., smart tag) associated with the pillbox using the ARCore augmented images API. As soon as the 2D augmented image is detected the Web API is invoked, which returns the matrix with the medication information augmented on the camera view, including intake times and dosages of the prescriptions. Furthermore, it allows you to tick the checkbox when the medication is taken. However, the checkbox is only enabled 15 min before and after the intake appointment. The user can also click on the minimize/maximize button to shrink or expand the augmented matrix view. For instance, Fig. 5 shows the complete list of medication to be taken for the current day in the expanded view.

Navigation Service

The navigation service also requires the use of the web portal and the Android application. The primary or secondary user can use the web portal to add and manage their favorite places (unique name of the place, the coordinates of the place, etc.) of the older adult. The scope of the web portal is to provide easy to use and larger UIs for entering data, in these cases some usual places that the older adult commonly needs to commute to during the week.

The exposed Web APIs provide access to the places data from the Android mobile application. On the frontend, the tiles-based view is shown that allows selecting the navigation service, which loads up the camera view in AR mode, presents a dropdown menu with the user's favorite places, from which the user can select the location to navigate (e.g., home, grocery store) and then clicks the "Start" button that initiates the AR navigation. During the co-creation process the end-users have provided feedback, which indicated that although their favorite places are retrieved and displayed in the app so that they can navigate to these locations, they would still like to have the capability to be able to search and navigate to another location. Taking into consideration this important user feedback, the navigation service user interface was updated (see Fig. 6) so that it can accommodate this user requirement.

The implementation of the service is based on the ARCore technology and the Mapbox APIs, which enable to detect the current location of the user, getting navigation instructions and rendering this information as augmented

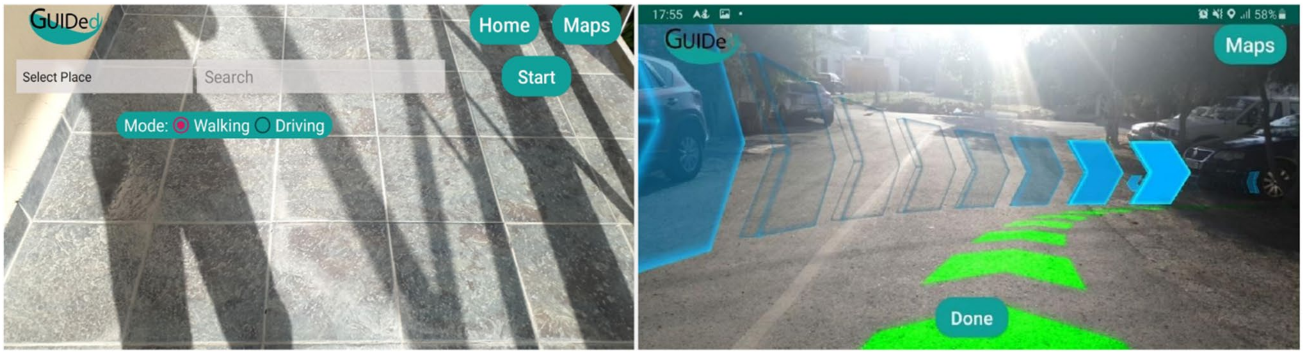


Fig. 6 Selecting and navigating in augmented reality view

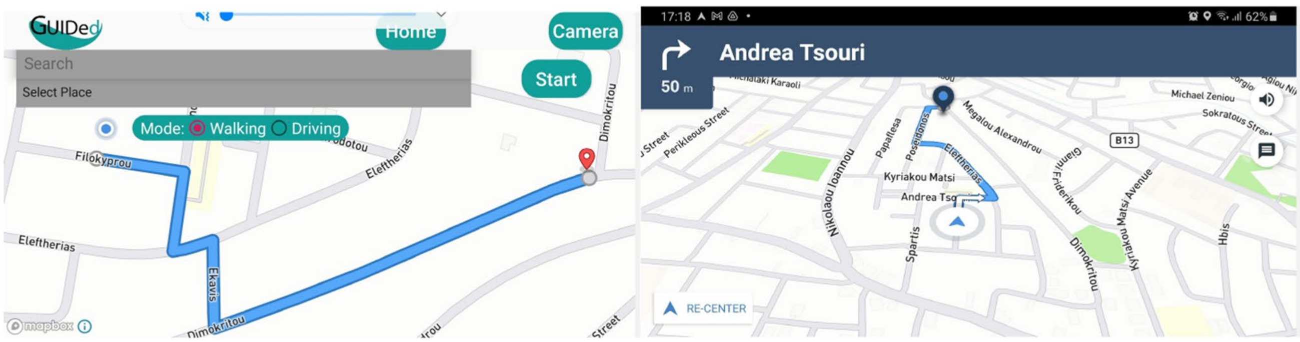


Fig. 7 Selecting and navigating in maps view

visual cues (i.e., direction arrows), providing an augmented reality navigation experience to the users (see Fig. 6). The user is also able to click the "Maps" button on the top right, to enter a maps based navigation mode, if that is preferred by the user. The user can once again either select from favorite places or can search for another location (based on the updated user interface) to navigate to in maps mode. The user also has the capability in maps mode to click on a location on the map to indicate that point as the destination. Based on the three possible interaction methods (see Fig. 7), the user selects the preferred one to input the destination, and as soon as the user clicks the "Start" button the route is plotted and the map view navigation begins (see Fig. 7). This enables users that are more technology-oriented and more accustomed to the map view to use this mode of navigation. Finally, based on the feedback received during the co-creation process, for safety reasons, the older adults requested voice instructions in order to avoid have to watch the screen all the time while walking.

Communication Service

The Communication Service aims to address the issues of social isolation and loneliness that older adults experience, by offering a sense of real-life physical presence between the older adults and the communicating family members, healthcare providers, friends and even a stranger (explained further below). This is achieved by providing a video calling service with a simple (yet functionally complete), minimalist design and easy-to-use UI, that is also appropriate for use by older adults. Using the service, older adults can remain in contact with family and friends while engaging in everyday activities, such as eating together, drawing with the grandchildren, knitting and much more.

