Reversed Multi-Layer Design as an Approach to Designing for Digital Seniors

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ABSTRACT

The personal computer (PC) has been around for more than 35 years by now. Today, we find early adopters of the PC who have been using computers at home for 25 or 30 years and are now themselves in their eighties or nineties. Despite this there is still a lot of research focusing on how to introduce and teach the use of information technology to older people. In this paper we argue that it is time for a shift to designing for digital seniors, i.e., older long-time computer users. Over time this will be the dominating user group and we need to design for continued use of IT rather than guiding older computer novices. The paper also presents the concept Gracefully adaptive user interfaces and provides a case study in the form of a prototype re-design of Facebook aimed at exploring and illustrating how designing for digital seniors can be approached.

CCS CONCEPTS

• Human-centered computing → Human computer interaction (HCI); Graphical user interfaces; HCI theory, concepts and models;

KEYWORDS

multi-layered design, older users, adaptable interfaces, social media

1 INTRODUCTION

In 1984, Apple introduced the Macintosh personal computer marketing it as “the computer for the rest of us”. Microsoft released the first version of the Windows system in 1985. This means that the personal computer (PC), as we know it, has been around for more than 35 years by now, and it was developed by people who are now in their sixties and older. Today, we find many early adopters of the PC who have been using information and communication technology (ICT) for various purposes at home for 25 or 30 years and are now themselves in their eighties or nineties. In a few years people who have spent their entire working lives in the era of digital computers will start retiring. Inspired by Quan-Haase et al. we refer to these older long-time users of ICT as digital seniors [26]. While the population of digital seniors is constantly growing, a lot of the work related to ICT and older adults still focuses on how to design technology that can be adopted by older adults with little or no skills of using ICT. In addition, although research on HumanComputer Interaction and aging have been conducted for some time, and laboratory studies on what adjustments might be made to accommodate older users’ changed cognition have been performed [38] this perspective gives little information on everyday obstacles in real life ICT-use among older persons [41]. There is a need for in-situ research concerning older, computer literate, persons’ use of ICT. Thus, we believe it is time for a shift of focus to study the research question:

How can we design systems that suit the needs of digital seniors, i.e., older long-time users of information technology, when their cognitive and physical abilities are affected by age?

In order to start finding answers to the above question, we are working on ways to create user interfaces and systems that will facilitate for users to continue to carry out the core ICT functions they are used to even if they can no longer take advantage of all the features available in the system. The kind of users we are aiming at can be illustrated by the following scenario:

A few years ago, Alfred, today 86 years old, was a very active computer user who used e-mail, Facebook, managed his photos digitally and tried to keep up with the latest news. He had recently bought a new laptop to replace the stationary PC he built for himself some years ago, which was getting a bit sluggish. Although his advancing age, and declining senses such as reduced eyesight, made using the PC slightly more complicated, Alfred still enjoyed the new freedom of being able to access his data and contacts anytime anywhere. Then he started to experience problems remembering how things worked, what the purpose of all the buttons and menus were, what to do next to fulfil a task and so on. He also started to experience problems in his daily life. After a while he was diagnosed with dementia. Even if Alfred tried to help the situation by writing memory aids and attaching sticky notes with instructions to his computer it was as if using technology just did not work. The laptop Alfred had customized to suit his needs felt

alien, overwhelming and confusing, logging into Facebook was impossible and sending and receiving e-mail just didn't work. Since Alfred feels how he is losing his technology skills but not his wish to communicate with others and take part of what's going on, the situation is now very frustrating and contributes to creating a feeling of isolation. Alfred wants to reach out to his old network but cannot make it as he is hindered by the complexity of the systems he once used to master. And it seems like there is no way to make things simpler to allow him to focus on the things he really needs.

To investigate how to support digital seniors like Alfred, we introduce the concept of gracefully adaptive user interfaces (GAUI:s). By a gracefully adaptive user interface we mean a system that can be gradually simplified and adjusted to fit the needs of users with declining cognitive and physical abilities. The goal is that digital seniors should be able to continue to perform the tasks they are used to in a way they can handle despite any possible ageor health-related loss of capability. The approach is feasible due to the flexibility that can be built into ICT. Contrary to a physical product, a software system does not need to be static or designed for one type of user only but can adapt over time and adjust to the specific needs required by various kinds of users. The gain of introducing GAUI:s is that the growing group of older adults that use ICT, in particular for communication, will be enabled to do so for an extended period of time, without a need for learning new systems specifically built for older users.

The contributions of this paper are threefold: (i) the introduction of, and the argumentation for, the focus on designing for digital seniors rather than finding new ways to teach the older population about ICT, (ii) a general description of gracefully adaptive user interfaces based on multi-layer design (iii) the description of the case study Klara Facebook, which illustrates one particular realization of a GAUI along with some preliminary evaluation results.

2 BACKGROUND

2.1 Aging and Technology

As we grow older, our mental and bodily functions change. What type of aging symptoms a person gets is very individual [10] but can roughly be divided into four types: chronological aging, biological aging, psychological aging, and social aging [39]. The consequences of the natural process of aging are among other things deteriorated eyesight and hearing, changes in memory, slower speed of processing, less precise motor skills and drier skin [3]. All of these might have an impact on ICT use. Beyond this normal and "healthy" aging process, old age can also bring a number of diseases such as dementia, stroke, etc., which then further limits our abilities. Aging and technology has been studied from several angles. Within the area of psychology, for instance Van Gerven et al. [37] present a combination of psychological theories that can help when designing technology for seniors and Wagner et al. [40] provide a thorough literature overview of the field while Czaja et al. [9] attempt to categorize factors predicting technology use. From an HCI angle Quan-Haase et al. [26], interviewed seniors to explore how they use communication technology in their daily life and Reeder et al. [27] created two personas modelling the oldest users intended to support design.

2.1.1 Cognitive Problems. The focus of the present paper is on supporting effects of cognitive problems caused by aging. The most common cognitive problems connected to using digital interfaces are attention, working memory, and long-term memory [10].

