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ORIGINAL RESEARCH

eSticky: An Advanced Remote Reminder System for People with Early Dementia

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Abstract

While the European population is ageing, the number of people with dementia is dramatically rising. With this comes an increased need for products that help affected people to be more independent and able to live in their own home for as long as possible. eSticky addresses this need by providing a sophisticated reminder system that replaces the old-fashioned sticky notes by electronic versions thereof, which can be programmed from near and far in a device-independent manner via the internet and using a standard web browser. For this purpose, a set of low-cost ePaper displays are used, accompanied by a small and unobtrusive base station situated at the user's home, and supported by a web platform for user management and the authoring and scheduling of the message reminders. The displays can be placed at several strategically useful places in a user's home, to enable users and/or care persons to place reminders that will, based on the user's daily routines, most probably be read. A sub-set of displays, named *active displays*, even enable the user to press a confirmation button to show that he or she has actually read the reminder. The confirmation is then made available to the authors of the particular reminder through the web platform. The system is developed using a user-centred design approach, to take all stakeholders' wishes and needs into account, in order to come up with a system that is easy to use and provides good service to many people. In this extended version of the paper, besides a detailed description of the technological advancements of the project, both in terms of software and hardware, we provide an insight of the eSticky device design methodology and results from the design user evaluation.

Keywords Reminder system · Dementia · Older adults · Independence · Design · Internet of things · Assistive technology

Introduction

The number of people living with dementia worldwide in 2013 was estimated at 44 million. By 2030, this number is expected to reach 76 million and by 2050 rise up to 135 million [1]. It is also foreseen that by 2030 one in five people will be older than 65 years of age and almost half of the people that are older than 84 will have dementia [2, 3]. In Europe, data show that the age-specific prevalence rates have been constant over time and this trend is expected to continue in the future [4].

Alzheimer Europe's 2013: the prevalence of dementia in Europe report [5] estimated that the average EU population who were living with dementia at the time was 1.55%. The report further indicates the population for Italy being 1,272,317 (2.09% of the total population), for Austria 145,431 (1.73% of the total population), for Cyprus 11,250 (1.07% of the total population) and for Poland 501,092 (1.31% of the total population). The fact that this report shows that there are people living with dementia in the age band of 30–59 is worth noticing. Even though the number of affected population within this age band in comparison to older age bands is considerably less, it indicates that dementia can also be experienced by younger adults too.

Studies in many countries have attempted to quantify the financial cost of dementia. This has proven to be

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a challenging task but what is clearly agreed upon is that these costs are large and growing. In OECD member countries, which include Italy, Austria and Poland, a significant portion of health spending is linked with the direct costs of dementia (e.g. nursing home care). A cross-country variation does apply nonetheless [5]. In addition to the direct costs of dementia there are also significant indirect costs too; the outcome of the impact on families, carers and the wider community. As previously mentioned, it is difficult to quantify the full cost because measuring and estimating the indirect costs presents methodological challenges (e.g. quantifying with a monetary value the cost of informal care). Hence, different approaches are used in different studies leading to uncertainty on the resulting numbers. From a European perspective, it is noticeable that we account for about a third of the annual global costs [5].

Insufficient support from professionals and health care services to stimulate self-management abilities is often experienced in the early stages of the disease, while interventions for coping with dementia are rare. Moreover, medical treatment still remains as the main focus of such interventions. Rather, an approach that adopts a more holistic view of the person and their needs is required, as was also proposed in [6]. Most people with dementia would prefer to continue living in their own homes. This situation would have a positive impact on their quality of life while also keeping them closer to their families. Furthermore, it would benefit them financially too, since formal care at home can be expensive and, in some cases, not even possible [7]. Either way, the burden for both family and paid caregivers is heavy. As the elderly population increases and the number of younger adults' decreases it will become even more unviable to expect younger adults to assist older persons with their long-term care needs in general, including those due to dementia. Long-term care workforce shortage, caregiver burden and high costs of care have led to an increase of interest in the potential of Assistive Technology (AT) to substitute for, complement, or supplement paid and unpaid caregiving for people with dementia [8].

AT that supports people who are living with dementia varies greatly. Their goals are commonly cited as maintenance of independence and providing a sense of autonomy, relieving caregiver burden and contributing to better safety. From simple standalone devices to more complex integrated systems, by helping a person remain independent for as long as possible, it enables them to live longer in their own homes than would otherwise be possible. Everyday living, monitoring, safety, communication, as well as automated prompts and reminders are areas where AT can be especially helpful for persons with dementia.

Since the purpose of AT for memory impairment compensation is to offer reminders or prompts, dementia has thus been equated to memory impairment. It must be noted, however, that people living with dementia are not just forgetful, but their ability to recall information, recognise objects and create new memories are also affected. As a result, storing, retaining and recalling new knowledge is a problem. In turn, their ability in learning and remembering how to use AT devices is likewise impaired. Existing products that offer reminders seem to have neglected this aspect and hence their design does not consider the type and range of cognitive impairments found with persons in this population.

The eSticky project aims to design and develop small and novel eSticky displays that provide reminders and prompts to people living with dementia. The novelty of the product will lie in its design and its affordability, as well as in the combination of several reminders into an integrated, remotely configurable and extendable system. Resembling traditional sticky notes, the proposed eSticky displays will be affordable to the point that a person living with dementia can purchase multiple displays and stick them in different areas of his or her home. By having eSticky displays located in every room of the home, family members and/or caregivers can predetermine, based on the normal daily routine of the person living with dementia, in what area of the home it will be more effective to set a reminder on the respective eSticky display. Reminders and prompts can be set using the eSticky web portal. Let us assume that a person living with dementia has a doctor's appointment at 12:00. The evening before the day of the appointment a family member uses the web portal to (remotely) set a reminder for 08:00 (the next morning) on the eSticky display that is located in the kitchen and also sets a reminder for 11:00 on the eSticky display that is located in the TV room. These eSticky displays were purposefully chosen by the family member since he or she is aware of the daily routine of the person living with dementia. This routine usually entails that the person be in the kitchen between 07:45 and 08:15 for breakfast and watch favourite TV shows between 10:30 and 11:30.

The user-friendly and intuitive design of eSticky makes it accessible to people with disabilities and easy enough to use to enable people with beginning dementia to set their own reminders.

The main target group of eSticky consists of people with age-related obliviousness, people with beginning stages of dementia and people with beginning Alzheimer's disease (only in an early or medium state), so-called primary users, who can live independently in their homes or professional institutions for older people without any special help. The stakeholders also include informal carers (family members, so-called secondary users) and formal carers—care service providers offering 24/7 assistance, retirement homes, nursery homes and their formal staff (healthcare professionals, i.e. tertiary users). eSticky will be used directly by older people with memory problems and their caregivers, families, etc. who will use it for the good of the primary users.

In the initial phase, the project activity picked-up from the older adults and carers/families to analyse the demands and needs and the platform specification, to guarantee that these demands and needs are respected in the hardware configuration of the device and the adaptation of the software platform and services. For the evaluations that are being conducted in the project, a total of 40 older adults will participate, in two countries, Austria and Poland. Besides the evaluation with 40 older adults, a considerable number of secondary (family members, friends and informal caregivers of older adults) and tertiary users (formal caregivers, professionals working with older adults) has been recruited in the context of the project for testing purposes. These would be admins, persons managing the user roles and the displays, and, more importantly, the authors of the messages for the older adults. The total number of users involved in the eSticky research is, therefore, much larger than 40.

In a full user-centred design approach (UCD), end user-oriented partners constantly monitor, discuss, evaluate and provide feedback based on the system development activities, so as to guarantee the proper implementation, integration and optimization of the platform. The goal of the UCD is to make products which have high usability. This includes how convenient the product is in terms of its usage, manageability, effectiveness and how well it is mapped to the user requirements. To achieve it, the development of eSticky notes is user driven right from the beginning of the project. The important aspect of planning user requirements was to define the process of recruiting users, policy for user involvement, taking into account local cooperation organisations (national associations, centres and non-governmental organisations), own contacts and communication channels of end user partners in Austria and Poland, as well as inclusion and exclusion criteria of users, exit strategy, data collection methods, privacy design and ethical issues.

Since depending on users' condition some of them have reduced cognitive capabilities, there are certain additional ethical issues that need to be considered. Legal and ethical issues are especially considered for the testing and evaluation phases of the application with the end users. This requires the authorization by the end user and/or family member. The end user partners have produced a detailed "Informed Consent" process (signed by either the users themselves or their legally assigned representatives) that guarantees transparency and include information such as a description of the project and its aims, a specification of the role of different end users in the project, self-determination of the end users (to be able to turn off systems or services at their own discretion), contact person in the project (for ethical issues and related questions) and exit rights for individual end users (withdrawal possible at any time, without a reason and costs). It is worth underlining that the end user partners have applied for ethical approvals by ethical committees in Poland and Austria to ensure compliance with national guidelines regarding Informed Consent and confidentiality.