The Social Communication Service differs from existing similar apps in the market in three fundamental aspects: 1) it targets older adults who are not ICT competent, making thereby the appropriate design decisions in terms of UI elements' size and colors, 2) the workflow of the service and the architecture of the various functionalities have been designed and developed having in mind HCI (Human Computer Interaction) related parameters like usability and ease-of-use, targeting at the same time older adults, and 3) it offers the "Meet Others" functionality, an innovation of GUIDed that was proposed by partners during the co-creation process and that initially received positive feedback from the end-users.

"Meet Others" enables primary users, through the push of a virtual button, to conduct video calls to another GUIDed primary user in a random fashion. The remote user receiving the call also belongs in the GUIDed community, i.e., he/she is a GUIDed user as well, and is randomly selected by the GUIDed system, provided that the preferred languages of the two users match, and that the remote user has agreed to the communication request at the moment of the call.

The GUIDed services including the Social Communication Service were briefly described in [13]. In that paper, the architecture and technical information about the service were also provided. In this paper, the focus is on the "Meet Others" functionality as an innovation of this service and of the GUIDed system overall.

Architecture

The Social Communication Service was developed using the WebRTC framework. WebRTC is a free, open-source framework that enables Real-Time Communications with audio and/or video, by providing web browsers and mobile applications with the means for real-time communication via its APIs. The Social Communication Service includes two different architecture designs: a Client–Server architecture between Android devices (smartphone/tablets clients) and a signaling server that is used for setting up the connection between two communicating users, and a P2P (Peer-to-Peer) architecture between two Android devices for conducting the video call. It is important to note that the signaling server does not retain any information about the two clients during a video call, thus ensuring the user's privacy and data security. All WebRTC clients' data are deleted as soon as the signaling process is terminated. Apart from the signaling process, the server listens and handles any special case events, e.g., client disconnection, client reset and client network changes. More on the Social Communication Service architecture and the WebRTC can be found in [13].

Workflow

The Social Communication Service can be divided into two main features, the video call process conducted via the GUIDed app and the process of adding new contacts to a primary user conducted via the web portal. The former is mainly handled by the WebRTC API and the signaling server, as previously explained in Section "Architecture". The latter takes place through a suitable web UI on the GUIDed web platform, where a primary or a secondary user assisting a primary user can add other GUIDed users as contacts of the primary user, by initiating a contact request to them. These requests are considered pending until the recipients of the requests accept them. Users may view their pending contact requests and accept or decline each request via the web platform. The process of initiating contact requests and accepting them currently cannot be conducted via the GUIDed app. The reason is that, as the communication service targets older adults who are not ICT competent, an appropriate web UI would allow assisting users to do this process on behalf of primary users. Following the co-creation approach, the older adults requested this functionality on the mobile app and thus it was added, following feedback from the Living Labs.

Another feature of the communication service is the "is favorite" concept. A user is enabled to add a contact in his/her favorite contacts list via a corresponding checkbox on the web platform. Favorite contacts are the only contacts that are visible through the GUIDed app. The idea is to avoid having too many contacts appearing in the UI of the GUIDed app, something that would reduce ease-of-use.

Figure 8 shows the workflow for the "Meet Others" functionality. Adding a new contact to a primary user can be done during a video call with a "stranger" in the "Meet Others" mode. Through the Android application, the user can enter the "Meet Others" mode by clicking a virtual button on the contact's list screen so that the process of finding a suitable candidate begins. Based on the user's preferred language, the algorithm run by the Signaling Server will respond with a random GUIDed user that meets the language requirement and is also currently online and available for a video call. Figure 9 shows the incoming call from the "Meet Others" process. When both users agree to the video call, it initiates. During the video call, there is an option to send a contact request to the communicating user. If done, a pop-up appears on the receiving user's screen notifying him/her of the contact request and providing an accept/decline option to immediately notify the sending user of the result.

Improvements of the Communication Service

The results from the Living Labs (see Section "Living lab tests results") have shown that several primary users would prefer to have some of the functionality offered only through the GUIDed web platform in the GUIDed app as well. Thus, improvements of the communication service include enabling the users in initiating and accepting contact requests through the GUIDed app. In addition, the "is favorite" feature that was not enabled by default will be implemented to be enabled by default. This will reduce the steps of the process of adding a new contact by 1 step, and thus simplify the process. In addition, the "Meet Others" feature is being currently re-assessed in the project, since in the Living Labs, several older adults expressed privacy concerns when actually using the prototype.