Attention is a common problem when getting older and can give problems when using more complex interfaces. There are a few types of attention, for example, *selective attention*, the ability to focus on stimuli and disregard other stimuli that are irrelevant, and *divided attention*, to process two or more tasks/information at the same time [14]. In general researchers agree that selective attention decreases by age, however, it is debated whether this is also true for divided attention [14, 15]. Divided attention problems seem to occur among elders when the tasks are complex, but not for simpler tasks. The cause of the problems is debated [14, 15].

Working memory is the process of holding items in the shortterm memory and at the same time process these items, for example, repeating a few digits backward [14]. This includes common everyday tasks like problem-solving and decision making. Working memory is getting worse when aging [14]. The big problem with reduced working memory is that together with reduced attention older people have a harder time remembering how to do a chain of actions to complete a task, especially if the chain is more than three actions long [10].

The long-term memory is used when remembering information that is stored for longer than 60 seconds [15], and is, for example, present when completing a chain of actions to perform a task [10]. When the long-term memory is getting worse a user has a harder time performing a chain of actions without getting help with what to do next [10].

2.2 Universal Design and Usability

The core idea of *Universal Design* is that products, environments, programs and services should to the greatest extent possible be designed to be usable by everyone without any special adaptations or changes [28, 33]. Universal design was first described by Mace in the late 1980s and is also known as *Design-for-all* and *inclusive design* [33]. Universal design is governed by 7 principles [33] describing its main ideas. The first principle is "Equitable Use: The design is useful and marketable to people with diverse abilities." The principles are further explained in a number of guidelines where part of the guidelines says that one should strive for an appealing design using the same means for all users [33].

A related term used in the realm of ICT is *Universal Usability* [30]. The goal of Universal Usability is the same as that of Universal Design, i.e., to design systems which enable the largest possible group of users to successfully use ICT [21]. Shneiderman meant that Universal Usability would be reached when 90% of the households could successfully use ICT once a week [30]. Today, 95% of all persons above 8 years old in Sweden use the Internet

daily [2], so in some sense the goal has been reached. However, there is still work to be done on how to best adapt ICT for all [21]. One of the approaches mentioned by Meiselwitz et al. [21] is the use of *MultiLayered Design* [31], an approach where an application is from the start designed to enable optimization for diverse users (see section 2.4).

2.3 Adaptive and Adaptable User Interfaces

According to Miraz et al. the key to accessibility for all the diverse types of users of ICT lies in adaptation or *plasticity* of user interfaces [23]. Plasticity here indicates the inherent property of ICT to adapt, conform and mould itself to the needs of the end user. Stephanidis summarises adaptation as balancing the needs of (i) the type of information to be displayed; (ii) the level of interaction and (iii) the source of knowledge adaptation [34]. There are two main approaches to designing plastic user interfaces, namely adaptive and adaptable systems. An adaptive system attempts to adjust automatically to the expected needs of each user. Typically, this involves a user model and an adaptation strategy [4]. The general idea of user modelling [4] is that by keeping a model representing the user's characteristics, interests, etc. applications will be able to better serve the needs of the individual user. Typical features of user modelling systems include the use of stereotypes to cluster users into groups and keeping track of the users' activities [17]. For an overview of the use of user modelling in human computer interaction see [12]. An adaptable interface provides efficient means to let the user do the customization of the application. A problem with adaptive interfaces can be that the user might feel lost, not knowing what happens and it is therefore important to find mechanisms that let the user stay in control [32]. Akiki et al. [1] present an overview of model-driven adaptive systems as well as a set of criteria to evaluate the strengths and shortcomings of the state of the art. An example of the use of an adaptive approach specifically intended to support older users can be found in [19].

2.4 Multi-Layered Design

An application based on multi-layered design (MLD) includes two or more interfaces or layers, each containing a predetermined set of functions [7, 8, 31]. The idea behind the concept is to gradually increase the complexity and number of features available in a system to facilitate for new users and fit it to individual needs. An MLD application starts with only the basic features available and new features can be introduced over time as the user becomes more advanced and needs to be able to do more complex things. Moving towards the use of more, or different, features, means to move to another layer. A parallel can be drawn to games where players often advance to a new layer when they have mastered the present one. An example of a multi-layered user interface is given in Fig. 1. It shows an image viewer application [7] where the complexity and number of features can be adapted to fit the needs of the user.

A few different ways of structuring the features of an application into layers have been suggested [31]. One way is to start with a few functionalities in a base layer, and then add roughly the same number of additional functionalities with each new layer, see Fig. 2 (c). Another approach is to use fewer layers but let the number of functionalities that are added increase with each layer, see Fig. 2 (b). A third version is to have a few thin layers building up the foundation followed by a few layers on the same level with different contents, which forms a mushroom like structure where the user can get a more personalized layer, see Fig. 2 (d). There are no clear rules for how the user interface of each layer should be organised or how the presentation should change when new features are introduced. However, each layer should be designed to support a certain set of tasks or group of users. That is, each layer should be designed to form a coherent whole in the shape of a well-designed reduced functionality interface.

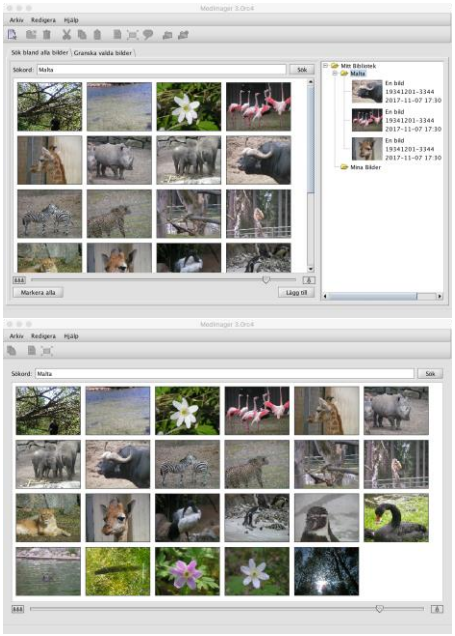

Figure 1: Top: the multi-layered image viewer with all features on, including organizing editing and sharing images. Bottom: only the basic feature to search and browse through available images.