Another goal of this project is for the system to be used by as many people of the target group as possible. Therefore, the consortium follows the "Design for All" principle during all evaluation, design and implementation steps to fulfil this criterion.

In this paper, we provide a technical overview of the proposed solution. We describe the software modules of the system and the hardware devices used. Important components of the eSticky system, such as the middleware, the Web server with its UI mock-ups and the displays are discussed in terms of their design, development and evaluation. Specifically, the initial UI mock-ups of the Web server and the designs of the displays were evaluated by end users. The evaluation results will drive the redesign of the modules and the final development of the eSticky system.

The paper is structured as follows: the "IoT Importance for Older Adults" section discusses the related work. The "eSticky System" section describes the eSticky system in terms of architecture and software/hardware components. The "Design Process" section presents the design process of the displays. The "Web Server UI Mock-Ups and Results from User Feedback" section discusses the Web server UI mock-ups, their evaluation by end users and the improvements made based on users' feedback. The "Testing of Non-functional eSticky Displays" section presents the testing of non-functional eSticky displays by end users, and finally, the "Conclusions" section discusses the conclusions.

IoT Importance for Older Adults

The Internet of Things (IoT) can improve older adults' quality of life. Additional important benefits resulting from their use include decrease of strain on national health systems and decrease of system operational costs overall [9, 13]. As an ageing society, the use of such technology should be pursued for improved lifestyle, independence and home health care and promotion [10, 11]. Coupled with the design and development of this technology solutions and services, one needs to consider the five basic programmes proposed by the General Assembly of the United Nations in 1991 (UN, 1991) when care is offered to older adults: independence, participation, care, self-fulfilment, and dignity [12, 13].

The potential of the IoT paradigm in the context of assisted living for older and fragile adults is discussed in [23]. Considering the peculiar requirements of this user group, the authors evaluate the paradigm from functional and technological perspectives. In their review of the state-of-the-art, they mention that research on matching users' needs, values, habits and lifestyles are evident in the literature, especially in the design of new IoT-based AAL

systems [14–16]. One IoT platform that was implemented to take care of older adults at their home is presented in Pires et al. [17]. In their study, a smart TV was used to convey health-related information to the individual, using an unobtrusive method (i.e. as additional commercials). Others [18, 19] have focussed on adopting user-centred design approaches for the design and development of an e-Health platform to assist older adults in smart cities. An IoT architecture was modified to also include an additional layer in [20] that would help address specific needs of people with diverse disabilities. Efforts have likewise been directed towards standardisation, focussing on effective user-centric IoT-based AAL solutions [21]. Moreover, it was reported that more promotion is needed in this regard, since lack of standards is seen as a major challenge to the actual spread of IoT-based AAL systems in healthcare specifically. In [22], it is reported that in addition to efficiency and security, system flexibility and learnability are likewise key features of the user-centric IoT design that could significantly increase the level of system usability.

The study in [24] investigates the effectiveness of an electric calendar, showing the date and schedule automatically for older people, and to prove the characteristics of appropriate users. The participants were 27 older adults with or without dementia (9 men, 18 women, 72–94 years old). The study design was a cross-over randomised controlled trial, with 15 participants (55.6%) allocated to the first group to use the electric calendar, and 12 participants (44.4%) to the second intervention group. The outcome measures are daily behaviours and cognitive function assessed by the Mini-Mental State Examination and Neurobehavioral Cognitive Status Examination. Participants showed significant increase in total Mini-Mental State Examination score after intervention period, whereas there was no significant difference after no intervention. Daily activities related healthcare were improved. The participants with positive outcomes showed higher motivations and around 18 points in Mini-Mental State Examination. Most healthy older adults mentioned that electric calendars were useful, but unnecessary. Using the electric calendar was effective in improving global cognitive function and daily activities.

There is a need for continuous surveillance and assistance, and support of elders, causing a big financial and human burden on individuals and their caregivers [25]. Interconnected sensing technology, such as IoT wearables and devices, make a promising solution for objective, reliable, and remote monitoring, assessment, and support through assisted living. The study in [25] presents a review of the above solutions that consist of both earlier review studies and individual case studies, exponentially evolving in the last decade. In doing so, it examines and enlists them according to habitual aspects of interest such as health focus, from specific diseases to general eldercare. The paper presents IoT technologies, from wearables to smart-home sensors, from analysis to fall detection and indoor positioning to involvement, and exploratory assessment and result measures, from validity to precision. Statistics derived from this classification are intended to provide an overview of the current state-of-the-art, as well as future trends and effective methods. The authors in [26] satisfy the demand for services that make use of cutting-edge technologies and gadgets. Nowadays, both loneliness and psychological distress are common challenges that elderly people encounter these days as a result of living alone, being abandoned, or having limited communication with their children and family. They outline the creation of an integrated platform that uses IoT to administer and provide a wide range of services to elderly people to address the difficulties described. The proposed platform relies on wearable sensor devices to collect real-time data and store it in a cloud server.

As a relatively new reality, the IoT is transforming our daily lives and has the potential to transform modern healthcare by providing more personalised, preventive, and collaborative care [27]. Aiming to combine these two important topics, an IoT-ready solution for older adults living assistance, which can monitor and register a patient's vital information as well as provide mechanisms to trigger alarms in emergency situations is presented in [27]. Because of its effective low-power/low-cost and wireless properties, this solution may be worn discreetly and comfortably everywhere and by anyone. Experiments demonstrated a good system performance for the implemented functionalities, and regarding the autonomy, an average battery lifetime of 306 h (around 12 days) was achieved. For the working range, the system has proved to perform well within a range of 60 m before the out-of-range warning being triggered. In [28], a smart-home IoT infrastructure for the support and extension of the independent living of older adults in their living environments that also responds to real needs of caregivers and public authorities is proposed. The proposed infrastructure provides a safe environment for the aged, mitigates frailty, and preserves quality of life and autonomy by seamlessly integrating health and monitoring devices. It also includes a decision support system that provides advanced analytics and visual analytics mechanisms to formal and informal caregivers of the elderly for efficient monitoring of their health and activity status, as well as a method for easy implementation and testing of the installed equipment.

The project HABITAT's (Home Assistance Based on the Internet of Things for the Autonomy of Everybody) [29] aim is the development of smart devices to support elderly people both in their own home and in retirement homes, embedding them in everyday life activities, reducing the expenses for healthcare due to the lower need for personal assistance, and providing a better life quality to the elderly users. Developed within the framework of the project, a digital platform

for Smart Homes that exploits IoT technologies (Radio Frequency Identification, wearable electronics, Wireless Sensor Networks with Artificial Intelligence) is presented [29]. The platform's flexibility in allowing the interoperability of different smart devices is especially highlighted.

A platform for social interaction, based on Augmented Reality (AR), was deployed in the homes of older adults [30]. Its two main components were the affordable robot platform built from TurtleBot robot and the underlying software system built on top of ROS, in charge of the interaction interface and the user tasks, called MYRA. The purpose of the study was to evaluate the platform and AR in real environments, focussing on effective use by older adults. To test the platform, a generic assistance system and a drug dose control system were implemented.

It has been shown that although older adults can benefit from technologies that help them complete everyday tasks, they are often neglected as a target group in AR research. In [31], results are presented of a study in which people aged 50 years or older were asked to perform actions by interpreting visual AR prompts in a lab setting. Results demonstrated that, when utilising two of the four augmentations (ARROW and HIGHLIGHT), users were less successful at performing activities than when using the other two augmentations (ghosted OBJECT or GHOSTHAND) augmentations. In addition, it was noted that user confidence in doing actions varied depending on the action and the type of augmentation. Overall, users favoured combining AUDIO + TEXT prompts (the control condition), but the GHOSTHAND visual prompt was the most popular. The reasons for these discrepancies were discussed and recommendations were provided to AR content creators for older individuals. This research was the first to compare AR in older persons in a non-industrial setting.

Advances in technology can offer older adults benefits like maintaining their independent lifestyle and remaining socially connected with others. As the integrated use of AR technology within daily lifestyle continues to increase, its potential in impacting older adults' lives in multiple ways remains real. Yet, in addition to the aforementioned studies discussed, more studies are needed in order to determine whether this potential can indeed be realised and impact positively on this specific user group. The fact that this user group is particularly volatile to cognitive and physical decline, and tend to experience digital exclusion, may mean that AR technology could be difficult for them to understand and use. It would be interesting to see more results in this aspect in the near future.

