Tailor-made Accessible Computers: An Interactive Toolkit for Iterative Co-Design

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ABSTRACT
An increasing number of people with little experience in technology desire to use the Internet and web related services like social networking or online information research. However, the way most computers are designed today does not allow many older people to participate in this key technology due to their lack in computer-literacy compared with younger generations. Age-related impairments and disabilities can further complicate or deny the use of conventional computers. To remove existing barriers, we created a series of tailor-made computers, which met specific needs like improved accessibility or particular aesthetics. To accomplish this, we used a co-design toolkit that we created (a) to provide senior users with early tangible experiences of their future systems and (b) to iteratively convert it into the final implementation. In this paper, we demonstrate both the toolkit and the resulting designs of accessible Internet computers.

Author Keywords
Co-design toolkit; accessible computing; prototyping;

ACM Classification Keywords
• Human-centered computing~User interface toolkits • Human-centered computing~Systems and tools for interaction design

INTRODUCTION AND SCOPE
Older adults are an age group in expansion that has a low adoption rate of technology compared to younger adults [16]. While the TV is widely spread among older people and constitutes the most popular media device, Internet use is progressively decreasing with increasing age, and only 45% of all people older than 69 years in Germany have access to the Internet according to a recent representative study [8]. In contrast, about 80-90% of all teenagers, young adults or mid-aged adults are online regularly. Still, senior people too can benefit significantly from having access to computers and the Internet, for example, to research information, for entertainment or to fight social isolation and loneliness, which is a severe problem among older people [1]. Access to such technologies can help them stay independent and continue living in their own homes [2]. However, many devices are poorly designed [7], and there are only a few commercial companies that created desktop or tablet computers specifically to meet older people's needs, for example [9; 13; 15].

To support the adoption of new technology by older adults, researchers in HCI and TEI have investigated the design of technology for this particular user group (see Rebola's research [11] for a range of exemplary devices). Today, user-centred and participatory or co-design approaches are increasingly employed to make devices both more usable and useful for older people [2; 12]. Nevertheless, a number of researchers stated that they had difficulties on some occasions in exchanging ideas with older participants [18].

To add to the research about accessible Internet computers for older users (or users with physical impairments), we drew on tangible interaction design and created a series of tailor-made computers. To reveal the requirements of the prospective users, we employed a prototyping kit (*Infobricks*) that we introduced to support the participants in imagining the possibilities technology can afford, hence, to make technology more tangible for them.

We seek to contribute two different types of insights with our demonstration. First, we share new forms or tangible designs for accessible devices, which extend the conventional idea of personal Internet computers (commercial products for older users mostly rely on touch screens or mouse/keyboard based interaction [9; 13; 15]). Second, we reflect about co-design or participatory design processes with older adults and how these approaches can be augmented with new interactive toolkits, taking into account that electronic prototyping and rapid product design is available at low cost now.

Our target group is primarily comprised of older adults that have no or only little prior experience with computers and difficulties in using this technology. While this latter characteristic (a lack in computer-literacy) is what all of our four participants (abbreviated with P) have in common, the age varies significantly between our participants (65, 70, 75, and 91 years old). Their physical abilities too differ

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between no physical impairment and age-related problems with (fine) motor control. Hence, the devices we build are adapted to the participants' needs and customized to a high degree. Accordingly, these designs can be classified as somewhere between novel, tangible, and accessible (Internet) computers and assistive technology. In the next section, we detail our design approach.

DESIGN APPROACH

It is a known problem that technologies, designed particularly for people with special needs, are abandoned on a regular basis. In a seminal survey, Phillips and Zhao [10] found that important reasons for unused or unusable devices were that people haven't been involved close enough in the process of device selection and also that people experienced a change in abilities over time.

To avoid such pitfalls in the design of accessible computers, we involve our participants closely in the design process. To be able to account for their ideas and needs, we created an interactive prototyping toolkit (*Infobricks*) as mentioned in the introduction. The kit allows a high amount of flexibility to support the collaborative exploration of form and function between participants and designers or researchers. After the completion of the prototype, it is still possible to (re-)configure aspects of the software or some tangible components to account for potential changes in user needs.