MLD has among other things been tested as an approach to simplify word processing [20, 31], map visualization [16], viewing and sharing images [7], blog editing [8], the macOS environment [6], air traffic control [22], introducing older users to mobile applications [18], dynamic geometry software [29], and league tables in the health sector [36]. As mentioned above, it has also been suggested as a suitable approach when designing for Universal Usability [21, 31].

Designing an MLD system has 3 key elements (i) deciding how the features should be divided into a set of layers, (ii) designing

each layer, and (iii) designing a mechanism for moving between layers. Clark and Matthews suggest that layers in MLD interfaces can be divided into two subcategories, feature layers and mixed layers [8]. Feature layers are layers that consists of one single category of functionality and within a feature group there can

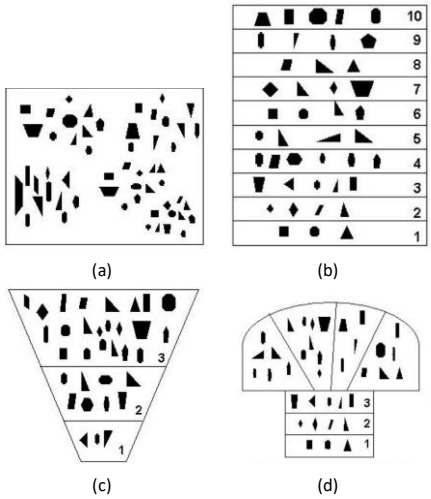

Figure 2: Shneiderman's suggested structures of multilayered design, (a) a regular interface, (b) multi-layered design, (c) expanding multi-layered design, (d) multi-layered mushroom [31]. © ACM

be several layers. Mixed layers, on the other hand, can contain features covering different kinds of functionality. A problem with mixed layers can be that if a user wants all functionality within one category, then many other features from other categories will be added as well [8]. The feature layer approach can be one way to create a more fine-grained design when there are many different functionalities available in a system. A detailed procedure for the process of dividing functionality into layers has been suggested by [5]. Designing the user interfaces of the individual layers is so to speak mainly a matter of following ordinary best practices and principles. However, it may be advisable to do stable extensions of the user interface between layers. That is, it is better to fill empty space and add items than to move things around, as described by interface patterns such as Spatial Memory [35, p. 20]. This approach is for instance followed in [7]. Most previous work on MLD put rather little emphasis on how to move between the layers and present something like a simple slider [31]. Clark and Matthews [8] use a settings panel for selecting between several feature layers, but also discuss how e.g., knowledge about what the user has done previously can be used to select an appropriate start layer. An interesting overview of some previous solutions can be found in
[11].

A reasonable doubt about the MLD approach is if it can be regarded as a promising solution to improve (universal) usability. The concept was introduced rather long ago, and it seems that most of the papers that can be found were written between 2000 and 2010 and that it has not really caught on and been taken up in mainstream user interface design. A potential explanation could be that using MLD adds complexity to the design process and that the benefits are not considered to outweigh the costs for commercial software. Another reason could be the lack of well-designed solutions for layer selection. Still, MLD stands out as a conceptually rather simple and easy to realize solution for simplification of complex user interfaces.

3 GRACEFULLY ADAPTIVE USER INTERFACES

We coined our approach to supporting digital seniors' continued use of ICT *Gracefully adaptive user interfaces*. The concept has its roots in research on adaptive and adaptable user interfaces and in particular the idea of multi-layered design. All these notions have their basis in the flexibility that ICT makes possible and the fact that it is fully possible to create systems that can change over time and be adapted for the individual user. This makes IT systems different from physical products which are manufactured according to given specifications, with a set of static unchangeable functions physically built into the product. *We define a gracefully adaptive user interface as a system that can gradually simplify its presentation and interaction in order to adjust to the needs of users with declining cognitive and/or physical abilities*. The concept can be seen as a form of reversed multi-layered design.

While the intention with MLD is to gradually increase the complexity and number of features available in a system to facilitate for new users to learn and to not be overwhelmed by the system's complexity, a GAUI works the other way around. It starts out with all the features the user is accustomed to and adapts to the user's skills and abilities by scaling down, that is, by simplifying presentation and feature set over time. There are several research challenges in developing the concept of GAUI:s, e.g., understanding what problems the users encounter, finding the best patterns for simplifying typical designs, detecting which level of adaptation the user needs, deciding the mechanisms that control the adaptation of the interface and so on.

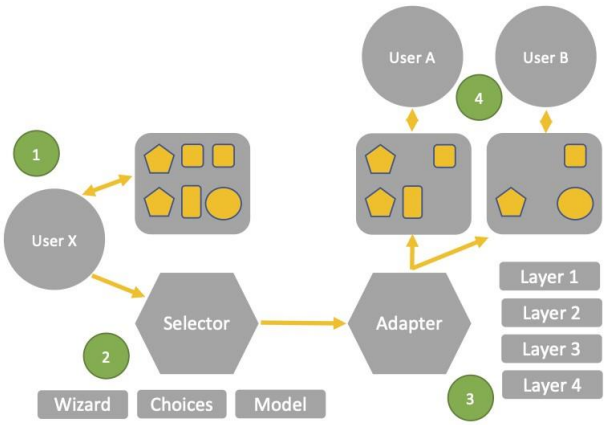

Figure 3: A high level general organization of a gracefully adaptive user interface based on MLD.

A high-level description of a GAUI based on Multi-layer design is shown in Fig. 3. The various components in the figure can be explained as follows:

(1) At first a user (X) interacts with the full interface illustrated by the grey box with some orange shapes.
(2) To simplify the interface a selector mechanism is used to adapt the interface to the individual user. This mechanism can have many forms, e.g., a wizard, a set of checkboxes to make choices, or a user model.
(3) Based on the output from the selector mechanism an adapter is used to select a suitable layer. The role of the adapter is to map data from the selector into a specific specialized coherently designed user interface.
(4) After the selector mechanism and the adapter have been applied the user is presented with specialised user interface. Here A and B represent two different users and their respective adapted interfaces.

The various components can be developed independently. That is, many different selectors can potentially be used to map into one set of layers, and the development of the layers does not depend on how the selection is made.