Technological advances may offer benefits for older adults, such as maintaining their independence and connection to society. Nevertheless, adopting new technologies like AR may be difficult for older adults commonly due to the decline of cognitive and physical abilities and/or their familiarity, apprehension and understanding on how to use modern technologies.

Table 1 describes related work and how eSticky compares to it, emphasising on means of differentiation.

eSticky System

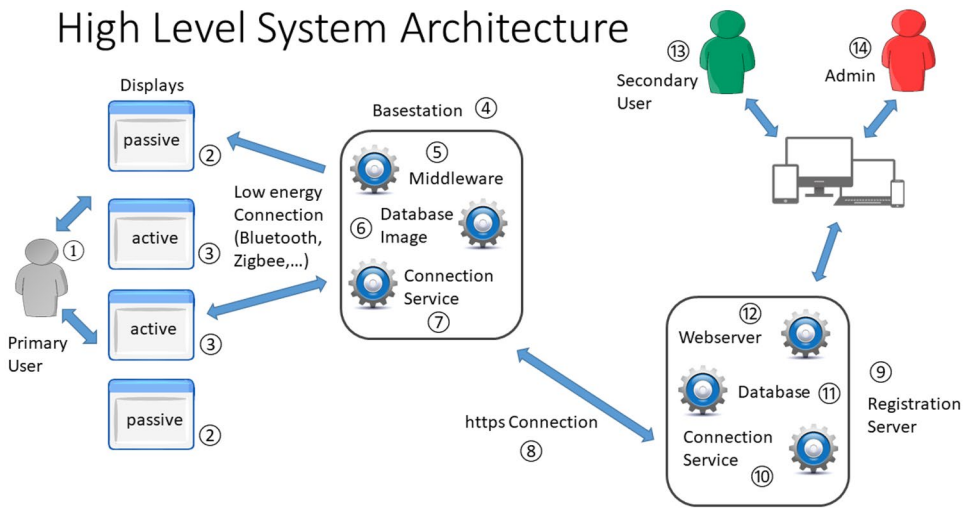
High-Level System Architecture

The high-level system architecture (see Fig. 1) shows the relationships between the different system components:

(1) Primary user: can read the messages on the displays and will thus be reminded of certain things. The primary user can read messages and, if an "active" display (with a confirmation button) is used, can confirm messages. **(2) Displays (passive)**: passive displays simply show the reminder messages. The user has no possibility of interaction with a passive display. The base station sends messages to the displays (at a specified point in time, according to the database entries), which show these messages with the determined display parameters. These messages are shown for a (user-defined) time period. **(3) Displays (active)**: same as passive displays, only that the user can make simple interactions here, i.e. he or she can press a button to confirm that the message has been read. The user's answer will then be sent to the middleware and later passed on to the registration server and stored in the database. Relatives or carers can view this user's confirmation on demand via the web application. After confirmation by the user, the message is deleted on all displays. **(4) Base station**: the base station (RaspberryPi v4) includes the middleware, an image of the database and a connection service to interact with the registration server. The base station has a preconfigured admin user account for service purposes. **(5) Middleware**: the middleware manages the displays. It uses a reduced image of the system database (that is located on the registration server) that contains the upcoming messages to be displayed and other related info. **(6) Database image**: temporarily stores the upcoming messages scheduled to appear on the displays at specific points in time. After sent to the displays, the messages are deleted, while new upcoming messages are retrieved from the server at regular time intervals. The middleware communicates with the displays using a pairless Bluetooth Low Energy (BLE) connection. **(7) Connection service**: sets up and keeps alive an https connection to the registration server. **(8) Constant https connection**: connection between base station and registration server, used to: i. get image of database, ii. get notifications, when database has been updated, and iii. send users' confirmation messages to be stored in the database. **(9) Registration server**: contains a connection service, the database and a webserver. **(10) Connection Service**: Maintains the communication with the base stations.

Table 1 eSticky system in comparison with related work

Related work	Description of related work	eSticky
[14-16, 20, 28]	Proposed an architecture/framework to design a new IoT-based system and analyse it	eSticky system will be implemented, evaluated, and improved based on user's feedback
[17]	Convey health-related information to the user	Provide users with a variety of information through messages for everyday tasks, including health-related information
[18, 19]	Design and develop an e-health platform to assist older adults in smart cities	Use of a base station at user's homes that communicates with displays to assist older adults in their home
[21]	Observed the lack of standards being a significant barrier to the real adoption of IoT-based AAL systems, particularly in the field of healthcare	Implementing a reminder system for the people with early dementia that makes the life of the user easier
[22]	Observed that the key features of a user-centric IoT design not only need to be efficient and secure, but also must include system flexibility and learnability for a more usable system	The design of the eSticky system was done considering flexibility and learnability. These will be measured during the evaluation of the final system by older adults
[23, 25]	Observed that research on matching users' requirements, values, habits, and lifestyles is visible in the literature, particularly in the creation of new IoT-based AAL systems	eSticky design can benefit from this related work by adopting the methodologies proposed
[24]	Analyses the effectiveness of an electric calendar, showing the date and schedule automatically for older people	eSticky system offers scheduled messages to older adults in real time via displays positioned in the older adults' homes
[26]	Wearable sensor devices are used by the proposed platform to gather real-time data and store it on a cloud server. Offer an application that makes it easier for an authorised person to handle relevant information about older people	Use of displays to assist older adults in their home by offering them scheduled textual messages
[27]	Offers an IoT solution for older adults (living assistance) that can monitor and record a patient's critical information as well as activate alarms in emergency scenarios is provided. In terms of autonomy, an average battery lifespan of 306 h (about 12 days) was attained	Use of displays to assist older adults in their home by offering them scheduled textual messages. In terms of autonomy, the battery lifespan of the eSticky system is expected to be 3–6 months
[29]	An IoT digital platform for Smart Homes is proposed, together with smart devices to support elderly people both in their own homes and in retirement homes	Use of displays to assist older adults in their home by offering them scheduled textual messages
[30]	An AR-based platform for social interaction was introduced. The purpose of the study was to evaluate the platform and AR in real environments, focussing on effective use by older adults	Use of displays to assist older adults in their home by offering them scheduled textual messages in real time. No AR functionality is proposed in eSticky
[31]	Results are presented of a study in which people aged 50 years or older were asked to perform actions by interpreting visual AR prompts in a lab setting	Displays are used to interact with older adults, which is estimated to be easier in usage compared to AR equipment



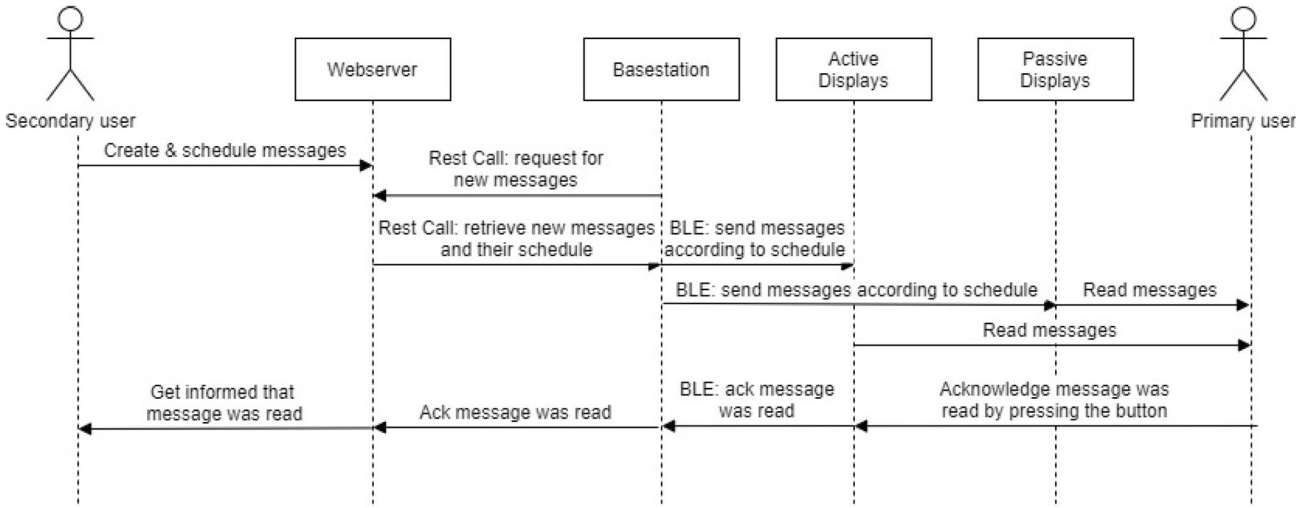


Fig. 1 High-level system architecture

Fig. 2 The eSticky sequence diagram

(11) Database: stores all the messages, their schedule, their layout as well as the assignment to which display(s) every message will be sent. The users' confirmations will also be stored here. **(12) Webserver**: delivers the web app that lets the secondary users configure the system (set user-friendly name for registered displays, user management, etc.), maintain the message schedule (incl. setting the messages and their parameters) and view the primary users' confirmations. Special attention is paid to responsiveness, usability and accessibility (WCAG 2.1 AA) when implementing the GUI. When a secondary user changes something, it is stored in the database and the respective base station is notified via the connection service. **(13) Secondary user**: relatives and carers (and also primary users, if their dementia still allows it) can communicate with the web application via different end devices (e.g. PC, tablet, smartphone). They can i. create new messages, ii. parametrise messages (view), iii. create schedules for the messages, iv. select the displays on which the messages should appear, and v. view the primary users' confirmations. **(14) Admin**: The admin configures all system relevant settings: i. a user-friendly name for the registered display-IDs and ii. user administration (user name, password, rights and roles).