The use of such an interactive kit distinguishes the work presented in this paper from most other research into accessible computers for older people. It involves prototypes that can be assembled together with the participant into working systems, and in further iterations these can again be reassembled as needed. This procedure usually demands a number of meetings and several weeks of time, since the participants are encouraged to take their interim prototype home to test it in their natural environment. Once a stable set of requirements is established, the resulting design is transferred into a final prototype (which also can be re-configured to some extent if needed at some point in time). Thus, the overall design process can broadly be divided into two parts. (1) Co-design sessions with interactive prototyping are followed by (2) the assembly of the final system in our workshop using tools like 3D-printing, laser-cutting or CNC-milling.

PROTOTYPING TOOLKITS IN CO-DESIGN

Designing useful technologies for older people requires a deep understanding of their issues and needs (see e.g. [17]). This can be hard to obtain for designers who probably experience a different life context [6; 14]. Older people again might experience difficulties in imagining what actually can be created using technology [12; 18].

To overcome this gap, Rogers et al. introduced the *MaKey MaKey* invention kit to senior workshop participants and invited them to create future input devices [12]. Being provided with this tangible experience, the participants learnt what was possible in principal, and moreover, they were able to reconfigure the *MaKey MaKey* components into an innovative piece of technology. Hence, the *MaKey MaKey* kit allows the users to create their own computer input devices without knowledge of programming and electronics or design craftsmanship.

In contrast to Rogers et al. [12], who introduced tangibles as a powerful means to temporarily explore quite fragile and limited prototypes for input devices, we are interested in co-designing accessible Internet computers that last and are actually deployed or used for years. For this reason, we adapted parts of the *MaKey MaKey* concept and created our own toolkit *Infobricks* for the co-design of accessible Internet computers. In a prior publication [5], we described the requirements gathering of a predecessor version of *Infobricks* including a case study where one *maker* used one provided *Infobricks* kit to build a DIY computer for her mother.

In the present paper, in contrast, we make use of *Infobricks* as an intermediate step to provide the prospective users with interactive experiences to make an informed selection of functions. Subsequently, if the design met their expectations, we finalize the prototype into a tailor-made personal and accessible Internet computer (see Figure 3-6 for examples).

Prototyping Toolkit Infobricks

Infobricks is comprised of several components (see Figure 1), a main module and optional peripherals. This modularity enables us to collaboratively explore together with the senior users what functions or characteristics their computer should have and to quickly adjust the design proposal accordingly. (Note, further details about the *Infobricks* system can be found in the description of the toolkit's predecessor implementation [5].)

Hardware. The extension board (displayed in Figure 1, labeled with 2) is connected to the main module using

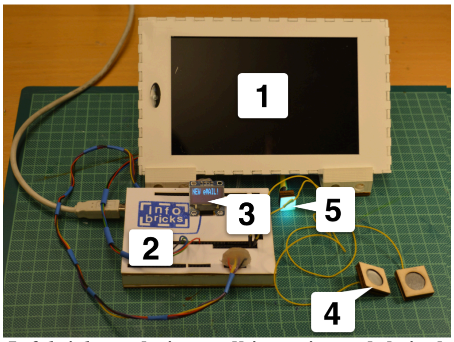

Figure 1. *Infobricks* co-design toolkit: main module incl. screen (1), extension-board (2) for optional components like small OLEDs for displaying text (3), up to twelve extra capacitive buttons (4), feedback LEDs (5), etc. The screen is available in different sizes. The kit can be configured into a working system. Sticky tape, glue, plywood boxes, and cardboard are used to temporary connect all chosen components (see also Fig. 2).

Bluetooth or USB, and again, provides ports for connecting additional user interfaces with wire like small OLEDs for displaying additional contextual information (e.g., "you have received a new message"), buttons or feedback lights (for indicating important events like an incoming message etc.). A RFID reader (e.g., Figure 4 left) can also be attached, should the participant wish to work with RFID tokens that trigger certain user-defined actions (e.g., the presence of a token can be set to open the browser app).

Software. As the main module is based on a modified (rooted) version of Android, regular Android applications that ship with this operating system are available to the user. Moreover, we provide a number of custom apps to improve accessibility. Our photo app, for example, can automatically receive photos and associated annotations that are sent to the system externally by using a corresponding smartphone app. These received images are then presented on the main module as if it was a digital photo frame.