It is important to note that the term Gracefully adaptive describes a vision or an end goal rather than a fully realized or finished concept. The starting point is the goal to help users like Alfred mentioned in the Introduction to continue to use ICT. A basic assumption is that starting from the full user interface they already know should be helpful. Taking Facebook as an example, when Alfred gets worse and e.g., can no longer use the marketplace to buy and sell things but still wants to follow the feed, the marketplace items no longer need to be present and the result is a simpler interface. To remove this feature could then be seen as a graceful adaptation in the sense that it supports Alfred's ability to continue to use the relevant parts with less distraction from features he no longer needs. The model in Fig. 3 is based on the assumption that reversed Multi-layer design is a suitable way to realize the simplification. Other approaches are possible, but the MLD approach is feasible and easy to understand. One could also argue that the concept is in line with ideas about Universal design and usability, in the sense that the goal for the full interface of an application should be to, as far as possible, be designed to support all users. The GAUI concept then simply adds a possibility to support even more users when the standard design is not enough. The model is completely open for different kinds of selector mechanisms. These can be adaptive doing automatic adjustments or controlled by the user. To explore the various possibilities is an area for future research. In this paper a selector mechanism based on the *Wizard* design pattern [35, p. 86] with a simple adapter that maps responses into layers is used.

4 METHODS

The work presented here has been performed in the context of the research project *Digital Seniors*[1] focusing on how to design digital technology that adapts to the people's aging process. The project follows the research through design approach [43], where constructive and creative inquiry is posed into the field of research. Accordingly, the prototype Klara Facebook (roughly Handle Facebook), presented here has been created to explore and learn about how reversed multi-layered design can be a way to design for digital seniors and investigate how the concept is experienced by the target group. The multidisciplinary research team consisted of experts in interaction design and computer science, a psychologist, as well as a close collaboration with the organization SeniorNet[2], focusing on supporting older persons use of ICT through peer learning.

In the initial face of the project some interviews around seniors' IT use were conducted. These have been reported elsewhere and the results are briefly summarized in section 5.1. The design and development process followed an iterative user-centred approach where a first phase of collecting data was followed several iterations of design and prototyping and a concluding evaluation. Most of the sessions involving users had to be conducted online due to the Covid-19 pandemic.

To get a detailed understanding of how older adults use Facebook six semi-structured interviews were conducted. Each interview lasted for about 30 to 50 minutes. The interviewees were between 67-80 years old and had had a Facebook account for several years. The interviews were video recorded by two cameras, one recording the participant's face and upper body, and one recording the participant's digital device. The topic of the interviews was to explore how the participants used and experienced Facebook. The interviews and the analysis were performed by 2 of the authors. Results from the interviews are presented i section 5.2 Interviews.

To complement the qualitative data from the interviews, a questionnaire containing questions regarding which Facebook features were most used was distributed. Each question had the answers "Yes", "No", "Rarely", and "I do not know". The questionnaire was distributed in several groups on Facebook and to the SeniorNet organization. The results from the questionnaire are presented in section 5.3 Questionnaire.

The data collection phase was followed by an analysis with the goal of distributing the features of Facebook into different layers (section 6.1), the design of a selector mechanism (section 6.2), resulting in an interactive prototype demonstrating the concept developed in Figma. These steps were followed by a formative evaluation. The evaluation consisted of a heuristic expert evaluation using Nielsen's heuristics [25], aiming to remove inconsistencies and ensure understandable language, and a Think Aloud evaluation [13], via Zoom complemented with a short semi-structured interview. The participants were four adults over 65 years recruited via convenience sampling. The work was done by

[1] https://digitalasenioreren.wordpress.com

[2] https://seniornet.se

one of the authors who had not been involved in the design phase. The results from the formative evaluation can be found in section 6.3 Formative Evaluation.

Following the design phase the interactive prototype described in section 7 Klara Facebook was implemented.

The final prototype was evaluated in 2 separate studies. In the first study the prototype was released to the public and tested in the wild by volunteering users. An online release event was organized where Klara Facebook and the goals behind the project were presented. The attendees were mostly representatives from different voluntary groups with the goal of supporting older persons' use of ICT (e.g., SeniorNet mentioned above), but also for instance librarians working with older library visitors. Users that downloaded Klara Facebook were invited to take part of a study about the extension. If they accepted and used Klara Facebook they were presented with a short questionnaire after one week of use to follow up on their experience. The results from this phase are presented in section 8.1 Testing in the Wild.

In the second study the Klara Facebook prototype was evaluated using a think aloud protocol complimented with a semi-structured interview. We recruited 12 participants aged 64-83 years old (5 male, 7 female) old to experience Klara Facebook for 1,5 hours in online sessions via Teams. The sessions walked through the entire experience, from installing the extension, running the selector wizard, to questions about the experience and the resulting adapted user interface. The results from this part can be found in section 8.2 Think Aloud Tests.

5 DATA COLLECTION

5.1 Prior Findings

In the early phases of the Digital Seniors project, we conducted ethnographic work by taking part of the activities of SeniorNet and interviewing some experienced older ICT users [42]. The interviewees aged 72, 77, and 82, described themselves as competent users and preferred talking about the things they had learned over any problems they encountered when using ICT. They saw themselves as being able to do most of the things they needed but expressed some annoyance with how the services worked like, too many ads, unwelcome friend suggestions, etc. In short, they gave the impression of being social media users like anybody else [42].

5.2 Interviews

The six participants interviewed during the development phase did not, in general, experience any major problems. They expressed that they really liked Facebook and how it made them connect to old friends again. Three of them mentioned that they like to share interesting posts on topics that need attention or are educational, while one interviewee said: *"I do not see Facebook as a source of information, I see it more as social, instead of calling and have contact with my siblings and friends and so on"* Some of them complained about a few usability issues, for example, the order of comments on a post was not always in chronological order, which made it hard to follow a conversation.