Figure 2 shows the sequence diagram of our system, depicting the process from the point of creating new messages and their schedule by the secondary user, to the point where the messages reach the primary user who may read them and confirm (acknowledge) reception of the message (for those shown on active displays). As the figure shows, the Basestation retrieves new messages and their schedule from the Webserver via REST Calls and, after storing them and processing them in the middleware, sends the messages to be displayed via BLE to the corresponding active and passive displays according to the schedule.

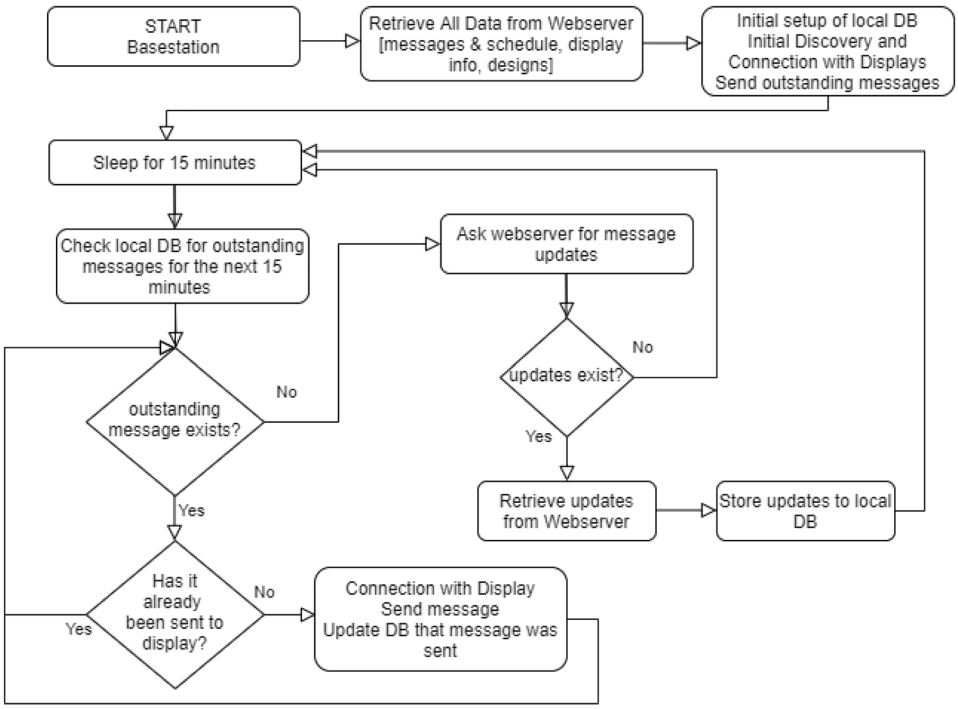


Fig. 3 The Middleware's workflow

In the remaining of this section, we will focus on the base middleware and how messages are handled and sent to the displays.

Middleware and Connectivity

The aim of the middleware is to forward the appropriate messages to the corresponding displays, according to a predefined schedule created by secondary users via the Webserver. The middleware runs on the base station that is situated at the home of the primary user. It connects to the webserver to acquire upcoming message updates for the particular primary user, as well as the upcoming messages' schedule. The middleware consists of 3 modules: the reasoner, the scheduler and the sender. It also interacts with the local MySQL database image where it stores the messages acquired from the webserver in order to send them to the displays at the appropriate time for each message. In addition, the database image also serves as a means to support the system for several hours in case of internet connection failure, as the messages will be retrieved from there and sent to the displays according to their initial (prior to internet connection failure) schedule.

Components

In the following paragraphs, the components that compose the middleware are described. Figure 3 shows the system workflow (DB stands for database image).

Reasoner

The Reasoner Component retrieves the user-scheduled messages from the webserver and stores them in the middleware's database image. A set of appropriate REST calls are issued to receive new messages, as well as updates for existing messages. Other information retrieved include details about how the messages should appear on the display of choice (determined through the "designs" of messages, see Fig. 3), as well as connection/communication related information about any new displays that may be added to the system. All retrieved data are stored into the middleware's database image.

The messages will be sent to the displays at the appropriate point in time, decided by the Scheduler Component based on the messages schedule. There is a distinction between "simple" and "complex" messages, where simple messages define a single appearance on the display, whereas complex messages are "iterative", meaning that they appear more than once on a display. The available iteration intervals consist of daily, weekly and monthly repeated messages. For the monthly repeated messages scheduled after the 28th day of a month, we have adopted the approach of MS Outlook,[1] scheduling the message on the closest (to the original) date within each month (e.g. a message scheduled for the 31st of January will be repeated on the 28th or the 29th of February, and on the 31st of March).

[1] outlook.live.com/owa/.

Scheduler

One of the major roles of the base station is to decide when messages need to be sent and where. This task is being handled by the scheduler which is responsible for defining what messages are in line to be displayed, on which displays and when these messages should be sent to the displays. This is done by regularly checking the database image whether any messages are to be displayed in a specific time span (currently, within the next 15 min), in which case the scheduler will retrieve them and place them in a queue. The messages in the queue will be handled and sent to the respective displays by a different module, namely the sender. Once a message is placed in the queue, the scheduler marks the message as "in queue" and moves on to the next messages.

Sender

The sender is the module responsible for sending the messages in the queue. It is a simple and lightweight module, able to read the messages, connect to the corresponding display and send the messages, logging at the same time any errors. BLE is used to establish the connections between the Raspberry Pi base station (via the sender) and the displays. BLE is a low-power, short-range wireless technology (two communicating devices should be placed no more than 10 m from each other).

The sender module is a Python programme that runs on the middleware of the base station. The display, which is an Arduino, is programmed to receive the message from the middleware and then render the appropriate image with the text on the display screen. A synchronisation between the middleware and the displays is essential, as the messages need to be sent to the displays sequentially one at a time and at a specific time intervals. In case the middleware delays for any reason to search for a display, the connection could be missed entirely as the displays accept incoming connections only at specific time intervals due to power constraints. The sender enters into a stand-by operation itself, whereas the scheduler wakes up the sender in order to send any upcoming messages to the displays.

Having two separate modules for implementing the tasks of the scheduler and the sender is preferred, as opposed to having a single module performing both tasks, as these tasks are sensitive regarding punctuality through long time periods and need to be able to recover from any unexpected issues/failures that may occur. Having two different modules ensures that, in case the sender fails to send a message to a display for any reason and/or stalls (e.g. network or connectivity problems), the scheduler will continue functioning as normal, ensuring that no other messages are lost due to issues. In addition, if these modules were to be combined in one, big delays would become more probable as well. As the message sending procedure may be time consuming compared to other functionalities of the system, after the continuous use of the system through time, delays could accumulate which may result in missing messages. This possibility is eliminated by the separation of the two modules.

Hardware Decisions About the Displays

An important requirement of the project in terms of the hardware components was to find an appropriate solution to facilitate the displays that will be placed in the local environment, i.e. the end user's house. Prior to defining the final design, that is based on the ESP32 microcontroller, the consortium was also considering two alternative solutions from the market. Both solutions satisfied the specifications of the project and provided pre-programmed displays that can be easily set up in the end user's house. The specifications for the displays included among other, long battery life to avoid recharging in time intervals that are less than 6 months. That would allow for a technician or a family member/healthcare professional to undertake this task. The first solution was rejected due to the fact that it required an extra device, a hub that was responsible for connecting with the displays and sending them the messages to be displayed. This process is now facilitated by the base station. In addition, some displays did not support the decided communication protocol, while those that did, were extremely energy consuming. About the second solution, while it did not require any extra devices and all of the displays supported the communication protocol, it did not provide enough support in terms of maintenance, configuration and programming of the displays.