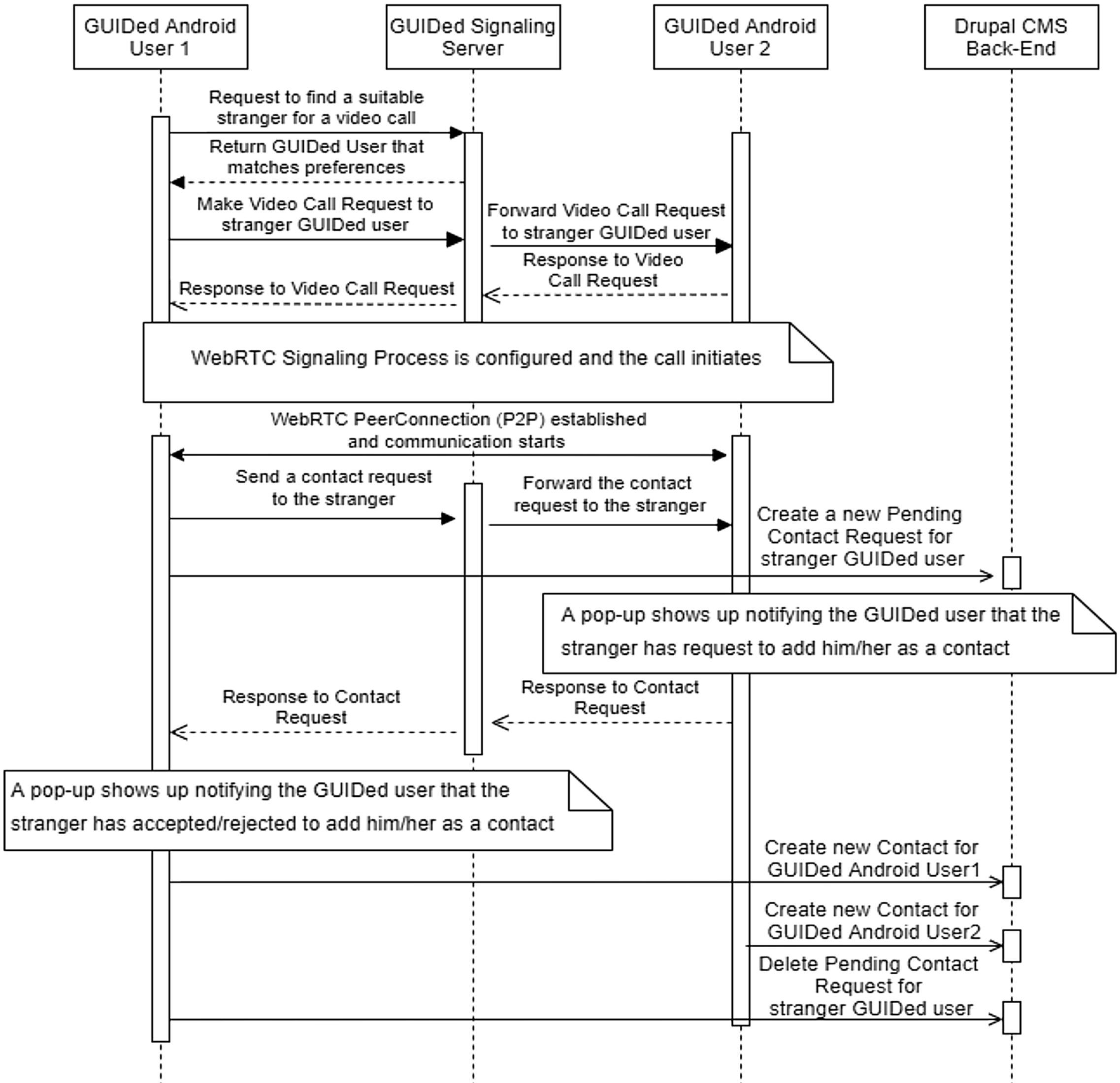


Fig. 8 Sequence diagram for the "Meet Others" functionality

Smart Home Services

From the user's perspective, the smart home and sensor services can be described as follows. The "Home Control" service allows users to control their home environment. It provides features such as control of lights or power sockets. The "Home Sensors" service monitors the users' homes and alerts when a threat is detected, or allows the end-user to check the status of the sensors, e.g., if they have been tampered with, if the battery is running low. Furthermore, push notifications are sent to primary and secondary users associated with a specific smart hub. In the current implementation, the "Home Sensors" service can track the presence of smoke, carbon monoxide, as well as the state of doors and windows (open or closed) for safety and security reasons.

The central hardware component responsible for "Home Control" and "Home Sensors" services is a smart hub that is based on the Raspberry Pi micro-controller. Together with a set of sensors and actuators, it needs to be installed and configured by a technical person in the older adult's home. The Raspberry Pi connects over a Web API to the proprietary Drupal instance running remotely on the cloud, and to the third-party smart home system deCONZ installed locally. The deCONZ smart home system allows future extension to cover more devices. In addition, a "Configuration Client" application is served by the Raspberry Pi, which allows the configuration of smart devices (naming, room configuration, device type—e.g., light, smart home system—e.g., deCONZ). This is done during installation by a technical person.

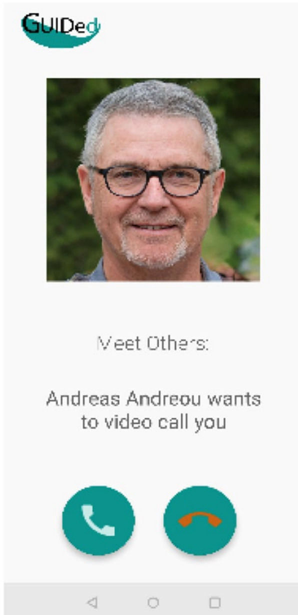


Fig. 9 "Meet Others" process: the receiving user's incoming call

From that point onward, users can use the "Home Control" and "Home Sensors" services from the Android mobile application. The application allows the user to control the devices by scanning the Augmented Reality image (i.e., smart tag) associated with a specific actuator or sensor device, and be immediately presented with the device-specific UI controls to directly perform actions such as: turn on and off the lights, change dimming and color of the light, control the smart plug (Fig. 10a, b) or to receive UI modal windows with information such as the sensor state (Fig. 10c). The mobile application also offers a second HCI mode, where the user can click and enter the "Menu" mode, where via a graphical user interface the user can locate, select and control the devices from any location.

Evaluation Results and Lessons Learned

In this section, the results of the user evaluation are presented, ranging from the results of the GUIDed paper prototypes tests, through the results of the semi-functional mock-up tests, to the first physical testing of GUIDed prototypes during the Living Lab sessions with users in each country.

Research Hypotheses

During the preparation of the testing phases with the users, the consortium made some assumptions with regard to the needs and requirements of the users. The four main hypotheses were the following:

Ease of Use

We have assumed that all users are prioritizing and valuing the ease-of-use of a system very high. Therefore, our efforts were towards developing an application that is easy to use even for the less technologically advanced users.

