

Making a Customized DIY-Computer with Infobricks

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Making is about learning new skills, creative explorations, and solving problems; but it is also about giving and caring for others. Many makers enjoy creating unique and bespoke presents to give them to people they care about to enrich their life. To support and exploit this motivation, we designed a modular toolkit named Infobricks, which was conceived for creating DIY and accessible computers. For a grounded requirements gathering of Infobricks, we conducted a study featuring six makers. We present a functional prototype for Infobricks as an embodiment of the findings from this study. Moreover, we illustrate Infobricks in a “lived scenario” featuring one additional participant who used the kit to create a computer for her older mother. Overall, our ambition in this paper is to design a toolkit like Infobricks and to demonstrate how it can provide e.g. senior citizens with customized computers by drawing on the constructive energy and skillset of makers.

DIY. Makers. Accessibility; Design tool; Senior users; Design concept

1. INTRODUCTION

In recent years, the ‘maker movement’ picked up momentum at an increasingly fast rate. One of the community’s most important venues, the World Maker Faire (New York City), attracted more than 100.000 visitors lately. The attendees were united by a high amount of enthusiasm for engaging in creative explorations. Being part of a community, information exchange, and discussions are of crucial importance to the makers (Dougherty 2012).

Since makers enjoy creating their own and individual products rather than consuming mass-manufactured goods, the rise of the maker culture was facilitated by the recent availability of digital manufacturing tools such as laser cutters, 3D printers or CNC mills. Until recently, such professional and semi-professional technologies were reserved for companies; hobbyists could not afford them (Tanenbaum, Williams, Desjardins, & Tanenbaum 2013). In contrast to earlier “Do-It-Yourself” (DIY) and tinkering movements, makers can now use these digital tools to achieve better outcomes. However, digitalization did not only improve, for example, accuracy, it also enabled the exchange of designs and the formation of maker networks and communities (Lindtner, Hertz, & Dourish 2014). Consequently, a recent book about opening a workshop for makers (a “makerspace”), characterised makers and their particular mindset as follows:

“Making makes your brain hurt, your fingers sting and your room dirty: things you just can’t buy. The Maker movement has brought a philosophy of sharing, acceptance, and creativity [...]. We share what we make and help each other make what we share” (Kemp 2013, p. IX).

Perhaps to little surprise, lately, researchers from the HCI community have started to explore how this positive energy, attitude, and the competence of the makers can be exploited to create technology that supports people with special needs. Hurst and Tobias, for example, collated a number of cases where individual people helped others by creating DIY-assistive technologies in order to compensate disabilities (Hurst & Tobias 2011). In this publication, the DIY- and the maker mentality showed an enormous potential in creating supportive technology which is not expensive and generic, but affordable and highly customized.

While DIY-assistive technologies like special input devices, tools for communication or aids for mobility have been published in the HCI and related communities, there is a lack of research about accessible DIY-computers. For this reason, we report how we conceived, created and studied Infobricks, a modular system for creating customized and accessible computers. Thus, in this paper, we contribute the detailed documentation and exploration of a toolkit targeted at makers or tinkerers who wish to create more accessible computers for others (or themselves).

We go on to outline related work, before we report the requirements and design of Infobricks.

2. RELATED WORK

2.1 DIY- and Maker Assistive Technologies

Motivated or alerted by the low acceptance rates of assistive technologies, Hurst and Tobias (Hurst & Tobias 2011) looked into the practices of amateurs who successfully built their own DIY-assistive technologies. Drawing on seminal work (Phillips & Zhao 1993), they summarized the following factors as relevant for the abandonment of conventional assistive technologies: *“lack of considering user opinion in selection [...], ease in obtaining devices [...], poor device performance [...], and] changes in user needs and priorities”* (Hurst & Tobias 2011, p.11). They further found that being in control, passion, and lower cost were important motivators for creating DIY-devices. Kane and colleagues (Kane, Hurst, Buehler, Carrington, & Williams 2014) emphasized the importance of integrating the affected individuals into the design process to increase the success rate of assistive technologies.