Design Process

To maximise the support for people with dementia through the eSticky system, it is beneficial and important to develop the product with a professional design process. Therefore, several appropriate design methods have been applied. The focus is on the primary users with their dementia needs and needs of older adults in general.

The design process started with market research to get an overview especially with regard to the aesthetic, functional and ergonomic needs of people with memory problems. In addition, an analysis of material and colour trends was carried out in relation to the target group, mainly older adults. To integrate these results into a useful tool for the design process, a design mood board "world of the user" was developed. This is a visual impression through picture examples from this research.

To have a guideline for the following design development, a design brief was developed. The customer needs were identified through the analysis of the design research

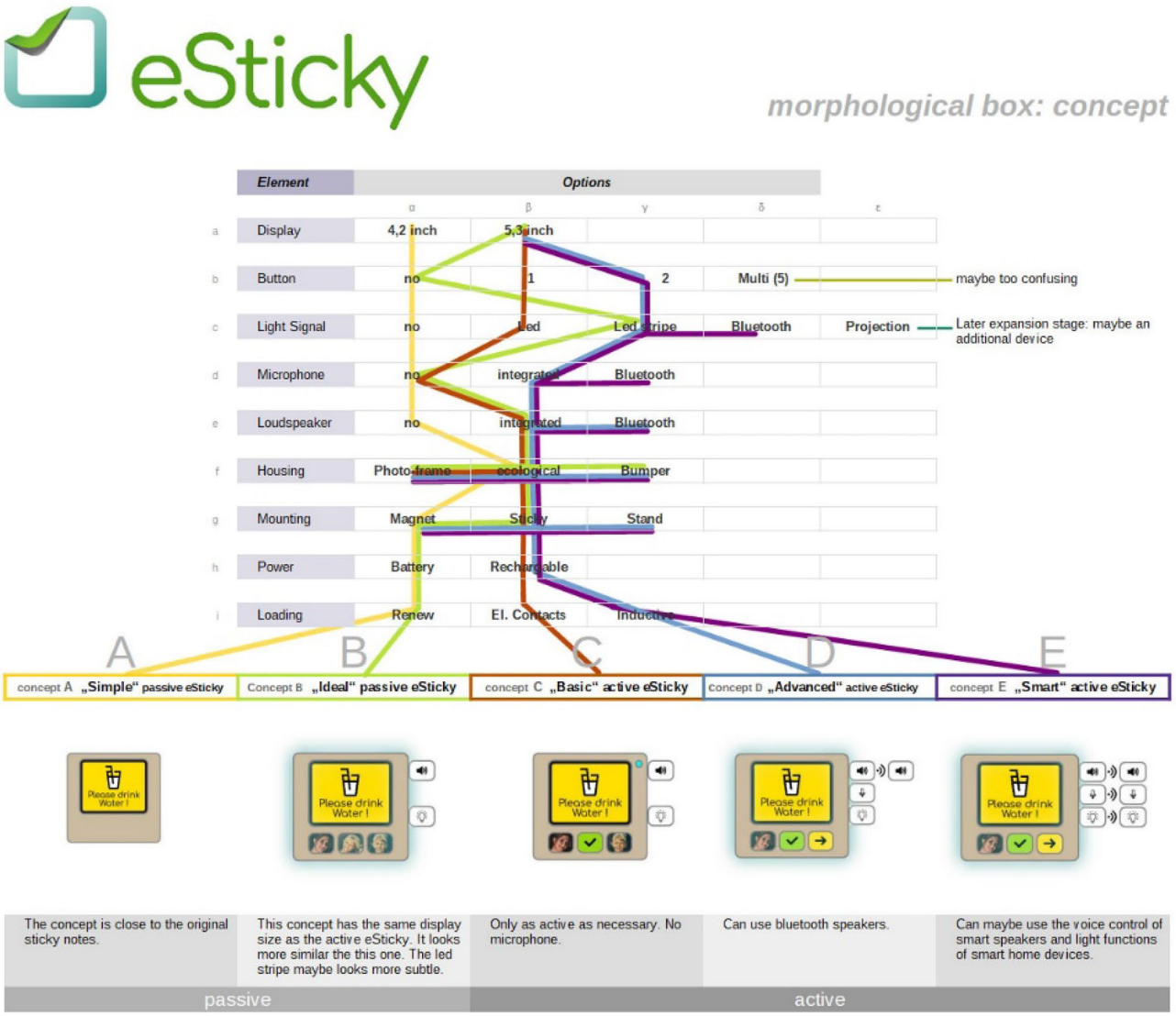


Fig. 4 Morphological box: concepts

results and the results of the user participation by the user-experience partners, which in turn led to the specifications for the product design in aesthetic (psychological), practical and symbolic (social) terms. Following, the legal requirements were determined. The aforementioned activities were conducted always having in consideration a key requirement of the eSticky design: the primary users' need for a familiar look and feel of both the physical case and the user interface to accept the product.

A design concept process often starts with an idea-finding method, and in this case, brainstorming and card sorting methods were used. Basic ideas and concepts were generated and discussed among partners in terms of human-centred design, involving many stakeholders in the design process. Initial design drawings were created and discussed with an awareness of usability (see Fig. 4).

The next phase of design development is the design sketch phase. The refinement of the design sketches was realised through renderings on an interactive pen display and on paper. In this way, different product shapes of the casing could be created. The graphic design and icons of the user interface for the eSticky displays were also created (see Fig. 5). These designs were evaluated by the designers and the team members. A selection of different design drafts formed the basis for the next step: the technical design process.

In this phase, the hardware was translated into design drafts, resulting in an innovative product form. Designers

Fig. 5 Variations of the user interface design for eSticky displays

and hardware partners collaborated in determining the hardware components and operating elements of the product. The human–machine interface was refined to achieve a more ergonomic design, while practical functions such as handling, cleaning and maintenance were also optimised. For the design, roughly dimensioned technical construction drawings and various external shapes were created as a basis for further model construction (see Fig. 6).

Several non-functional touchable 3D pre-models were made from cardboard or similar materials (i.e. low-fidelity prototype) to attain first impressions of proportions and ergonomics. Designs of non-functional touchable 3D models, made with a CNC router and by hand, were produced repeatedly to examine aesthetics, proportions and detailed ergonomics. These were tested by the end users and the results are discussed in Testing of Non-functional eSticky Displays.

Web Server UI Mock-Ups and Results from User Feedback

With primary end user's needs in mind, a first set of the Web server UI mock-ups was designed by the technical and the design team. The goal was to design a UI, which is intuitive and guides an end user through the system configuration and message creation in an easy way. Although it was clear at the time of mock-up creation that further design steps were going to be needed, the mock-ups were created in a way that allowed the users to experience the planned basic structure and user guidance of the eSticky system, thus enabling them to give valuable feedback for further enhancement of the UI.

Description of UI Mock-Ups

When the system is started for the first time, the user chooses a language on a welcome page, before setting up the components. Once the user has given the base station a user-friendly name, he or she can login or register to the system depending if they already have an account or not. In the case of registration, users have to enter their first name, last name, email address and a chosen password. Afterwards the user, who is now the administrator of the base station, has to pair the displays with the system. Further, it is possible to add other supervisors to this base station by inviting them via their email address. Once this walkthrough has been completed, the login page appears. The users that have been invited via their email address get an email with a confirmation link, leading to the eSticky system to join the base station via login or registration.

After successful login, the message list is shown. The user can add a new message to the system via a "create"-button,