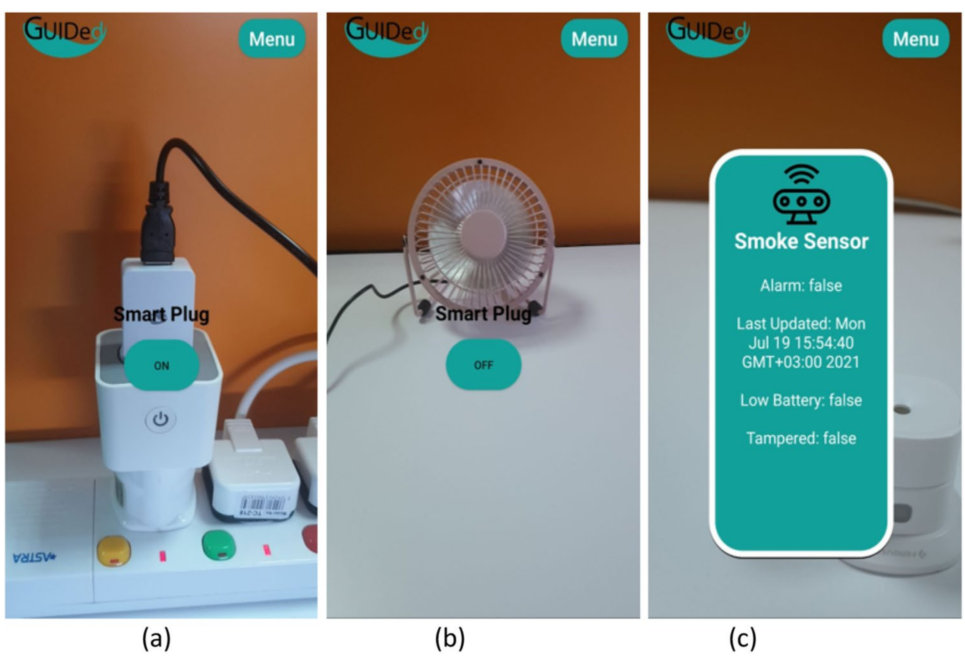


Fig. 10 Augmented reality: smart home control and home sensors

Technophobia

One of the greatest challenges and hypotheses made during this project was that a majority of the users over 65 years old are not familiar with the ICT and a large percentage of those are even afraid of using ICT in their daily lives. In addition, we have considered that depending on the location of the user, e.g., Poland, Norway, Cyprus, and Austria, users might have different preferences in the services they need to use in the GUIDed application. For example, Norway has a higher quality healthcare system, which already provides a service similar to the medication planner or in Cyprus the distances are very small so there is minimum need to use the Navigation service hence the GUIDed application should provide to the user the ability to select the preferred services.

Alignment with HCI Principles

Another hypothesis that was detrimental during the design and development of the GUIDed system was that if the system did not follow the HCI principles, it would not be accepted by the users. The following principles were considered during this process: visibility of system status, match between system and real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, esthetic and minimalist design, help, diagnosis and recovery from errors, as well as documentation and Help for the users.

Paper Prototype Results

The qualitative results of the paper prototype testing showed that all of the users found the application understandable and easy to use, which is an encouraging finding considering older participants' low technological literacy. Some suggestions for improving usability and accessibility included increasing the contrast of the screen colors and taking under account color blindness when choosing the palette. In addition, changing the labels of some buttons (e.g., replacing the term "user interface" with something more intuitive), and replacing some of the icons with more appropriate ones (e.g., replace the icon of S1. Health and Nutrition (now it is called "Medication planner") service with a "heart" or a "first aid kit"). Despite the fact that participants rated the app as intuitive and easy to use, most of them requested an introductory training to support them while using it. The training component has already been planned and incorporated in the GUIDed application via an innovative assistant, utilizing AR technology. With regard to appearance, most participants showed a preference towards user interface design No2 (with tiles) since, according to them, it seemed cleaner with larger buttons than user interface No1 (with the list of services).

Participants rated positively all of the services included in the GUIDed system. As they stated, the GUIDed system combines "all important services in one" constituting it an "everyday life companion" and "assistant". Two of the services rated as most useful included the Smart Home Control service and Smart Safety (now Smart Home Sensors) service as they simplify everyday procedures and offer convenience and safety, respectively. Some participants valued less some of the services due to personal lifestyle preferences. For example, older adults who did not take medication stated that they would not use the Health and Nutrition (now Medication Planner) service so much. In addition, all participants provided the GUIDed team with suggestions for additions and improvements in order to suit their individual needs.

More specifically, participants requested the addition of an emergency button in the GUIDed application home screen to provide an easy means to call for help in case of an emergency. Regarding the Medication Planner service, participants requested the addition of a reminder to measure their blood pressure or sugar levels and fields to insert those measurements in the app. For the Navigation Service, people requested the implementation of voice guidance apart from visual notifications as it seemed easier for them to have auditory assistance while walking around. With regard to Home Control Service, users stated that it would be helpful for them to have the ability to control their TV or front door. Finally, for the Home Sensors Service and the Communication Service users requested the incorporation of anti-theft devices and the simplification of the calling process (e.g., a call should be initiated when the user touches the photo of a contact stored in the app).

Mock-Up Tests Results

A general short summary of each country's recommendations is presented below:

For Cyprus, the main focus was on safety issues. This includes for example granting the ability of the secondary user to lock certain services or features such as the "meet strangers" (now it is called "Meet Others") option in the Smart Communication Service or ensuring that a navigable user registration and deletion process is available. The two most useful services among those offered involve the Smart Health ("Smart Medication Planner") and the Smart Communication Service.

For Norway, the main focus was using the application when not home. This would also imply lower costs as a result. For example, allowing one to control the Home and Safety (Sensors) services when away could enable that person to turn on and off the lights when away on holidays or receive information about the levels of moisture in the house and act accordingly. The services that participants did

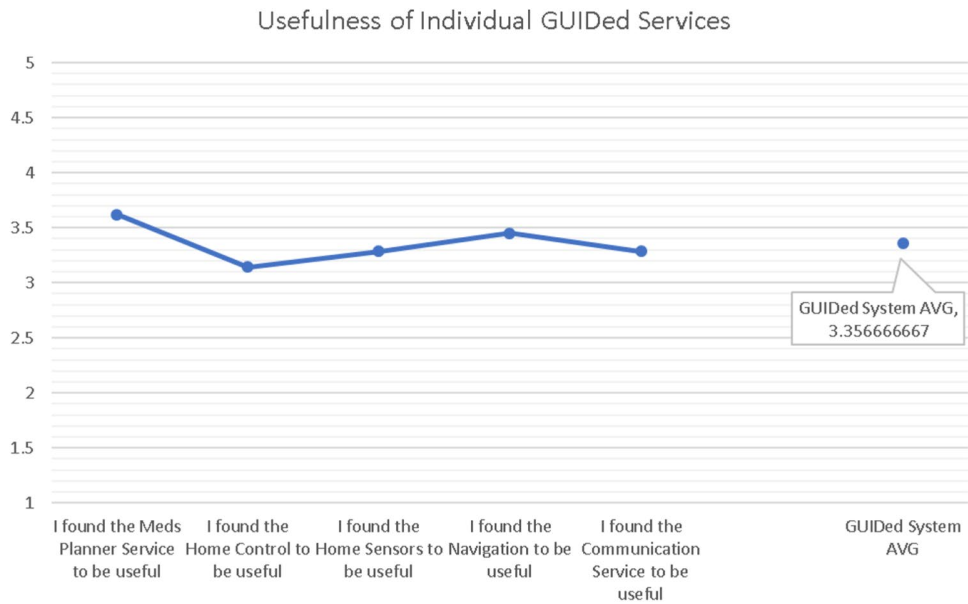


Fig. 11 GUIDed services perceived usefulness

consider to be most useful were the Smart Safety (Sensors) and Smart Navigation Service.