Similarly, we created a simplified e-mail client or chat application that allows the users to exchange text messages in an easy way. It offers more accessible user interface elements and interactions compared with conventional e-mail clients. Messages can be sent to a set of predefined users, who can reply using a smartphone application or another *Infobricks* system.

For (quick) customizations, custom background screens, audio recordings, text messages, and videos can be uploaded to the main module. In this way, the designer can for example upload a custom design for the start screen. In addition, *Infobricks* can be configured to show a welcome text message displayed on a small OLED screen on boot-up together with this start screen. At the same time, a custom audio recording could welcome the user and give instructions for how to operate the system.

Moreover, a configurator app can be employed to assign different functions/apps to different buttons and RFID tags, given the corresponding components are supposed to be integrated into the design. This behaviour is accomplished by using a simple scripting language that we defined and which features different keywords and variables so that physical buttons, custom text/audio-messages, feedback lights, and system events can all be linked quickly in a useful manner.

Overall, the modularity and high degree of customizability described above are key factors that enable our hands-on and tangible design process. Usually, within the duration of one co-design workshop, *Infobricks* can be adjusted according to the elaborated user needs. To this end, we bring cardboard and plywood boxes with prepared mounting holes etc. to the workshops (see Figure 2). After a period of user testing, the prototype is transferred into a permanent installation (as displayed in Figure 3-6), should the setup be satisfactory. In that case, components of

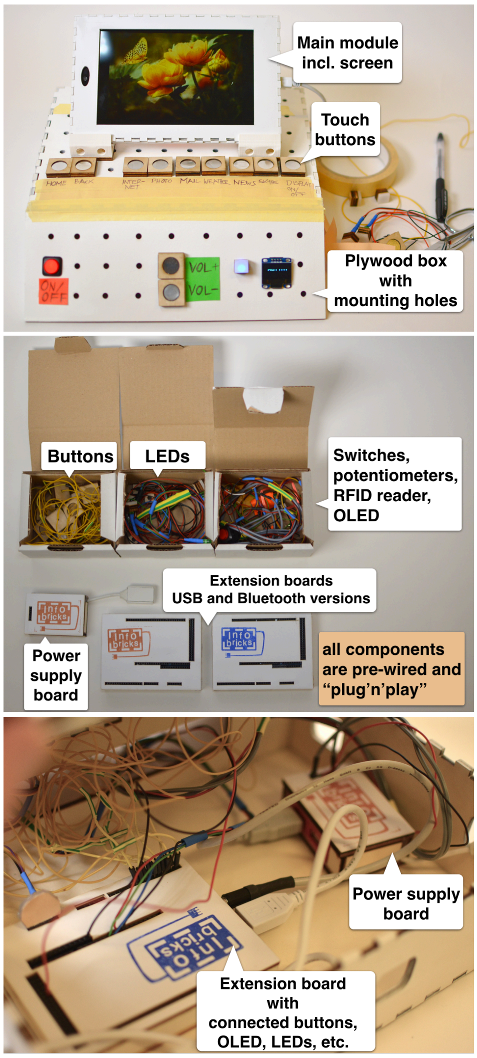

Figure 2. Top: toolkit temporary assembled using a plywood box and glue/tape. Middle: different toolkit components. Bottom: Extension and power supply boards revealed in opened plywood box.

Figure 3. Two completed prototypes for accessible Internet computers resulting from the design sessions. The arrows point at features for displaying text messages and providing quick access to important functions like opening the email or shutting down the system.

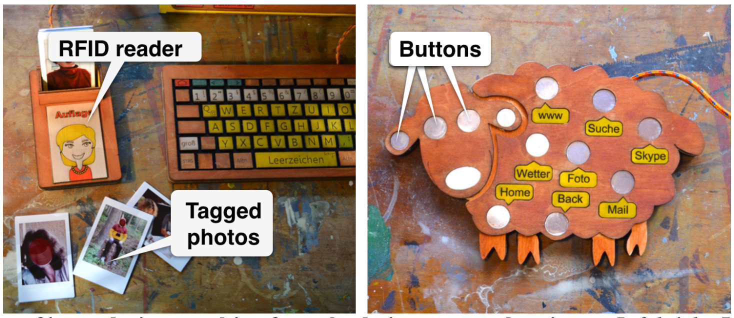

Figure 4. Detailed views of input devices resulting from the design process drawing on *Infobricks*. Left: polaroid portraits including hidden RFID tags can be placed onto the reader device to open the email client with the corresponding addressee already filled in. Customized computer keyboard (partially visible). Right: quick access button board in the shape of a sheep to be connected to the accessible computer for triggering favorite apps and functions.