Interview person 2: Yes, to follow a feed of comments can be a problem, because they are not always in sequence. Say that I am following a feed, then I see that someone posted this 7 hours ago, and there is a new and it shows that that was posted 10 hours ago. And I have a hard time following the thread. I cannot see who said it first. Four of the participants expressed concern about privacy and two of them mentioned the expression *"Big brother is watching you"*. Due to the privacy concerns, the participants used various strategies to feel safer. Some of them did not post anything on their wall, at least not personal content. One barely read their news feed because they were afraid Facebook would see what kind of content they liked to look at.

Interviewer: When you read posts, do you usually like and comment a lot then?

Interview person 6: No, no, I have learnt that, if I even read, because then this eye sees that I... Now she has been there, she is interested in this and then you get a lot of similar information and that bothers me.

One of the participants felt a great fear of doing the wrong thing and mess something up, while others when asked felt more confident and did not hesitate to try out new functionality. Another thing that two of the participants mentioned was that the younger people close to the participant were busy and lived hectic lives. Because of this the participants were hesitant to ask for help. For example, one interviewee said:

Interview person 1: And then I notice that when I ask my children, they become a little bit annoyed, because they have more older persons around them, they do not like that you always come and ask too much.

Another interviewee said the following about the youth:

Interviewer: If you need to ask someone for help about something on Facebook, do you have anyone you would ask then?

Interview person 3: Yes, I would ask my daughter I think, mmh she is around the age of 45 and yes know most of this... but on the other hand, you are so busy around the age of 45 and have children. One slightly surprising finding was that one participant looked a lot on how much response they got from their uploads. They mentioned that a picture where they write about what is in the picture gives more likes compared to a picture with no description. One of the participants also expressed some irritation towards younger people. They said that our society is really discriminating towards older adults and "youth fixated".

Interview person 1: Even if I retire, my brain is still working and I am still a pretty functional citizen. It does not go one night and suddenly you are slow and I think that this is important to think about when meeting older adults in different contexts. [...] As soon as you turn 65 you get a label in your forehead, it is us and them, and it is according to me very youth fixated in our country. And we are a huge group and our group only gets bigger and bigger.

5.3 Questionnaire

In total 37 answers were recorded. One participant was under 65 years old and was therefore removed from the data. The results are presented in Fig. 4. As can been seen in the figure several functionalities like scrolling the feed, groups, birthdays and messenger were used by almost all users. More divisive functionalities include Games, Marketplace, and check-ins, where some use it and some do not.

6 DESIGN AND PROTOTYPING

6.1 Creating Layers

The interviews provided an understanding for the users as being rather competent users with an interest in using Facebook. While it is hard to pinpoint a specific feature that can be connected to a particular statement in the interviews, this empathy for the users is important for the design process [24]. The analysis of the questionnaire indicated that there was a set of commonly used features (Fig. 4). However, the data from the interviews and the questionnaire did not make it possible to identify any clear correlations between this core functionality and different more advanced features. It was therefore decided that the best approach for the layer design was

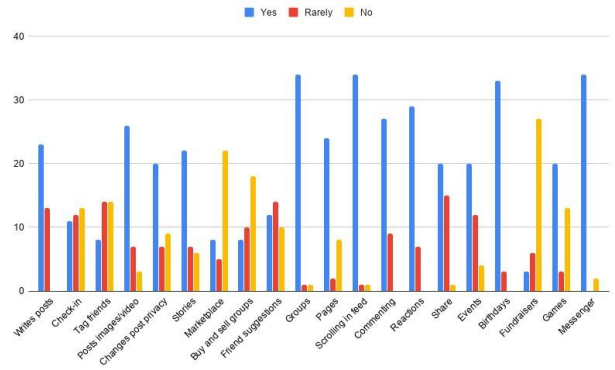

Figure 4: Result of the questionnaire

to use feature layers (section 2.4). The overall layer structure is illustrated in Fig. 5. In addition to the base layer, it consists of six main feature layers, where some are divided into sub-layers.

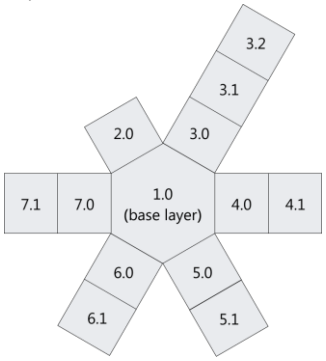

Figure 5: Visual representation of the layer structure

The base-layer consists of the eight most common features from the questionnaire. These were indicated as "Yes" or "Rarely" by 94-100% of the respondents. Further, "Crisis response" was also added since it might not be often used but needed in case of a crisis. Thus, the features of the base layer are: Write posts (only text), Messenger, Birthdays Share, Reactions, Commenting, Scrolling in news feed, Groups, Crisis response.

To decide on the different feature-groups we went back to a grouping of Facebook features made in the beginning of the project. The first clear functionality-group identified was "Content creator". All functionality related to creating content associated with posts was listed followed by investigating which functionality older users utilized the most. This was done by looking at 20 older users' profiles and noting what functionality was used in their posts. The users were semi-randomly selected from the members list of a Facebook group for seniors. Only members who had public profiles were chosen. With help from the collected data, three layers within the content creator functionality-group were formed, which can be seen as layer 3.0, 3.1, and 3.2 in Table 1. These were based on how many of the users utilized each functionality. Other layers were created from our groupings of Facebook functionality and resulted in the layers also presented in Table 1. Layer 2 is about user privacy. Layer 4 represents a "suggestions" layer. The fifth layer is a "content consumer" layer which decides in general what extra things should be in the users' news feed, and in the more advanced layers, the possibility to customize their news feed. Layer 6 is related to economy with buy and sell, jobs and fundraisers, and finally layer 7, is about games.

6.2 Designing the Selector

Several options were considered for creating the selection mechanism. The first decision was to create a solution where the user is in charge rather than trying to build an adaptive solution based on e.g., user modelling and machine learning. While such selector mechanisms are definitely worth investigating we wanted to first explore adaptable mechanisms. The next decision was to base the design of the selector on the *Wizard* design pattern [35, p. 86]. A wizard is suitable to guide a user through a task in a stepwise manner. The wizard based selector is shown when the user first starts Klara Facebook and can be run again later to make changes.