For Poland, the main focus was that of accessibility and design for all. For example, the colors, fonts and specific features of the services, like the "Meet Others" function of the Smart Communication service, could be selected by the user themselves to suit their situation and needs. Of the services offered through the application, participants included the Smart Home Service and the Smart Safety (Sensors) Service among the most interesting to them.

For Austria, the main focus was the inclusion of further functions enriching the overall experience. For example, with respect to the Smart Navigation service, participants would like to see it expanded so as to include a tracking feature where the primary user could alert the secondary user of their location in case they got lost. The two most important services for participants were the Smart Navigation and Smart Communication Service.

Living Lab Tests Results

In terms of the quantitative evaluation of the Perceived Usefulness (PU) of the system prototype, this has been assessed in the living labs, and it is presented in the following graph (see Fig. 11). In overall, the services of the Medication Planner and the Navigation received the highest scores, followed by the Communication service and the Home Sensors. Finally, the Home Control received the lowest score. This can be attributed to the fact that the smart home devices presented some network instability issues outside the laboratory environment. These issues have been identified from the user feedback and are currently fixed in the next release of the system.

Furthermore, the usability is presented in this work through the feedback presented in the following sections of this paper. In fact, the evaluation identified usability issues and the feedback was taken into consideration for the improvement of the system prototype. Based on the lessons learned the next version of this application has been released that resolves issues identified and provides a Minimum Viable Product (MVP) to be tested during the field trials.

Living Lab testing results are presented for primary and secondary users distinctly in the following sections, providing a clearer view of the two end-user target categories. For the tertiary end-user target group, results at this stage are more focused on the business aspect of the system, thus deemed out of scope of the paper and not presented.

Primary User Results

In total, 22 older adults took part in the living labs from Austria, Cyprus, Poland and Norway. Most participants were female, accounting for 59% of the total. Most participants were aged between 60 and 75 years, which is our intended target market and this was represented in the sample by 72% of the total as opposed to 19% which were aged between 76 and 85 and a small 9% being over 85 years old.

Most participants stated to be at the medium IT level meaning they, in general, use a lot of devices such as smartphones, computers, tablets, the internet and applications and can perform a broad array of IT related functions with a low level of difficulty such as using social media. A rather small 5% of participants also stated their IT level as high while an expected 45% claimed the same to be low.

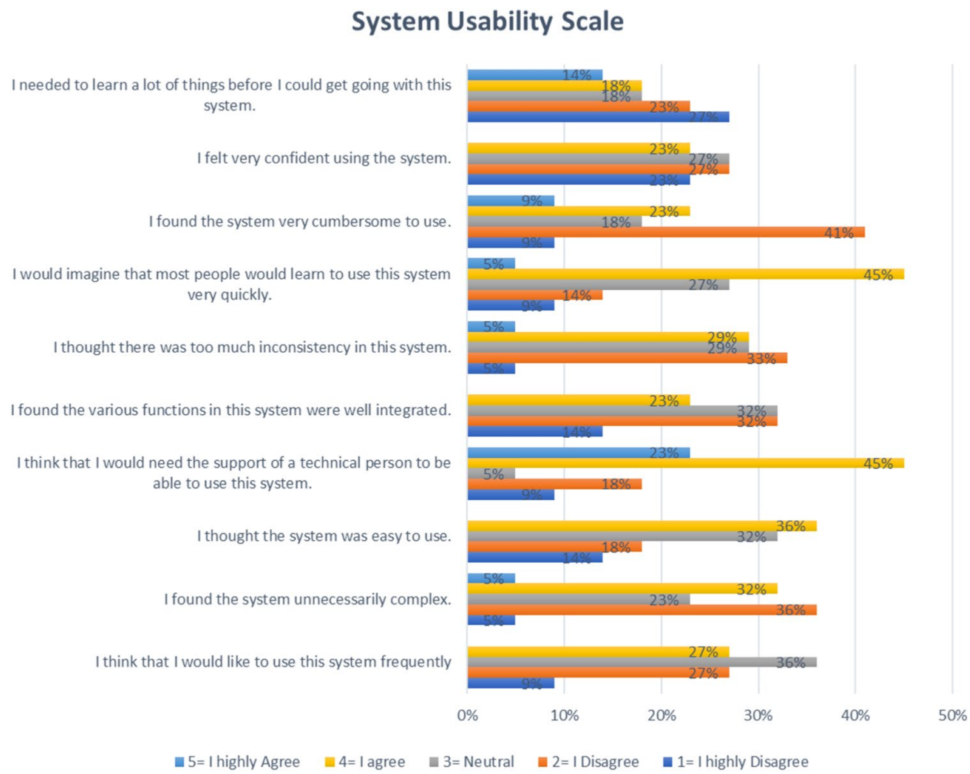


Fig. 12 SUS results—primary users

In order to test the general usability of the system, the standard SUS was employed. The SUS [35] is a standardized and reliable tool to detect the overall usability of an instrument. The SUS is comprised of 10 items, assessed using a five-point response scale which ranges from strongly disagree, to strongly agree. The SUS has a scoring system which delivers a single number that reflects the outcomes of the overall usability of a system. The scoring of SUS derives from the sum of score of each individual item. Each item score can range from 0 to 4. Specifically, for items 1, 3, 5, 7 and 9 the score yields from the scale value checked minus 1. For all other items, the score derives from the subtracting the value checked from 5. The value of the overall usability can be found after the multiplication of the sum of each of the 10 scores with 2.5 [35]. The possible scores to be obtained range from 0 to 100. Bangor and colleagues [35] developed a grading scale in which SUS scores below 60 were an "F," between 60 and 69 were a "D," between 70 and 79 were a "C," between 80 and 89 were a "B," and 90 and above were an "A." In terms of interpretation of this grading system, any value between 70 and 100 is considered an acceptable rating, while value below 70 denotes overall usability issues.