Fig. 6 Design sketches and CAD renderings of the eSticky displays

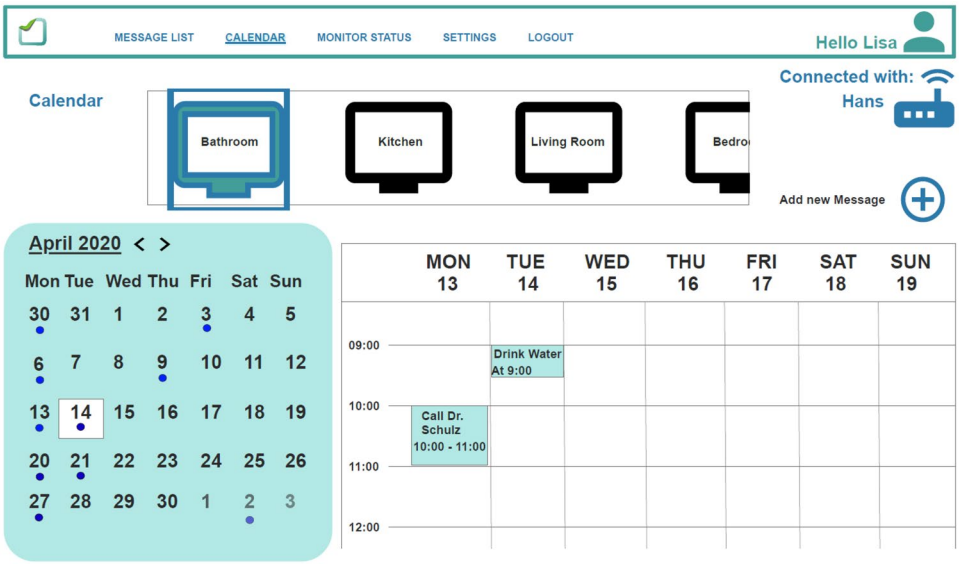


Fig. 7 Calendar view

which leads to a configuration page for a message. Here the user can enter the text for the message, the text colour, background colour, enter a start date as well as the repetition settings and decide if the message should be active or passive. If the message is active, only the active displays will be shown at the bottom of the page, where the user can choose on which displays the message is supposed to be shown later. If the message is passive, however, all displays will be shown, since active displays can serve both purposes. After submitting the message, the user will be linked to the message list again, where the message will be shown now and can be edited or deleted. When the user chooses to edit a message, the user will be linked to the same configuration page again, with the only difference that the fields are now prefilled. Furthermore, a preview of the message will be shown in this view, to give the user an idea of how the message will look like on the display.

As an alternative to the message list, the user can choose a calendar view in the main menu on the top of the page. In this view, the user can select a display and a week and then gets an overview of all the messages scheduled for that week, sorted by day and hour (see Fig. 7).

Just like in the message list, messages can be added, edited and deleted here. The blue dots on the monthly calendar (left-hand side) point out the days with at least one message already set for the display selected at the top.

The main menu item "monitor status" links to a page that shows all displays that are currently connected to the user's base station. This view includes the battery life, connection status and current message status of each display to give a quick overview of the connected components. This view also includes the possibility to edit or add a display. When a user decides to edit a display, he or she gets the same view as in the beginning when the initial display pairing took place.

A settings-view can also be shown if selected in the navigation. This page shows the whole information about the accounts that are registered for this base station. Editing an account is also possible here. The displays are also shown again on this page, split into active and passive and with a warning to check the display status in case this is necessary (i.e. low battery).

When a user logs out, the login page is shown again. When a user, who is already registered on the eSticky system for more than one base station, logs in, a page is shown after login where the user can choose to which base station he or she wants to connect. This is mainly relevant for professional carers, who might want to administer eSticky messages for several primary users.

Evaluation of User Feedback on Mock-Ups

The UI mock-ups were shown and explained to 27 users in Poland and Austria and quantitative as well as qualitative feedback was gathered and evaluated. Then conclusions were drawn on what changes have to be applied to the UI in order to meet user's needs and wishes. Some suggestions were outside the scope or possibilities of the project, e.g. the wish to be able to use own photos on the displays, instead of icons (the envisaged low-power and low-cost e-paper displays do not provide enough colours and good enough quality for displaying photos). However, many of the user's suggestions will be taken up and implemented in the actual system prototype. In addition, a detailed manual will come with the system to clarify things that cannot be made implicitly clear in the UI. The following list gives an outline of the most important changes planned:

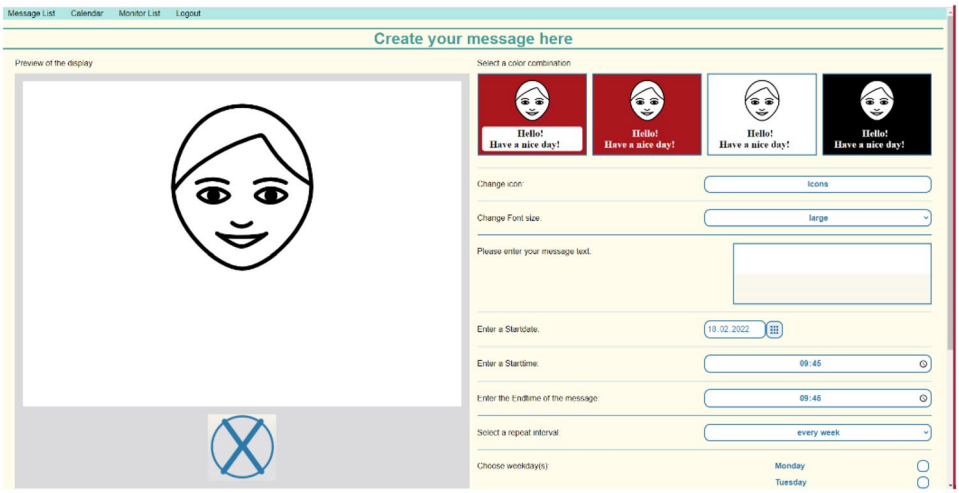


Fig. 8 Message creation window (upper part)

- The pairing process has been considered too complicated by many users. Therefore, either the displays will be shipped readily paired, or, in the ideal case, a possibility will be found how to do without pairing.
- Buttons need to have a consistent look and feel throughout the system and must always provide textual descriptions in case icons are used. Also, the positioning of buttons needs to be adapted in some views.
- An explanation of what the "active" and "passive" message types (and display types) mean will be given directly in the interface.
- An icon-overview will be added instead of the search field.
- Most users had troubles understanding the many options for message repetition and activating and deactivating those options. Since providing so many possibilities is not possible without a certain extent of complexity, a decision has been taken, in the light of usability, to reduce the amount of options for message repetition, only allowing daily, weekly, monthly and yearly repetitions, as well as a choice of specific weekdays.
- In the calendar view the distinction between active and passive messages will be made clearer by adding an "A" in the corner of every active message. A confirmed message will be marked by green colour and a check mark, while a "!" and red colour signal that the message has expired without being confirmed.
- Horizontal scrolling will be avoided at all times.
- Generally, text size (compared to icon size) was an issue for some users. Text will be larger in the next version of the UI.
- Users asked for light signals and sounds to attract the user's attention. There is an ongoing discussion about adding sound and LEDs to the displays. The main issue here is the power consumption, which must not interfere too much with long battery lifetime. Therefore, the final decision on this issue is still pending. It depends on the outcome of further tests.
- To allow messages of a certain length, but also to allow large messages for people with vision impairments, different font sizes for the message text will be possible in the future.

The Message Creation Window: An Example of the Improved UI

The improved version of the message creation window (Fig. 8) is split in half. On the left-hand side, it shows a live-preview of the message, as it will be shown on the eSticky display. On the right-hand side, it lists all possible settings in a well-structured way. There are 4 options for possible combinations of back- and foreground colours (only the options that offer good contrast and readability are provided). If a user wants to change the icon, the respective button will take them to a separate window, offering an overview of the existing icons (see Fig. 9), thus avoiding a long drop-down list or excessive scrolling.

Most other settings are pretty straight forward (drop-down lists, text areas, calendar, etc.). The repetition settings (better visible on Fig. 10) have been reduced to those necessary. The weekdays are only shown, when a weekly repetition has been chosen in the drop-down list. The switch for active/passive message is accompanied by a description of what active/passive means in this context. Changing the position of this switch immediately alters the icon and the text below the preview on the left.

The whole interface is responsive and works on display sizes down to a width of 320px (and even lower). WCAG 2.1 conformity guarantees high accessibility standards, opening the eSticky system to a broad audience while at the same time meeting legal requirements in a large amount of countries. There is no dedicated option to change the