Layer 1.0 (base)	Write posts (only text) Scrolling news feed Share, Reactions, Commenting Groups, Messenger, Birthdays Crisis Response	Layer 5.0 (consumer)	Events, Pages Memories
Layer 2.0 (privacy)	Change post privacy Friend list	Layer 5.1	Hide post Hide all posts from group/people/pages Snooze group/people/pages posts Turn on notification for a post Report post & Save post Videos on watch
Layer 3.0 (creator)	Post image or video Stories, Memories	Layer 6.0 (economy)	Marketplace, Fundraisers Buy and sell groups
Layer 3.1	Check in Tag friends	Layer 6.1	Recent ad activity Offers & Jobs
Layer 3.2	Change background on post Add feeling, activity or GIF Create fundraiser Ask for recommendations Send live video	Layer 7.0 (games)	Games
Layer 4.0 (suggestions)	Friend suggestions Suggestions in news feed Game suggestions (in the side bar)	Layer 7.1	Gaming videos
Layer 4.1	Recommendations		

Table 1: The functionality contained in each layer

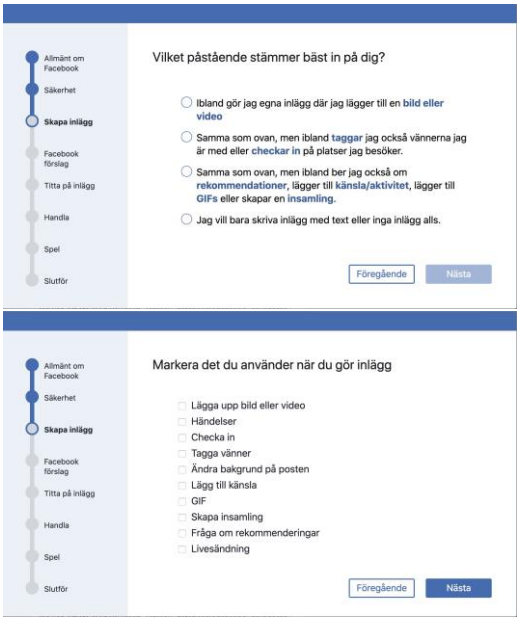

Figure 6: Top: the design where the user selects the option that fits best. Bottom: the design where the user should check boxes.

Two main approaches were tested as illustrated in Fig. 6. One where the user is presented with a number of statements and is prompted to select the one that best fits their use of Facebook, and one where the user is presented with several detailed options and checks the desired features. The main idea of the first approach is that the users should select *what* they want to achieve when using Facebook rather than describing details of *how* they do it.

To help in deciding between the 2 approaches a user test was conducted with 5 of the users that were interviewed about Facebook usage. The tests showed that the approach based on a number of
statements was preferred by most users and it was therefore decided to focus on this approach.

6.3 Formative Evaluation

The heuristic evaluation of the wizard revealed various details that were adjusted for the final version. The four participants in the formative user test, first ran the installation, then went through the wizard, and after that gave their opinion on the changes of the interface. Finally, they were asked to locate the extension on their browser, which was needed in order to be able to refine the adaptation by running the wizard again.

The results of the think aloud test showed that the language in the wizard was perceived as simple and easy to follow. However, the user experience could be improved in relation to the feeling of "being in control". In particular, the users wanted to know what

will happen if they choose an option before they choose it. In the next iteration we therefor added an information panel that could show the users visually which features of Facebook are influenced.

The overall reaction about the effects of the wizard on Facebook's interface was that the users understood that something changed after running the wizard, but they could not put their finger on what. To explore in detail the user experience of applying the wizard, the users need to use it for a longer period. The tests also identified several bugs in the implementation where the users' choices were not correctly reflected in the interface. Finally, the users could not locate the extension in their browser after the installation. Due to this, we created clear information and documentation on how to find the extension once the user runs the wizard.

7 KLARA FACEBOOK

Klara Facebook is a web browser extension that enables the user to modify the contents of Facebook with the goal of making it more adapted to the individual user's needs. The modifications are limited to elements in the main page. The first version of the web browser extension was developed in 2020 and it was updated during 2021 to accommodate for changes to Facebook. While the extension has been publicly available for download by anyone it should be seen only as a concept prototype for research purposes.

When a user installs Klara Facebook and opens Facebook for the first time they are presented to the selector mechanism in the form of a wizard. The very first screen presents the statement "I like Facebook as it is and do not want to make any changes**. If the user agrees, no more questions are asked, and the standard full interface of Facebook is used. Otherwise, the wizard walks the user through a series of views each containing a number of statements for the user to select from. Each statement concerns *what* the user prefers to do when using Facebook. An example screen is shown in Fig. 7. The left part of the screen shows a progress indicator and the view to the right shows context-sensitive help information intended to help the user to understand the presented information. When the user has completed the wizard, an animation is shown to indicate that the interface is being adapted according to the user's preferences and finally the adapted interface is presented. The user can select to redo the wizard at any time.

The overall style of the statements can be illustrated with the following translation of the text in figure 7.

Choose the statement that covers as much as possible of the functionality you use.

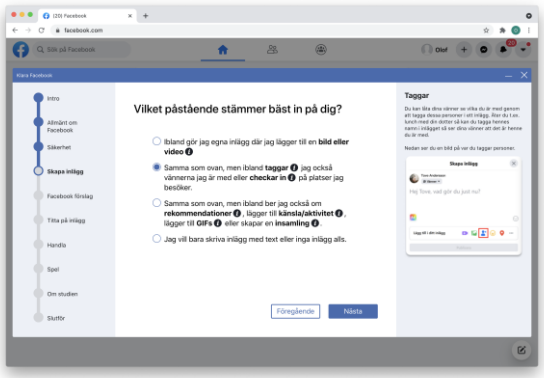

Figure 7: The selector mechanism used in Klara Facebook presents a wizard where the user selects between a number of statements to adapt the application.

(a) *Sometimes I publish my own posts where I add a picture or video.*

(b) *Same as above, but sometimes I tag the friends I'm with, or check in to the places I visit.*

(c) *Same as above, but sometimes I change the background on a post, add an emotion/activity, or add GIFs.*

(d) *I only want to write posts with text or no posts at all.* The user is presented with statements about the needs when writing posts. Writing a post offers many possibilities but they might not be needed. So a user that only writes simple posts but possibly add a picture now and then should select the first statement, a person that wants it all, should select the third one.