An increasing interest in the role of *making* in healthcare/wellbeing is also reflected by a recent CHI workshop about the “advances in DIY health and wellbeing” (O’Kane et al. 2016), and by the growing number of open-source designs for assistive tools such as prostheses on sharing platforms like Thingiverse.com (Buehler et al. 2015). Furthermore, there is a growing number of projects in the literature, where non-engineers and laypeople were supported in creating DIY-assistive technologies to compensate for different disabilities. Hamidi, Baljko, Kunic, and Feraday (2014) and Hamidi and Baljko (2015), for example, created a prototype for a communication board. This device allowed users who suffered from a speech disorder to play pre-recorded audio files (e.g., “thank you”) on the touch of a button. As a Raspberry Pi was the most expensive component, interested people could assemble their own communication board (the researchers open-sourced the design) at a very reasonable price. Moraiti, Abeele, Vanroye, and Geurts (2015) created a DIY-toolkit for occupational therapists that enabled them to create customized tangible and interactive objects to be integrated within therapy as smart and motivational elements. Hook, Verbaan, Durrant, Olivier, and Wright (2014) took a critical perspective on DIY-assistive technologies with respect to children and disabilities. They revealed a number of important aspects that needed to be taken into account when designing such devices, e.g., issues around robustness, usefulness, aesthetics, and repair.

2.2 Accessible Computers

As mentioned above, so far there was little effort in supporting individuals to build their own accessible computers. However, there is much research into designing easy to operate ‘off-the-shelf’ computers for older users. Hence, this can be seen as a ‘one size fits all’ approach where the solution is not tailored for *an* older user but for *the* older user.

Rebola (2015) collated a worthwhile collection of technologies that were specifically designed for older users. While this book is not restricted to accessible computers, it features a number of interesting devices from that category. For example, it described work by Baecker, Sellen, Crosskey, Boscart, and Neves (2014), who designed the InTouch tablet application to grant seniors easy access to basic functions such as Internet telephony. A few years earlier, a similar computer device named Building Bridges was developed and studied with respect to its potential in supporting older people to communicate (Garattini, Wherton, & Prendergast 2012). Additional research investigated a series of general-purpose Internet computers and networked photo displays, which were specifically designed according to the needs of older users (Güldenpfennig & Fitzpatrick 2013; Güldenpfennig, Nunes, Ganglbauer, & Fitzpatrick 2016). Other researchers focussed on senior users as *active* producers of digital content using computers (rather than ‘simply consuming’ content like video streams etc.). Waycott et al. (2013), for example, created a tablet application for older users, which allowed them to create their own photo collages and messages. In this research, they explicitly included the senior users in the design process of this app to be able to account for their special demands.

While the projects described above constitute interesting and successful attempts to make computers more accessible, they still depend on designers and professionals, who eventually create the devices or applications, and they come in ‘vanilla flavour’ (the same device for a whole group of users). Infobricks, in contrast, aims to advance research by introducing a new category of accessible DIY-device that can be assembled and customized by makers and tinkerers on their own, in particular, to then support their loved ones with these highly customized devices.

3. METHODS

The work in this article reports an artifact research contribution as recently classified by Wobbrock and Kientz (2016). According to those two authors, such artifact contributions *„ [...] arise from generative design-driven activities (invention). Artifacts, often prototypes, include new systems,*

architectures, tools, toolkits, techniques, sketches, mockups, and envisionments that reveal new possibilities, enable new explorations, facilitate new insights, or compel us to consider new possible futures. New knowledge is embedded in and manifested by artifacts and the supporting materials that describe them." (p.38).

Accordingly, Infobricks constitutes a prototype toolkit that we conceived to explore how the maker spirit can be exploited to create accessible DIY-computers. In line with Wobbrock and Kientz (2016), we argue that (interaction) design knowledge can be embedded in the design artifact *per se*. Infobricks is showcasing new interaction possibilities and configurations facilitated by its design. To demonstrate these possibilities, this contribution is complemented by a field deployment which serves as a "lived scenario" in this paper (a real-life instead of a made-up example).