Infobricks can be built into a permanent casing. The extension board (including other components) is small enough to be fit into the computer bodies (see Figure 2 bottom). In this way, the effort for creating the final system is restricted to building the new case for the electronics (including user interfaces like touch buttons etc.). Programming is not necessary, as the final system is configured with the same *Infobricks* software components as described earlier in this section.

We go on to present some indicative findings resulting from this co-design approach to create tailor-made computers.

INSIGHTS AND REFLECTIONS

Infobricks proved (and still is proving) to be valuable in exposing participants to technology and finally to create appreciated and accessible devices. In particular P2 and P4 benefited from their new computers, as they have been using them for over one year now on an almost daily basis. They too were the participants with least computer experience (almost none). To date, P1 is still using her computer occasionally, and P3 is working towards her goal to learn about regular tablet computers by drawing on her *Infobricks* design (as explained below in *item 1)* and *2)*).

In the co-design process, the physical and interactive artefacts served as "a common frame of reference between participants and designers" [7, p.1201], helped computational concepts to become more tangible [7], and took away computer-shyness. The participants showed a high amount of motivation in co-designing and later in using their systems. Coleman et al. [4] also found that older participants were generally more likely to accept technology if they were able to see a direct benefit from it.

Throughout all design processes, we conducted informal interviews and made a variety of observations. Drawing on a thematic analysis approach [3], we clustered design-related salient observations into four themes in order to present these insights in a structured fashion as follows.

1) Physical appearance of the designs: In the course of the co-design process, it became apparent that the participants favoured to have their own individual designs regarding the aesthetics of their accessible computers. Most important to all of them was a friendly, "non-techy", and familiar design that matched well with their homes and personal preferences. The design process of *Infobricks* allowed us to consider such preferences.

Figure 3, for example, shows a conventional Android tablet in the front of the picture, because P3 conceived her computer as a "smart dock" to which a regular Android device (running *Infobricks* software) could be connected. The dock featured quick access buttons and an information OLED to facilitate use. By having the regular tablet visible and unmasked, the participant aimed at creating an accessible Internet computer with a conventional, non-stigmatizing appearance.

2) Adaptability: Additionally, this feature of making the tablet detachable aimed at allowing *making adaptations* to the system. One day, with increasing computer-literacy, paricipant P3 anticipated to "transform" the accessible computer into a conventional tablet by waiving smart dock functions or even by completely removing the smart dock. Figure 5 shows P2's prototype where the main computer could also be detached from the dock. In summary, making the systems adaptable was a strength of *Infobricks* not least because of its software components. In this way, we addressed an agenda as proposed by Wobbrock and colleagues: "In making the shift to ability-based design, we move away from assisting human users to conform to inflexible computer systems, and instead consider how systems can be made to fit the abilities of whoever uses them." [19, p. 2]

One way to accomplish this design philosophy, besides building smart docks etc., is to make use of RFID tokens as input devices similar to work by Ylirisku et al. [20]. By employing this wireless technology, our systems could be extended easily with tangible elements. Figure 4 (left) shows RFID cards with portraits of people to open the email client ready to mail the corresponding addressee. In addition, RFID could be used to trigger different apps and functions as defined in the configurator application. In the same way, the interface could conveniently be extended into the homes of the users by configuring RFID tokens (or touch buttons) to remote-control power outlets (via 433 MHz transceiver technology) with additionally connected appliances (e.g., floor lamps).