The average sum of the SUS scale was calculated for all users and an average returned from these. The results are presented in Fig. 12. Overall, the system did not perform exceptionally well with most participants finding it rather hard to use. It is important to note here that this can be attributed to the fact that an early prototype was used in the living labs, as part of the co-creation and continuous and ongoing evaluation plan of the project, in order to discover and resolve early usability issues based on initial feedback from the users and thus deliver a fully functional system to be tested during the field trials to be performed in the users' homes.

The overall SUS returned an average value of 48 wherein 68 should be the average reached as this is the SUS standard average across applications in general. The SUS questionnaire will be repeated after the implementation of the field trials and the taking by the partners of corrective measures to counteract the negative score.

This relatively low score was especially reflected in whether or not participants found that there was too much inconsistency in the system (63% scoring this as neutral or worse) as well as their levels of confidence (73% stating this as neutral or worse) and whether or not they would need the help of a technical person to use the system with 68% agreeing or highly agreeing with the statement. All these are areas that could guide the partners into providing suitable solutions. Encouragingly and despite these results, most participants did believe that eventually, they could come to learn how to use the system with 50% stating they agreed or highly agreed with the statement.

These conclusions are further confirmed by the first impressions of the participants. Most liked a number of features about our solution and services with the highest popularity being awarded to the Medication planer and

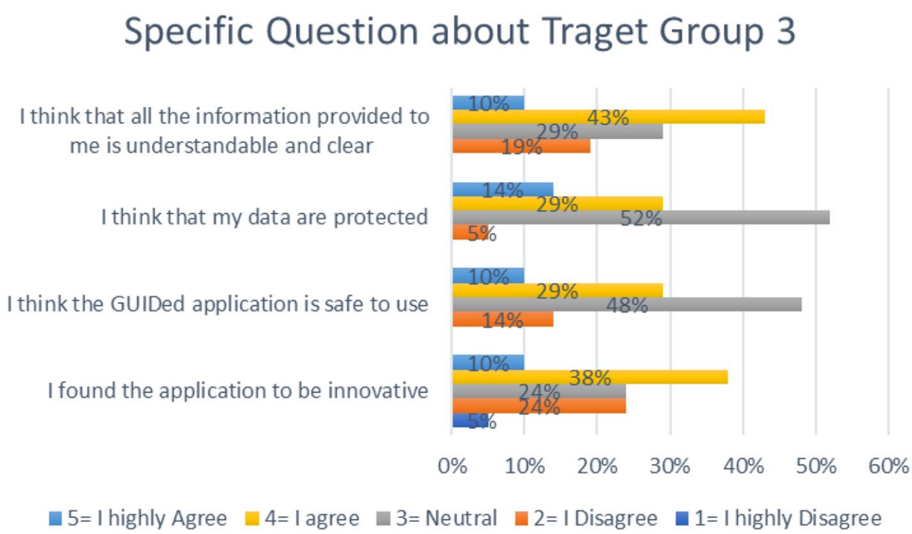


Fig. 13 System Questionnaire Part D—primary users

Home control. Another useful insight relating to the above was with respect to the training that needs to be provided. To this one participant commented when asked what would motivate them to use the system "To be shown more times how to use it".

Regarding the context of the application, the overall reaction is rather positive. Though the majority of participants felt neutral towards, it nonetheless we must keep in mind that the application was still in a developing phase with a lot of bugs. Moreover, it should be noted that around 58% of participants felt like they would need training in using the application. As such perhaps the percentage of participants that would be willing to use the application regarding it as useful and beneficial to them would increase once more training has been provided. Importantly a sufficient number of participants around half would like to have the application be operated on their behalf by someone else and have the option to disable some of the services. Therefore, it is important for the partners to take these into consideration when producing subsequent versions of the application making it more third-party user friendly and enabling a smooth selection of which services the primary users will be able to use.

In addition, participants would be willing to recommend the application to others. However, a large percentage of participants seems neutral or undecided to the question asked, a percentage which may perhaps improve into a more favorable response once some more familiarity has been built with the application.

Importantly participants seem to trust the application. When asked if they believed the information provided was understandable and clear, whether they felt their data were safe and the application is safe to use, participants answered by 53%, 43% and 39%, respectively, that this was the case as demonstrated in Fig. 13. A large percentage of 29%, 53% and 48% for these categories do seem to be ambivalent and so the communication efforts of the consortium ought to be targeted to ensuring that participants fully understand the safety mechanisms behind the application (see Fig. 13). Encouragingly around half of the participants characterized the application to be innovative, an element of excitement perhaps that the partners could utilize in their future efforts to introduce improved versions of the application.

Secondary User Results

In total, 21 secondary users took part in the living labs to get a better feel for the system in more simulated real-world conditions from Norway, Austria, Poland and Cyprus. Most of the participants were male, accounting for 57% of the total. Most of the participants (57%) stated to be at a high IT level meaning they in general use devices like smartphones, computers, tablets, the internet and applications and are capable of resolving any technical issues that might arise.

Overall and unlike the case with primary users, the system performed rather well with most participants finding it relevantly easy to use. The overall SUS returned an average value of 62.2, which is very close to the industry standard that is 68 [35], a result which is much welcoming considering that our product is still undergoing a co-creation process. Perhaps the results could be explained by the usual older adult's unfamiliarity with technology coupled with the need for more exposure and training regarding the application. As was mentioned before the SUS questionnaire will be repeated during the implementation of the field trials. During this time, the recommendations from both primary and secondary users will be considered so as to implement corrective actions to improve the SUS score especially with respect to primary users.

Additional insights for these conclusions can be found by examining the SUS categories themselves (see Fig. 14).