Given that we were interested in detailed and holistic feedback, and the explorative nature of the research endeavour, we chose a qualitative research paradigm. More precisely, we primarily conducted interviews, made observations including photo-documentation, and deployed the Infobricks prototype as a technology probe (Hutchinson et al. 2003). We analysed this data using a thematic analysis approach (Braun & Clarke 2006). That is, we exposed ourselves to the collected material – audio, written notes, photos, etc. – and qualitatively as well as iteratively investigated the data for underlying patterns. Through this approach we identified a set of salient themes (or user requirements) from the observations, which were particularly interesting with regard to the underlying primary research question (RQ) of this paper:

RQ: Based on considerations of makers, how should we inform the design of a toolkit for creating accessible DIY-computers?

3.1 Participants

We recruited participants (abbreviated with P from now on; see Table 1) from our extended social networks for informing the design of the modular system. We named this system Infobricks (Starter Kit) in this paper. To be eligible for study participation, P1-P6 (for informing the design) had to be makers, that is, they had to be members of a fablab/makerspace or had to have access to typical maker tools. Thus, they had to be experienced in 3D-modelling/printing, laser-cutting, 'playing' with electronics, etc. P7 was recruited after the Infobricks Starter Kit was built based on P1-P6's input to illustrate and explore how a maker would use the modular kit. Thus, this participant had to be prepared and motivated to customize Infobricks to their own needs. Excessive experience in making was not necessary for P7, however, skills and joy for crafting was a prerequisite. P7 used Infobricks

to create a customized DIY-accessible computer for P8 (her mother). Hence, criteria for P8 were to have no or little experience with computers, but having a desire for operating such a device. All participants gave their written consent, and there was no financial remuneration.

3.2 Procedure

The study in this paper was comprised of two parts: main part (A) for requirements gathering and ideation, and part (B) for a complementary case study. (A) involved participants P1-P6 and was conducted before Infobricks was created to inform the design of this system. (B) featured P7 and P8 to take a look at how the finished prototype would be received and used in a natural setting. Part (B) may also be read as an illustration or "lived scenario" for the use of Infobricks.

Table 1: Overview of the participants (P). With maker, we denote people with an interest in making and access to tools for digital fabrication. Experienced makers are people with substantial training in making (more than five years). A tinkerer, in this paper, is someone with a strong interest in creating personal products, but in a more conventional sense (e.g., painting or knitting).

Identifier	Gender/Age	Maker Experience
P1	M30	Maker
P2	M29	Experienced maker
P3	F27	Experienced maker
P4	F35	Experienced maker
P5	M27	Maker
P6	M39	Experienced maker
P7	F34	Experienced tinkerer
P8	F73	Not a maker. Retired teacher

3.3 Study and "Lived Scenario"

Part (A) – Main part: To inform the design of Infobricks, we created a simple mock-up of the system with no functionality. The concept and shape of this mock-up was inspired by our prior experience with accessible computers and related work. However, we did not invest great time and resources into the mock-up, as its sole purpose was to elicit feedback during the interviews of part (A). Thus, during the interviews, the mock-up was first presented to the participants along with explanations of what we were trying to conceive:

An easy to assemble toolkit for creating custom computers, primarily targeted at a maker audience with the main use case of creating accessible DIY-computers.

With those instructions and the mock-up in mind, the participants were then asked for their opinion about such a system and for their own design

ideas. We encouraged the participants to speak freely and tried to interrupt them as little as possible. When they mentioned ideas that we found particularly interesting, however, we asked them to elaborate on them. The resulting semi-structured interviews were recorded on audio for later analysis, and above all, to advance the mock-up into a functioning prototype for Infobricks.