3) Input modalities: In analogy to different physical appearances, participants preferred different user input modalities. While some participants preferred tangible user interfaces (e.g. RFID cards or objects with RFID tags), others preferred the touch screen (depending also on the specific task). Moreover, Android's built-in language processing capabilities were well received by the older users. Making use of the system by giving voice commands worked well for certain tasks (e.g., requesting the weather forecast for a specific place on a particular date). Thus, we see great potential in such natural user interfaces in the context of accessible computing.

We also co-designed a number of customized computer keyboards (see Figure 3 and 4 left) with different colour codes and labels engraved. It turned out beneficial to print short instructions with a summary of the most important functions, e.g., how to use voice commands, on the backside of the keyboard (see Figure 6). This served as an excellent reminder, and when the user felt overwhelmed by the system's complexity, the keys could be covered by placing the board on the table upside down.

4) Design as a method for inquiry: One interesting aspect of our research approach using the interactive toolkit was that the insights described above were generated by relatively quick design iterations in which the participants were exposed to the artifacts. That is, design was employed as a method for inquiry ("research through design"), and here the strategy was to "focus on the *right* thing; artifacts intended to transform the world from the current state to the preferred state" [21, p.497]. Hence, through an iterative process of design and feedback the problem was repetitively reframed and looked at from different angles, and the final prototypes embody findings and design knowledge that were created in the process.

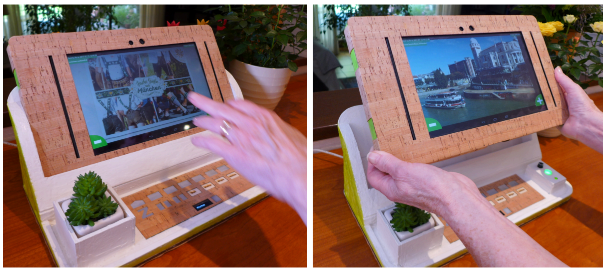

Figure 5. P2's Internet device where the main computer can be removed from the docking station featuring quick access buttons, OLED, and notification light. Computer and dock are connected via Bluetooth.

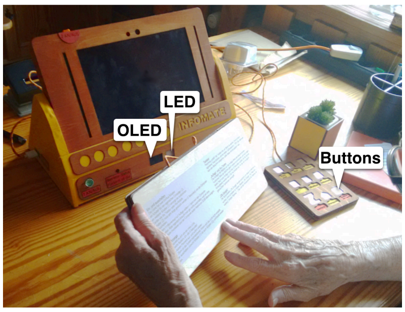

Figure 6. P4 studying the backside of her computer keyboard which contains hints and "tool tips" (e.g., how to turn on/off the computer, navigate using quick access buttons, etc.).

CONCLUSION

More than the half of older people (aged 69 years and above) are still excluded from the Internet [8], even though this group of people could benefit strongly from Internet related services (gathering information, entertainment, overcoming social isolation, communication, etc.)[2; 12]. Providing more accessible Internet computers can help overcome a lack in computer-literacy as well as compensate physical impairments in order to enable more senior people to get access to useful applications [2].

As older users are a very diverse group of people, designers or researchers can have difficulties in understanding their particular situation and user needs. Older people again can experience difficulties in anticipating technology that is yet to be implemented or intangbile [7; 12].

To bridge this gap, we introduced an interactive prototyping toolkit (*Infobricks*) for accessible computers to our co-design sessions. This provided us and the participants with a tangible tool for communication. Instant interactivity proved as a powerful device for older people to understand technology, and at the same time, it was valuable for us to understand what was needed. After a number of design iterations, and after some time between iterations to "let technology settle", the initial designs were eventually implemented into stable and final prototypes also making use of the *Infobricks* engine.

This iterative and interactive approach enabled us to understand and react to user needs, which we would not have uncovered in the same way following a different research method (e.g., observing and asking people about what they want to have or studying technology that already existed). We expect this prototyping approach to gain more importance in the near future, when accessible computers and Internet devices (or technology in the home in general) will increasingly "lose" their stable appearances, and interfaces will be found in new shapes and places. This will make imagining technology even harder for participants as well as for designers, and tools are needed to move from the abstract to the concrete.

This paper constitutes a prototype demonstration including some indicative findings. Future research will investigate in depth in which ways *Infobricks* can facilitate co-design, how the completed computers are used, and how accessibility can be operationalized in order to measure the effect of our Internet computers.

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