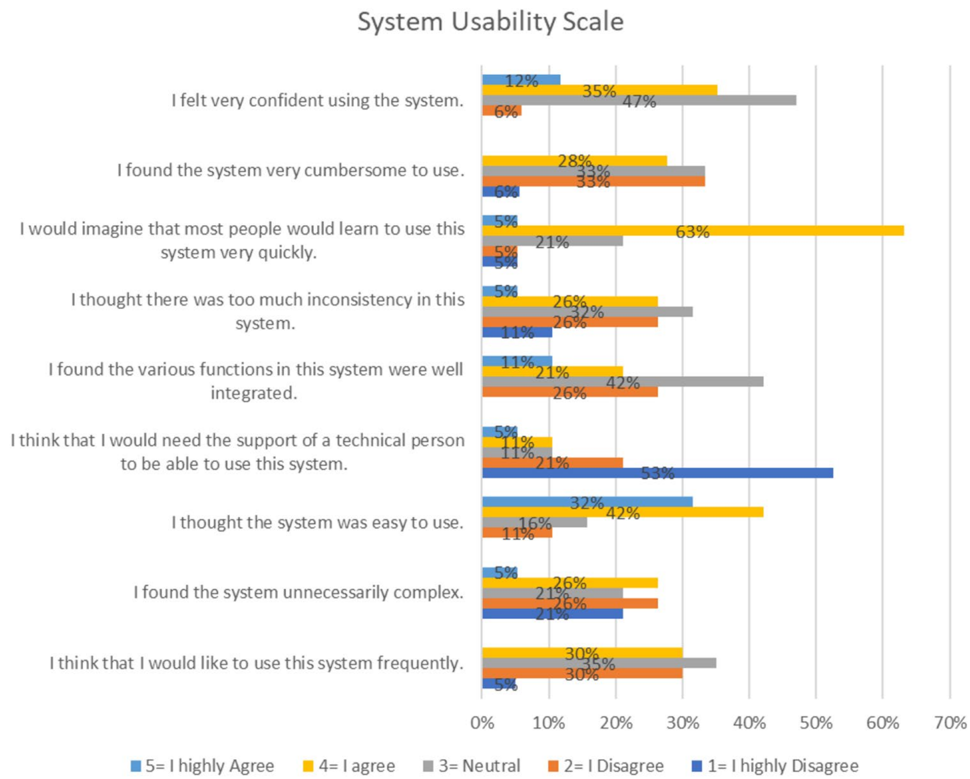


Fig. 14 SUS results—secondary users

Encouragingly as was the case with older adults, secondary users by an even higher degree do generally feel that most people would learn to use the system rather quickly. To this, 63% stated that they agreed and another 5% that they highly agree. Areas where perhaps the partners need to pay more attention to concern the overall organization of the system. Specifically, participants did feel by just 47% that the system was not unnecessarily complex and by only 33% that the various functions of the system were well integrated (see Fig. 14).

Secondary participants seemed more willing to use the application. Importantly, around 50% of our participants here do believe the application would be very useful in improving the quality of life for the person in their care. Moreover, around 65% of the participants do believe that the application would help the person in their care with their daily routine and the same number holds true with respect to helping participants in providing care to these persons.

Between 50 and 60% would recommend or strongly recommend the application to other possible users, including primary users, secondary users and caregivers alike. The category of users which secondary users would recommend this application more are other secondary users to buy for their loved ones. Combining these, the level of innovation and the highest category of users, secondary users, would recommend the application for reveals that participants do feel in general the application is rather innovative and certainly useful especially to secondary users who are responsible for older adults.

As with primary users, secondary users too feel that the application is trustworthy as demonstrated in Fig. 15. This is so as around 42% to 49% believe that the information provided is understandable, the data of the person in their care is protected and that the application is safe to use. As to the rest, most are neutral on the issues needing perhaps some more time to get acquainted with the application.

As to the services themselves, once more the Medication planner takes the lead. This is demonstrated in Fig. 16. Participants by a large majority of 90% declare this service to be the most useful of all the services provided. Second and unlike the primary participants comes the communication service with 72%, while the other services are ranked rather equally with about half the participants believing them useful to themselves and the person in their care. The lowest scoring service is that of Home control but here still 58% of participants did believe it useful for both them and the person in their care and as such we can assume that though some work needs to be put in the services, the application is on a very good path nonetheless.

Discussion

The results of the present study showed that in terms of the user interface, older adults preferred the elements being highly distinguishable from the background (big tiles over

Fig. 15 System Questionnaire Part D—secondary users

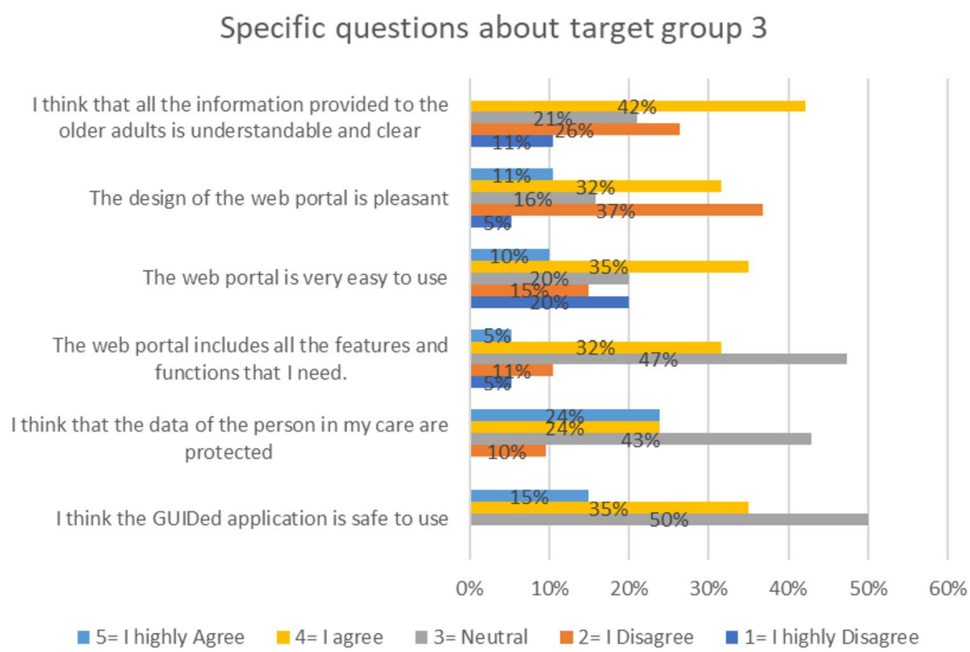
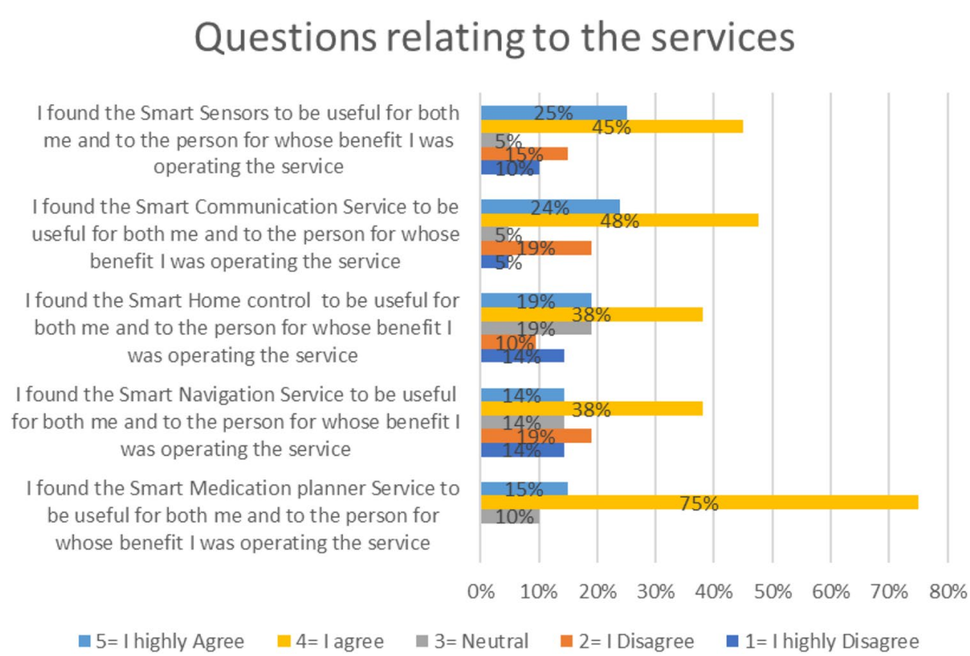