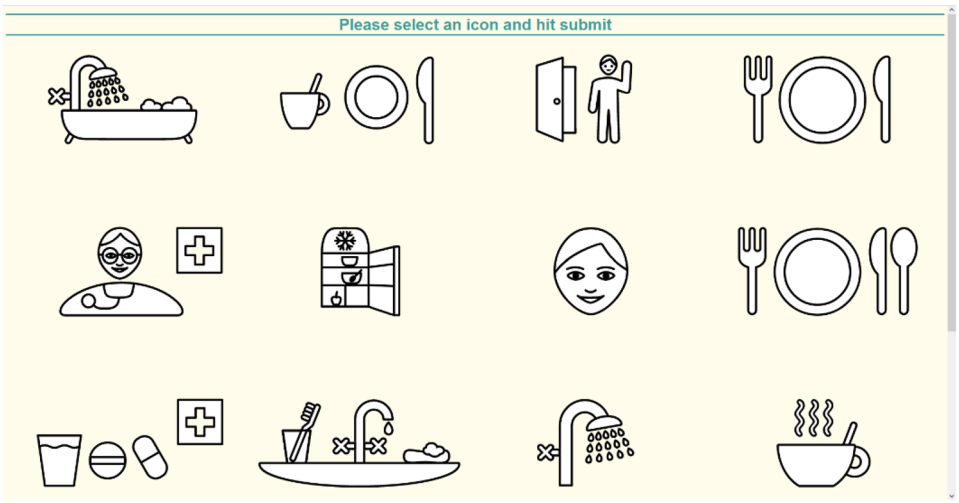


Fig. 9 Existing icons for message creation

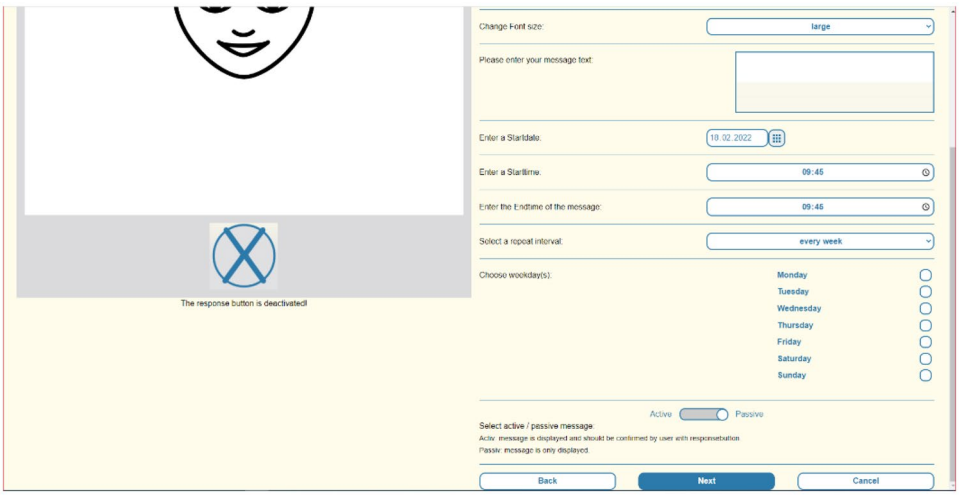


Fig. 10 Message creation window (lower part)

font size of the UI, since this can be accomplished using standard browser functionality. However, the default size is large enough for most users, while at the same time avoiding excessive scrolling.

Testing of Non-functional eSticky Displays

In the next testing phase, five models of non-functional eSticky displays, made of various materials and with a variety of appearance, were tested with users and analysed (see Fig. 11). The aim of this stage was to assess the physical appearance and acceptance level of eSticky displays by users. The users were presented with 5 different models, designed with different material combinations. Non-functional mock-ups were used, which did not yet allow for real interactions with the display and did not have any functionalities. Consequently, only material combinations and interactions with the physical form of eSticky displays were tested. The content displayed on the models was also assessed.

Due to the ongoing COVID-19 epidemic, user access was still difficult, but a total of 8 primary users, 4 relatives and 8 tertiary users (20 users in general) were collected throughout the non-functional model test in Austria. In Poland, data were collected from a total of 21 users, broken down into 14 primary users, 6 secondary users and 1 tertiary user meeting the inclusion criteria for the study. User demographics, their IT skills and area of residence data were also collected.

For each model (A–E), users were asked the same set of questions first, presenting each display model separately (in order: model A demonstration, question set 1–7, model B demonstration, question set 1–7, etc.). It was explained to users what materials each part of a given model consists of, i.e. the sides, back, upper and lower part, the display and the button with its location (under or above the display). In the case of the first 5 questions, the user was to choose an

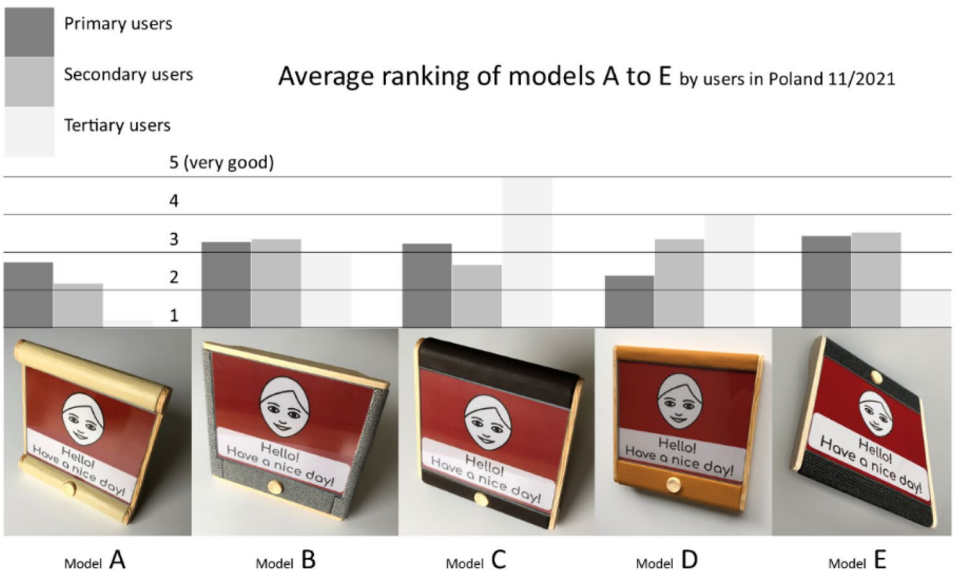


Fig. 11 Ranking of the models A to E by the users in Poland

answer from among those proposed, while the last 2 were to be answered at own discretion. After receiving the answer to these questions for each model (A-E), users were asked an additional 10 questions on the basis of which they could refer to all proposed models and define their preferences regarding the possible purchase of the displays and how to use them on a daily basis.

Users' opinions about the appearance and form of the tested displays were often similar. Primary users tended to be sparing in words. For them, this type of display, proposed in a modern frame and using natural materials such as wood or leather, is a novelty. Secondary and tertiary users usually described their observations more broadly and referred to the needs of their family members or charges.

Primary users assessed that in the model A they liked the leather upholstery and wooden casing (natural materials), as well as the colour, texture, solid workmanship and natural appearance of the display. However, they suggested changing the shape to a flatter one, and some skin colour to a darker one. It was then asked if the colour of the message could also be adjusted. In the model B, on the other hand, the pleasant material and wooden casing were appreciated, as well as the possibility of placing it on a table, but it was feared that the upholstery with the material may be non-functional. Doubts were also made in individual cases in the quality of the wood, as well as in the sense of the bulge at the back (it distorts the product and widens it). The model C was liked in terms of wood, but it was suggested to change to dark brown. The users liked the quality of the leather, its colour, but it was not to the liking of individuals. One of the primary users suggested changing the colour of the upholstery to lighter ones, e.g. grey or graphite. It was proposed to make 3 leather colours to choose from. The convenience of use in this model and its flat form were appreciated. In the model D, the users liked both colours, wood and material (nice, warm look), while it was suggested that the material should not get dirty (a different, darker colour of the material or a change to leather was also indicated). Sometimes the users did not like the shape of the device (reverse tilt). The model E was liked for the form, colours and wooden frame, while it was indicated that the button was non-functional and obscured the screen. There were also opinions that the fabric had a nice texture and one liked the upholstery on the back as well, but the risk of it getting dirty and looking bad was mentioned. Therefore, there were also voices to replace it with leather. One opinion concerned the possibility of making the top of the product higher (it lies on the table at a greater angle).

The most of primary users would like to buy one display (there were individual voices that 2 or 3 pieces would be appropriate). They would like to use the display with an additional stand or by mounting it on the wall, or even as a magnet on the refrigerator. There were also voices that some users would put it on the table. The size of the product was considered rather appropriate (there were also voices that it was too small), and the colour proposal on the display was rather satisfactory. It was once even suggested that the font could be smaller, but on a lightened background. The contrast was assessed as good (4 points/5 points) or very good (5/5)—the message was visible on the display and the light reflection was acceptable. Users rated the best charging option to have a battery charger and to connect the eSticky to the power supply/to an electrical outlet.