Part (B) - "Lived Scenario": After implementation, the Infobricks Starter Kit was given to P7, a tinkerer and beginner-maker, who gratefully participated in the study to use the kit to assemble an accessible computer for her mother (P8). P8 had an eager interest in computers (or in the corresponding Internet/e-mail applications), but only little prior experience or training with conventional computers. She did neither own a computer nor did she possess a smartphone. P7 was encouraged to build whatever suited her best with Infobricks. She was provided with a complete kit including auxiliaries (see Figure 3 and 4) and detailed instructions how the system can be customized. We asked her to use her smartphone to create a photo-documentation of the construction process (see Figure 6), and to give us an interview together with her mother P8 when the system was finished. There were no time restrictions, and P7 took the kit to her home.

We go on to present the findings of (A), which resulted in the design rationale of the Infobricks system. We then describe the Infobricks Starter Kit per se, as it resulted from the prototyping process. The kit embodies the findings of part (A). Subsequently, we report the case of P7, who used the kit to turn it into a DIY-accessible computer for P8. This part (B) should serve the reader as a "lived scenario" and support the understanding of how Infobricks can be used.

4. RESULTS

This results section is organized into three subsections: Infobricks design rationale as resulting from the maker interviews (see part A of the previous section), the description of the finished

prototype of the Infobricks system, and the presentation of the "lived scenario" featuring P7 and P8 (see part B of the previous section).

4.1 Results I: Design Rationale/Requirements

The underlying concept of Infobricks was to provide a modular, extendable, and transparent system that can be assembled into a DIY-computer. In particular, while conceiving Infobricks, we had the creation of highly-customizable accessible computer in mind and targeted at the maker community. Eventually and based on the makers' feedback, we designed a main module hosting the operation system based on Android. This main module can be (but not necessarily has to be) extended by connecting supporting modules using USB connectors or Bluetooth. By this feature, the maker or designer should be enabled to select extra functions according to their individual needs. A sketch of this concept is illustrated in Figure 1. In addition, these hardware components are complemented by software, which both provides a stock of basic functions that are easy to use and the option to further customize the software (introduced in section 4.2). Due to its transparency, that is, the openness of the design and availability of the sources (e.g., the templates for the laser cutter), the maker can draw on this basic structure and modify it.

During the thematic analysis of the interviews (part A), we identified a number of salient themes regarding what P1-P6 found of crucial importance with respect to the requirements of Infobricks. In the following paragraphs, we go on to explain these requirements (R1-R4) as they were established during the interviews. Subsequently, we show how we rendered them into the finished Infobricks prototype.

(R1) Interesting stock of basic functions

During the interviews it became apparent that the participants saw a demand in a stock of interesting and powerful basic functions. P6 explained this as follows:

"Such a system should offer an interesting stock of basic functions to enable you to get something interesting started right away ... without any frustration... There should be a solid stock of vanilla apps, appropriate killer-applications to make the system valuable. Later on, these apps should be complemented by additional apps, in case of this is needed." (P6)

Besides the fact that the operating system was based on Android (many apps available), we took account of this requirement (R1) by implementing a number of easy to use and customizable basic applications, such as a simplified e-mail client or a search app. These applications are explained in more detail in the remainder of this paper.



Figure 1: Illustration of the Infobricks system for making a customizable DIY-computer to empower marginalized user groups such as senior citizens. The concept encompasses different modules delivered as a set or "starter kit" that can be connected using USB or Bluetooth in order to adapt the system to the users' particular needs.

(R2) 'Hackability', repair, customizability

While we certainly influenced the participants' feedback regarding the system's modularity and customizability (we told them that our goal was a modular and customizable system), they also introduced their own thoughts and terminology in this respect. P2, for example, introduced the notion of 'hackability' and explained it using the following words:

"Hackability' is certainly a hot topic, if this [Infobricks] is meant to be for a maker audience." (P2)

"Glue is cool, using screws is cool, being able to replace parts and components is king." (P2)

Furthermore, in this context, the topic of 'repair' was of great interest for P2 as exemplified by these two quotes:

"The system [Infobrick] will break one day, because all technology breaks sooner or later. Then it doesn't have to be sent in or even get replaced, it can be repaired by someone in the family with an affinity to technology or making." (P2)

"When my granny pours her orange juice over the tablet 600 Euros are gone, but when the casing [of Infobricks] gets dirty, I simply replace it with a new one." (P2)

In line with the demand to be able to hack the system, or to repair it, was the desire to be able to customize its components. The main motivation of this demand was the special needs of senior users. This was highlighted with regard to usability issues, but also in the context of aesthetics and user experience. In the words of P5 and P6:

"For my grandparents I would probably cover it with textiles to match it with their living room."