Fig. 16 System Questionnaire Part D—secondary users



list of items, enlarged fonts and minimal use of scrolling and navigation bars). This finding is in line with previous studies suggesting that small buttons, over congestion of screen elements and small navigation features can cause discomfort to people aged 60+ mainly due to the age-related visual and tactile decline [37]. Furthermore, we confirmed that technical jargon should be avoided in apps addressed to seniors, as it not only reduces usability and accessibility but as studies suggest, it may also affect their self-perceived confidence in using the application. As a matter of fact, previous studies have suggested that older adults tend to attribute application difficulties to intrinsic (their own familiarity with technology) rather than extrinsic issues (a bug of the application) which further diminishes their confidence and willingness in to continue using the technology and ultimately, affects technophobia [38]. Given that the system tested in the present study was a developing tool with functionality issues in some cases, this theory also could explain the low ratings given by seniors in the individual items of the SUS scale related to technical navigation and operation of the app. The hypothesis can be further supported by the fact that younger people, namely secondary users, testing the same software/

hardware gave significantly higher ratings in the SUS. In accordance with the above, it was not surprising that most people asked for support during the use of the system including training and technical assistance.

In terms of user preferences, the present paper highlights that older adults prioritize health related applications and services such as the GUIDed medication planner and SOS buttons. This is understandable considering that "aging in place" is one of the most basic needs expressed by seniors [39], but also, a finding affecting older people's adoption and use of technology to be considered by future developers.

Another important finding is that older adults need an extent of customization and personalization. Modern applications targeting this population group frequently envision them as a unified sample with the same needs and limitations (e.g., all having visual problems and need for big buttons and fonts). However, this approach fails to attract users as it falls with the ageism realm not acknowledging individual preferences and differences [40].

The GUIDed application was designed to address all aforementioned issues adhering to principles of user interface mostly favored by seniors but also, considering individual preferences and needs. For example, the user interface of the GUIDed system can be customized and features such as Meet Others, activated and deactivated. GUIDed further addresses optimal user experience by proposing a unified plug and play model for the incorporation of many services thus minimizing the "app fatigue", meaning the need for multiple applications overwhelming the modern customer. Finally, the system considers technophobia and the intrinsic attribution of app-related failures by seniors and incorporates an AR assistant to actively assist users in troubleshooting. This user-centered approach constitutes a novelty in comparison to available apps which in the majority violate seniors' ICT needs [34]. On the other hand, the use of AR technology in the current system has raised some conflicted views in terms of usability indicating that AR may be a highly individualized preference which although considered by the GUIDed technological frameworks, it has to be further assessed in future trials.

Conclusion

This paper presented the GUIDed system including its five services from a technical and user perspective, as well as the co-creation process and the evaluation results of the paper prototypes, focus groups and Living Labs. The services were chosen to support the daily activities of older people supporting not only their independence but also incorporating their social needs. The development was conducted after and while considering recommendations from the literature including the results presented from the evaluation of the paper prototypes [13], as well as the focus groups performed. In terms of the usability aspect, the feedback includes improvements on navigation, transparency and visibility of user interface objects. In addition, the augmented reality functionality provides the capability for end-users to exploit the one-click interaction method incorporated as the integral part and the differentiating point of the GUIDed system compared to existing systems offering similar services. The one-click interaction method can improve usability but further testing in the field trials is required.

The described evaluation results are part of the co-creation process and methods that provided continuous feedback for the development of the GUIDed system. The feedback and improvements resulted to the current release of the system being tested in the user field trials, i.e., at the users' homes. The feedback from the trials will provide valuable insights, since this process will involve the continuous usage and evaluation of the system in the user homes. This will also allow collecting metrics on the use of the individual services by end-users, as well as feedback on the use of the system over a large period of time. Finally, the effect of AR interaction method on usability and user experience when using the system and the individual services will be evaluated against using the conventional user interface interaction method.

Limitations

The present feasibility study was conducted within the COVID-19 pandemic, and thus, opportunity sampling was employed rather than controlled randomization methods, which might have affected the representability of the study population. However, we consider the sample to be representative of people who are early adopters of solutions, since these were people who even during the pandemic were willing to try a new ICT product. Hence, we consider that this is a valid sample to serve as early adopters of our commercialized product as well. Furthermore, as in the majority of similar studies, the main methods for data collection included self-report instruments which may be influenced by participant's cognitive status, social biases and recollection. However, in all cases, participants were encouraged to express negative opinions about the system, the goal of the study being its future improvement.

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Data availability The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

Declarations

Conflict of Interest There are no conflicts of interest.

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