Secondary users pointed out that in the model A they like the materials (wood and leather) and the size (large display), although the edges of the model are unpleasant and sharp (the display may fall and, for example, damage the floor). This model, in the opinion of users, suggested that it

was mechanically strong. It was pointed out that it would be better to hold the skin (turn the display 90 degrees). It was suggested that maybe the whole thing should be upholstered in leather to prevent the device from falling. The fact that the rear panel is sticking out in this model was also not to be liked. This model was assessed as "too fancy" ("It would have to be simplified to an ordinary cuboid like a smartphone."). The model B appreciated the wood, simple appearance and size of the display. The appearance is considered nice, but the display is not functional—the edges are sharp and unpleasant (which creates additional risks when falling) and the material will get dirty. It has also been suggested to improve the quality of the upholstery. However, it was appreciated that it was better to hold in comparison to the A model. Some suggested changing the shape so that there was one thickness along the entire display (on the back, so that it gave the impression of a slim product). In the model C, users liked the texture and colour of the leather. Size and design were found to be fine too, but one had better turn the display 90 degrees so he or she can hold it in hands. It was also suggested that the button should not be in the middle on the bottom edge, but on the right side at the top, if the display is to be held in the hand, because it is not handy as it is now. However, if the display is to stand, the button at the bottom is fine. A feeling of discomfort when touching the edges was also further alleged. The back (thickness) should also be smooth, not curved. Weight reduction was also indicated as an option for improvement. The model D appreciated the wood, the size of the model, nice and light finish, facing the material with wood, the 'drop' design (form, thickening the model going down), although others would choose one thickness (like the bottom edge). However, it was suggested to change the orange colour of the material and the material itself (unless it was not meant to be touched), although it had a 'pleasant texture'. If the user would like to catch this model, then there is nothing to catch. The users also lacked a pleasant touch when grasping the wood ("Maybe if the wood were chamfered and rounded better, it would be more pleasant"). As for the colour of the wood, there have been suggestions that dark colours would be better. It has also been suggested that the base be flat so that the display can be set up. The model E liked the colours and design, the light shape, and the functionality would be fine if not for the button at the top (it should be at the bottom or on the side). The material was judged to be quite pleasant, but it was considered that the leather from the model C would have been better. The wood is more chamfered. There was a greater lightness of the wood in the model E, which may have a positive impact on the assessment of the entire product.

Secondary users indicated the probability of purchasing 1 display for themselves or their family members (e.g. for the kitchen). It was considered best to use the display by hand or to have an additional stand, or to be able to be mounted on a wall or even on a refrigerator, or placed on a table (there was no clarity in this criterion). Most of the size was assessed as appropriate (one user indicated that it was too large for the wall, and another that it was too small for the wall), and the colour proposal presented on the display was rather satisfactory (clear message, light reflection acceptable). There were voices that blue and white or red would be better. Contrast was rated on a scale of 4/5 (good) and 5/5 (very good). As a charging option, it was suggested to connect the eSticky to a power outlet, have a battery charger or own ideas like a docking station.

In the opinion of tertiary users, the model C of the display is the best option as it was found to have the most suitable materials and form. Its appearance is aesthetic, pleases with dark leather and has a large display. Model D was indicated as the second choice, because it has an aesthetic appearance and form (nice, ergonomic shape, push button forward) and corresponds to the colour of the fabric and the upholstery. However, light coloured fabric can get dirty (it has been suggested to choose upholstery fabric if it is not such one). The next model was the model B, which liked the form, large screen, nice texture of the casing (material) and the fact that the display can stand on the surface by itself (without an additional stand). However, its disadvantage was its careless workmanship (protruding threads from the upholstery fabric). It was also suggested to change the material to washable so that it would be easy to clean any stains. The model E was indicated as the fourth, mainly due to the non-functional button above the display, which covers the screen when clicking. It was suggested to move it down as with the other displays. However, one liked the shape of this model (compared with a calculator) and the thickened upper part (therefore, it does not lie flat on the surface). Model A was the least liked, as it was, in the opinion of a tertiary user, heavy. The bulge (protruding parts) was also not liked, making the screen appear hidden and obscured (a shadow appears). It has been suggested that fair leather will get dirty. However, one liked the simple shape and large screen in this model. It was also difficult to judge the innovation of the displays as they were non-functional.

The need to purchase 3 displays for oneself or family members/charges was indicated. As the best option for using the displays, the position on the table and the possibility of mounting on the wall, and even with the help of a magnet on the refrigerator, were indicated. The dimensions were judged to be adequate. However, attention was drawn to the proposed colours on the display that they are not appropriate—a black background and white icons/text would be better to increase the contrast (the display contrast was rated 3 on a scale of 1 to 5). It has also been suggested that there be an option to display the content as either picture only, message text only, or together. When it comes to charging options, the option of replacing the battery once a month and having

Fig. 12 Non-functional touchable design models of the eSticky displays

a battery charger was chosen. It was difficult to relate to the visibility of the message and the light reflection on the non-functional display model. It was suggested to test the ability to add photos and display them on the screen. If the quality is insufficient, the possibility of making a library from which one can add pictures was indicated. In addition, there was advice that one could use a separate SOS button. It is already widely used in solutions for seniors. It would make it possible to contact an emergency number if necessary and would be conducive to ensuring a sense of security.

Above, a brief summary of user feedback when testing the models A–E was presented. All detailed feedback was passed on to the technical partners and designers in the project who are working on the final forms of the eSticky models. On the basis of the above-mentioned opinions, another two (2) models were created, being the resultant of the best-rated features in the previous models. Once delivered to the partners responsible for user engagement, they will also be assessed with the participation of users. Ultimately, one model will be selected on the basis of which functional prototypes for testing in user locations will be made. Finally, the integrated prototype will be installed in the user's homes and field trials will be conducted in order to define further requirements for the development of the final product. The purpose of end user involvement in the project is to create a solution that will meet potential users' needs and expectations.

The results from the testing of the five non-functional eSticky display models were compared to the design brief by the designers and partners. For this purpose, the examination of the standard's adequacy in the field of ergonomics of human-system interaction was carried out with the following points: *Appropriateness of the task; Self-descriptiveness; Conformity with expectations; Learnability; Controllability; Robustness to user error* and *User retention.*

The evaluation led to the selection of a design model to be used in further technical prototype development (see Fig. 12). The designers also support the prototype design. The technical development is supported by the design consultation and selection process and provides continuous feedback to the technical engineer from a design perspective. This also includes the choice of materials, colours, manufacturing techniques and test refinements.

Users' Consent

Each user entering the study as described in "Evaluation of User Feedback on Mock-Ups" and "Testing of Non-functional eSticky Displays" sections, completed an informed consent form. Due to COVID-19 limitations, consent forms were sent electronically via Google Forms. The consent form contained information about the project, its purpose, and examples of eSticky applications for users. The need for users to participate in the system testing and provide us with valuable feedback was indicated, explaining that the eSticky development team was still working on the implementation of the solutions. As this was still the initial phase of the eSticky project, the participation involved expressing an opinion on potential solutions (provided in photos, descriptions or non-functional models) that will be included in the eSticky system. It was emphasised that, with the assistance of users, we can determine how well eSticky can be used in everyday life and what can be improved. Users were asked to test our prototype and express their wishes and concerns as much as possible. They were assured that their opinion would be anonymous and would be used in our reports and studies to improve the eSticky system. Users were informed that their participation in the eSticky project is voluntary and free of charge. No personal data would be used for the purpose of this research and all data will be anonymous. Any personal data provided by the user (name and surname, telephone number, email etc.) would be known only to researchers from the given country who take part in the study and will not be disclosed to third parties. When participating in the eSticky project, the user has been assigned an identification number to guarantee his/her anonymity. All data were securely stored and will be kept for up to 5 years after the end of the research, and then securely destroyed.

Conclusions

The current development progress of the eSticky system has been described in this paper. The related background has been provided and the user involvement throughout the design and development process has been thoroughly discussed. After an outline of the high-level system architecture, the work that has commenced to date on user interfaces

has been described, as well as the conclusions drawn from user feedback onto the UI mock-ups, collected from 27 users in Poland and Austria. Feedback resulted in a list of the most important changes that are planned to be implemented in the actual system prototype. Certain suggestions were deemed outside the scope or possibilities of the project and will thus not be implemented. The middleware was clearly described in its functionality and technical decisions in terms of hardware outlined.

The five models of non-functional eSticky displays (i.e. low-fidelity prototypes) were also evaluated by primary, secondary and tertiary users. In total, feedback was collected from 41 users in Poland and Austria, focussing mainly on aspects of appearance and form of the tested displays.

In conclusion, the user feedback from the evaluation of the UI mock-ups and non-functional eSticky displays has so far been satisfactory and promising for future system uptake, provided that some adaptations and improvements are made to both, which are already in progress. The system is shown to be quite safe towards internet connection failure, saving its status from before a failure occurs on the local database. The final system is intended to be very easy to use and it will enable users to remind themselves or be reminded (by secondary users) in a convenient way that is fit to ensure longer independence for the elderly end users. The current progress bodes well for the next testing phase of the project.

Currently, only demographic data were acquired by users (with their consent) during the testing reported in this paper. As future work, we will attempt to acquire user behavioural data (with their consent) that could, via the usage of a scientific analysis process and methodology such as deep learning, used to understand the behaviour of the user in how they are using the system. This would allow us to improve the system and make it more accurate in terms of the user needs and expectations.

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Declarations

Conflict of interest No conflicts of interest, financial or non-financial.

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