"Older people are often very picky with regard to technology, they want for example a tidy living room. Technology shouldn't look like technology at all. Here, I can see the strength of something like the [Infobrick] system, because everything can be tailored to their individual taste." (P6)

Hence, participants repeatedly stated that they wanted to be able to design the look of the system themselves:

"The shape [of Infobricks] should not be given. One should be able to change it." (P3)

"You should not paint the kit, for example, in green colour. You should leave it blank in order not to prime or influence the designers." (P3)

Based on this feedback we decided to use untreated plywood (and a notching-technique typical for makers) for creating simple rectangular

boxes to house the different components. As a response to the requirement analysis (compare P2's comment above) we used screws wherever possible to empower the maker to open our casings and modify/replace them if needed. This is illustrated in Figure 2, where a RFID reader module is disassembled as an example.

(R3) Modularity

Closely related to the requirement of 'hackability'/customizability was the need for having a modular system. In fact, the wooden casings, described in the paragraph above, can be seen as the protection or packaging of the electronic components that come in individual modules.

The importance of this modularity requirement was reflected by the larger number of occasions when the participants referred to it during the interviews. Here are some exemplary quotes:

"I personally have trouble targeting small keys, so there should be the option to change the keyboard for bigger keys." (P2)

"My mother has a hard time working with her PC, and she is dependent on having her own keyboard available. She can't handle a new keyboard that she is not used to at all. To help her, there should be the option to integrate her existing keyboard into the new system." (P4)

"The most existing feature for me is its modularity ... that everything has this maker style. This makes it easy for me, given that I have access to the laser-cutter layouts, to create for example a customized casing and wall-mount to install the device at the right height for my granny." (P2)

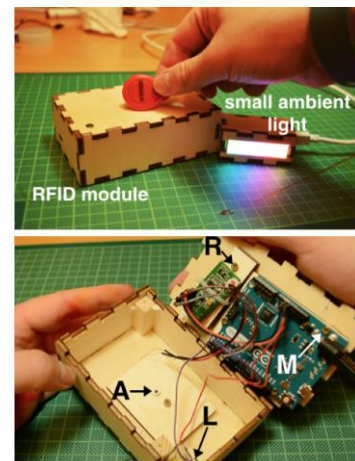


Figure 2: Top: RFID module with tag placed on top of it, and demonstration of a small LED module as an ambient light. Bottom: RFID module opened. Every single component can be removed using screws in order to support the 'hackability' of the module. In the bottom figure, antenna (A), LED feedback light (L), RFID IC component (R), and microcontroller board (M) are displayed and marked with arrows.

"Having USB connectors for all modules will be handy. This will simplify assembling it a lot." (P2)

"I like the idea that you have a set of modules at your home, and when you need to go somewhere else you unplug the main module and have a light version to go." (P2)

"If my granny can handle one particular [Infobrick] component, then I will give it to her. If one day, she might not be able to operate it anymore and she is overwhelmed by it, I can remove it again. This system provides some kind of plasticity which a closed system will never have." (P2)

(R4) Robustness

Finally, the participants demanded a certain kind of robustness from the system. In first line, they were referring to the behaviour of the software:

"The software should be easy to use, this is important. I mean, not for me, I can handle some complex software or programming, I mean the people who are supposed to use the system later on, they should be offered simple and bullet-proof programs." (P5)

Target group

Requirements R1-R4 marked the aspects of Infobricks that were most crucial to the participants regarding system functionality and characteristics. Consequently, R1-R4 emerged as patterns from the content analysis. In addition, we identified participants' comments on the *target group* as a theme. As stated above, our objective was to provide makers with a kit for creating their own accessible DIY-computers. However, repeatedly, the participants expressed their opinion that Infobricks might also be valuable to additional target groups:

"I think such a system would also be good for people with little computer-affinity in general, not just elderly users. My partner, for example, she is not really interested in computers or learning how they work. Still she wants or needs to use them. It would be beneficial for her to tailor a system to her needs that is more convenient than the PC that she now owns." (P1)

"My partner loves tinkering, but in an analogous way ... not with computers. Your system should also support and motivate tinkerers in creating their own computers without the need to deal with computers in great detail." (P1)

"I really like the concept and I can imagine that the system is not only beneficial to older users but also that I, for example, give a set to my younger cousin and I tell him 'OK, this is yours. Play with it, break it, I don't care. If it falls apart, I can create new parts for you. And if the electronic components break, I can provide cheap replacements. Go crazy, do what you want, it just doesn't matter'. So, I think, that the

toolkit could be great from a pedagogical perspective." (P2)

"Maybe it might be interesting for the seniors to customize the system themselves." (P3)

"Maybe the target group is not only makers but also school kids or beginner-makers who don't want to go into making very deeply." (P4)

4.2 Results II: The Infobricks System as Implemented

In this section, we provide an overview of Infobricks' hardware components and the corresponding software we implemented to run it. In addition, we detail in which ways Infobricks can be customized to support user goals. This prototype for Infobricks represents the embodied findings from the maker interviews.

The design of Infobricks was, on an abstract level, motivated by taking requirements R1-R4 into account and in a direct fashion by very specific suggestions by the participants, for example:

"I could imagine something like a light bulb ... this gives us a light that enables us to notify us about new messages ... Then I know, 'OK, this is lighting up when I have a new message ... or when I have to take my medication' ... then the device is giving me a reminder." (P1)

The Infobricks system is comprised of several components (see Figure 1 and 3), a main module and optional peripherals, which are connected with USB wires or using Bluetooth. This modularity enables the users to adapt and extend their individual Infobrick setup according to their needs. While additional features can be added easily, at the same time unused and maybe distracting components can be removed to reduce the cognitive load of the users.

So far, we have implemented the following modules for the Infobricks prototype in hardware.

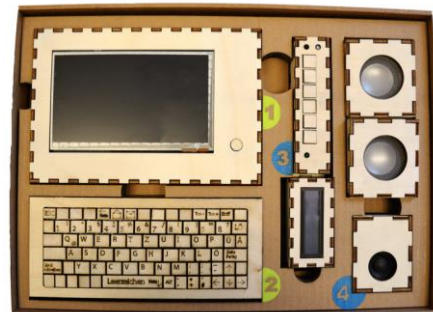


Figure 3: Infobricks Starter Kit consisting of main module (1), keyboard (2), input bars featuring buttons and other sensors (3), a small LCD display (3), audio speakers (4), RFID module, small ambient light, and some additional accessories like power supply or stands for aligning the display in a good angle. Note, not every component can be seen in the figure, as the packaging of the box is organized in multiple layers.

- M1) *Main module* (see Figure 3, number 1). This component constitutes the backbone of every Infobrick setup, it can be used as a stand-alone system, and accordingly the main module hosts basic functions: it runs the operating system based on Android 4.4 and a single-board computer (ARM Cortex-A5 1.5 GHz quadcore with 1 GB SDRAM), features a 7 inch multi-touch display (1280x800 pixels resolution), and provides access to the Internet and audio device (audio jack and build-in microphone). In addition, the main module features USB ports and a Bluetooth interface allowing the remaining modules (described below) to be connected as peripherals.
- M2) *Keyboard* (see Figure 3, number 2). We provide a small and wooden Bluetooth keyboard as part of the Infobricks system. It can be replaced with any other Bluetooth or USB keyboard, should it not be appropriate.
- M3) *Input bars* featuring extra buttons, temperature, and light sensor (see Figure 3, number 3). Modules with either six or twelve buttons are included within the Infobricks kit and can be assigned with shortcuts to functions of the main module. For example, one button could be 'programmed' by the user to shutdown the computer or to trigger the @-sign key event to make these functions more accessible. Temperature and light sensors are built-in to monitor the environment of the Infobricks system, if required by the users.
- M4) *Audio speakers* (see Figure 3, number 4). The users/makers can choose between mono or stereo speakers, Bluetooth or wired connection, and potentiometer or push button volume controllers, should they want to incorporate audio into their particular setup.
- M5) *RFID reader module* (see Figure 2). This component is capable of reading RFID tags, which can be assigned with particular functions. Hence, it enables the users to create shortcuts of interactions, very similar to the input bar buttons (M3).
- M6) *Small LCD display* (see Figure 3, number 3). This small screen can be connected to the main module in order to display additional and contextual relevant information to the user. For example, "the computer is booting up, please wait" or "you have received mail".
- M7) *Notification ambient light* (see Figure 2). In addition to the small LCD display, this small ambient light can be used to point the users to important and recent events, for example, new mail messages.