Fig. 8 illustrates what the user interface can look like before and after applying the wizard. The user interface consists of one of the pre-defined layers described in Sect. 6.1.

8 EVALUATION

8.1 Testing in the Wild

The general impression from the public release event for Klara Facebook was that there is quite some interest in the topic of supporting older persons' use of ICT and the event generated several follow-up presentations by project members requested by persons attending the event. In total 64 users downloaded the extension. Of these 22 answered the short questionnaire presented after one week of use. The questions were formulated as statements:

(1) I am aware that I have an extension installed that affects the appearance of Facebook (yes/no)

(2) The things I can do using the simplified Facebook fit well with what I want (1-5)

(3) Sometimes when I want to do something on Facebook it's hard to find in the simplified design (1-5)

(4) My feeling of control has been improved by the simplified interface (1-3)

All respondents were aware that they had an extension to simplify Facebook installed. The reply to if the contents of the simplified Facebook was suitable for their need was clearly positive with a

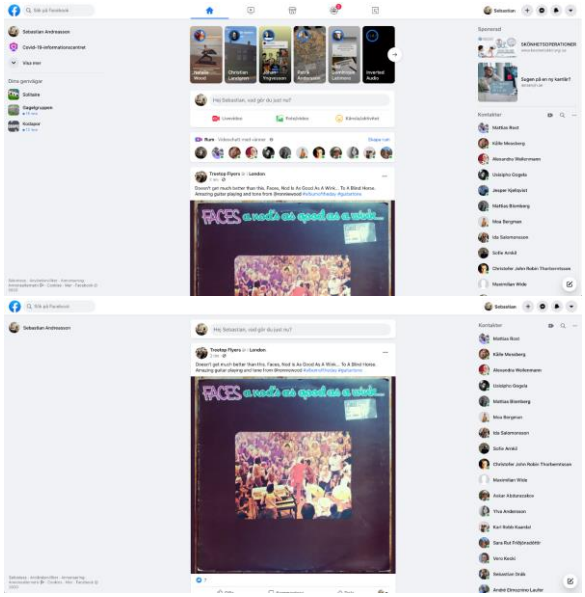

Figure 8: Top: Facebook with all features on. Bottom: Simplified user interface showing only the parts relevant for the current user.

mean value of 4.77 out of 5. Despite this they sometimes had problems finding things, mean value 2.59/5, where 5 indicated that they often had problems. Most users (n=15) experienced that their feeling of control had improved, while 7 did not notice any difference. The questionnaire also had an open question for comments. Only 6 users used this opportunity. Three of these were from users that mostly used Facebook on their mobile device and said that it would be nice to be able to simplify that as well. One was simply "It's nice that you change Facebook for the better". Two were requests from persons who wondered if we could simplify their sites for seniors as well. There were no negative comments.

8.2 Think Aloud Tests

Six of the 12 participants had used Facebook for more than 6 years, 5 for more than 10 years, one used Facebook for less than 1 year. The main three reasons behind their Facebook use were to see what others do, keep contact with family, and be part of Facebook groups

Their general experience of running the wizard was that it was easy to use for 9 out of 11 participants. After the user completes the wizard, the wizard disappears and it instead appears as a small add-on icon on the top right of the browser and a pop up appears with information about the extension. Seven out of 12 noticed the information popping up to show them the location of the extension after installation. However, while they saw the pop up, nine out of 12 could not find the settings for the extension. When they managed to find it, eight out of 11 participants understood how to turn off/on the extension.

8.2.1 Usability Issues. To make visible the changes that could happen to the users' Facebook after they finish the wizard, a slider was implemented on the first screen to show before and after views (see

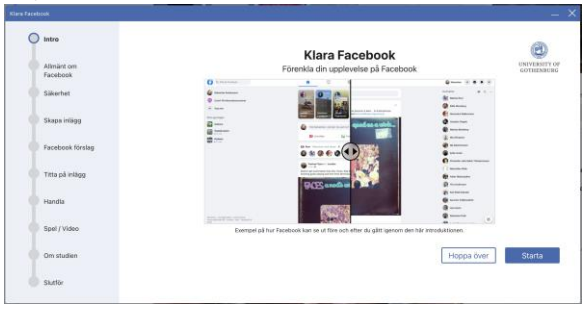

Figure 9: The first screen of the wizard. The user can drag the handle in the middle to see before and after views.

Fig. 9). One third understood how to use it to see what the effects of their choices could be, one third had to be prompted in order to understand where to look in order to be able to slide the arrows, and one third did not notice the arrows.

The progress bar on the left of the screen was noticed by two thirds of the participants, but only half of them understood the purpose of the bar. As they progressed through the wizard 10 out of 12 participants understood the purpose of the progress bar.

The users had no problems answering simple questions in the wizard but had some objections to more complex screens with multiple statements to select from, like the one in fig 7. For example, if the first alternative was "sometimes I play games on Facebook" and the next alternative, "sometimes do the above-mentioned action(s) and watch videos". They mentioned "what if I like to watch videos on Facebook, but I do not play games?". The help panel on the right side of the wizard (fig. 7) informed the users visually (with images) what feature of Facebook each option influenced. They had to click on the info icon in the text and then information related to the affected feature appeared in the help panel. Almost all the participants (11/12) noticed the help panel only when they were prompted by the interviewers and eight out of 12 interpreted differently how to interact with the info icon even though there was a pop up appearing next to the panel to point out the panel. Unfortunately, this panel further troubled the users as they did not know how to get rid of it in order to read the question in the main panel.

8.2.2 Opinions on the Simplified Interface. Seven out of 12 participants reported that their Facebook is more structured, relevant, and cleaner after the application of the wizard while the rest did not notice the difference. The users recognized that it may

be a bit difficult for some to use the extension but still found the approach to be novel and promising. Finally, 8 out of 12 reported that they could use the idea of simpler design in other contexts e.g., municipal websites

8.2.3 Suggested Improvements. The users suggested a few possible improvements for future work:

- To build a version for mobiles and tablets as most of our users prefer to use Facebook on their phone (7/12)
- To be able to see more clearly how the choices in the wizard affect the end result on Facebook
- More flexible choices e.g., one can chose to see videos without playing games
- A more obvious presentation of the help panel so people can notice and interact with it
- A possibility to ask questions about the security of the wizard.

Concerning the adapted Facebook users wanted to know what had been adapted, but they also mentioned several wishes not strictly related to Klara Facebook like more security support and making it easier to find the privacy settings.

9 DISCUSSION

A major motivation behind the concept of Gracefully adaptive user interfaces is that there is a need for a shift from trying to find ways to introduce ICT to older people and instead focus on designing for continued use of ICT for aging digital seniors. During the Digital Seniors project we have seen many examples supporting this idea. The entire SeniorNet organisation is run by digital seniors and we have met many competent ICT users. For instance, one of the members of the board had been working as a developer of advanced computer systems for some 40 years. Another anecdote is how one interviewee responded when asked if they did not use Facebook on mobile devices - "Only on the bus, that's what everyone else is doing". While there are of course still many older persons with little or no ICT experience, this group will diminish over time increasing the importance of designing for digital seniors.

Gracefully adaptive user interfaces is a concept for how interfaces, used by people, can remain usable as they get older. The way a GAUI should adapt is left open as far as the concept is concerned. Klara Facebook shows one way in which the interface can adapt. But it is far from the only way. The way Klara Facebook adapts the interface of Facebook is as a direct result of user action (as they go through the wizard). It can be argued that this is neither adaptive nor graceful. But as a result of answering the wizard, the idea is that the interface is adapted in a graceful manner such that the same functionality that the user expects from Facebook is still present, while the interface *gracefully* removes options not used that might be disturbing the experience. As mentioned in section 3 the name is a signal for the goal of creating interfaces that can (be) adapt(ed) to the aging user and the case Klara Facebook is a first step towards this goal.

Klara Facebook is a design that can be described as reversed Multi-Layer Design. It functions very much like MLD designs described in previous research (section 2.4), but the goal is different.

However, one could wonder why MLD? As mentioned in section 2.4 it is a concept that has not really been taken up by mainstream interfaces. Unfortunately, this does not mean that these have become much easier to handle, or that another better approach has taken over. Rather, most standard software is designed following a one size fits all approach. On the other hand, the user tests clearly indicated an agreement on that simplifying complicated user interfaces is appreciated and needed. One advantage of the reversed MLD approach is that the user interface consists of a number of coherently designed levels. The main alternative for simplification is probably an adaptive approach that tries to present the best possible GUI for each user. One downside of this might be that it is a

very difficult problem to automatically select and layout the user interface in an optimal manner. The reversed MLD approach can then be a practical solution supporting aging digital seniors.

One thing that needs more study is how the process of adapting the interface should be handled. Klara Facebook demonstrates one specific selector mechanism in the form of a wizard focusing on *what* the user wants to achieve when using Facebook. The user tests indicate that the users were positive to this approach, but some obvious problems exist. The most obvious one is perhaps *when* the interface should be adapted. In the current prototype this happens when the user first installs the browser extension and whenever the user feels there is a need for further adaptation. A simple solution would be to let the wizard appear periodically, or perhaps if the system notices that there are features that have not been used for a long time, or if it seems likely that the user is struggling with using the system due to observed errors. Another solution could be to use some sort of smart selector mechanism, that monitors the user's interaction with the system and selects the most appropriate layer based on that. For instance, Clark and Matthews [8] use information about the user's previous action to select the best layer. Regardless of approach, there is a need for running studies over an extended period of time.

As mentioned in section 2.1, aging users of ICT can face many kinds of problems, e.g., bad eyesight, dry skin, etc as well as cognitive problems. The work presented here is focused on simplifying a complex user interface by selecting an appropriate feature set. We are aware that the realisation of GAUI:s presented in Klara Facebook does not handle for instance problems related to not being able to see or manipulate small items on the screen. However, we do not believe that this limitation affects the relevance of the type of adaptations done in Klara Facebook. Rather it indicates that there exist several dimensions worth investigating to create the best possible experience for various kinds of digital seniors.

Finally, Universal Design suggests that one should strive for designing products and systems that can be used by all without modification. How does the approach of Gracefully adaptive

interfaces fit into this? We would like to argue that there is no contradiction. Klara Facebook contains the full Facebook interface and if that works well there is no need to make any changes. However, when needed it also allows the user to select to use a reduced functionality interface through multi-layered design, which was introduced as an approach for improved Universal Usability in [31] and presented as one of the suggested solutions by Meiselwitz et al. in their paper *Universal Usability: Past Present and Future* [21].

10 CONCLUSION

In the present paper we have argued that it is time to make a shift from designing ICT solutions focused on simplifying for older persons to *learn* how to use ICT and instead focus on the research question *How can we design systems that suit the needs of digital seniors, i.e., older long-time users of information technology, when their cognitive and physical abilities are affected by age?*. We have also presented a general model for Gracefully adaptive user interfaces focusing on continued use of ICT consisting of a selection mechanism, an adapter and a number of user interface layers designed to fit various users' needs.

To further investigate the research question, we have presented a case study, Klara Facebook, using the model of Gracefully adaptive user interfaces to create an adaptable version of Facebook. The case study suggests that a wizard containing a number of statements focusing on what the user wants to do might be an appropriate way to create an easily understandable selector mechanism.

The results from our preliminary user tests show that the users were positive to the overall approach but that there is room for further development. In particular, they did not always understand how the user interface had been changed to fit their needs and they wanted Klara Facebook to be made available for more platforms since most of them wanted to use Facebook on their mobile devices. In short one can say that the impression was that the users wanted more of the ideas presented in Klara Facebook. More simplification, application to more areas of Facebook and suggestions for that a similar approach could be good for other areas as well, e.g., public services.

In conclusion, we hope that the suggested approach can be an inspiration for others working with older users and their use of ICT and believe that designing for digital seniors is the way forward.

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