From a software perspective, the peripheral components of Infobricks like the input bars (M3) were powered by Arduino. The Infobricks main module was developed in Android, using a custom ROM provided by Hardwarekernel. In addition, we implemented a lean web application to provide the users (e.g., friends of the owner of the accessible DIY-computer) with a gateway for pushing custom content to the main module (e.g., photos or custom audio messages). In more detail, Infobricks offers the following software applications, which are primarily hosted by the main module:

- S1) *Android 4.4* including regular applications that ship with this operating system. However, we deactivated Android's typical navigation bar featuring home- and back button, as we found that it was hard to handle for many senior users. Instead, in the Infobricks system, home and back button events can be triggered using the input bars (M3) or a keyboard (M2). To accomplish this or other behaviour, the users can use the configurator app (S2) for customization.
- S2) *Configurator app* (Android) and *configurator web app*. These applications are used for customizing the system. Please note the paragraph below, where we further detail to what extent Infobricks supports adaptations.
- S3) *Photo app*. This application can automatically receive photos including photo captions that are sent to Infobricks by a corresponding smartphone app or uploaded using a web app. These received images are then presented on the main module as if it was a digital photo frame. The users can also browse all images sent to the device so far. Thus, this photo app constitutes a gateway for receiving greetings from family and friends in the shape of digital images.
- S4) The *conversation app* is a simplified e-mail client or chat application that allows the users to exchange text messages in an easy way. It is designed to offer simple interactions compared with a regular e-mail client. Messages can only be sent to predefined users, who can reply using a web application (see configurator web app).
- S5) *Video tutorials app*. This application constitutes a 'video gallery', that is, users can use this app to assemble a collection of (self-made) videos or tutorials. These videos can then be played, for example, by a senior citizen for whom the Infobricks system was set up.
- S6) The *search app* provides the users with a simplified interface for conducting searches on the web.

- S7) *Need help app*. This is a simple yet powerful application that captures a screenshot of the current view of the main module on the touch of a button. This screenshot is then automatically sent to a contact person who can use the image to understand and explain better where the Infobrick user got confused using the system.

Customization.

The individual applications and features described above allow a number of adaptations to the system, and in fact, the underlying motivation of Infobricks was to provide a DIY-computer that is easy to customize and set up to meet people's individual needs. The backbone of this functionality is Infobrick's extendibility via USB or Bluetooth and two configurator applications as described next.

Configurator web app (S2) can be accessed with a conventional browser, and it is used to upload custom screens, audio recordings, text messages and videos to the main module (M1/S1). For example, the user can create and upload a custom start screen to be shown on boot-up together with a welcome text message displayed on the small LCD screen. At the same time, a custom audio recording is welcoming the user and giving instructions or hints for how to operate the system. The web app is also employed for sending texts and URLs to the conversation app (S4) and images to the photo app (S3).

The *configurator app* (S2) is run directly on the main module and thus implemented in Android. It's primary purpose is to assign different functions to different buttons and RFID tags, given the corresponding modules are connected to the system. In addition, it can be used to set or enable/disable basic functionality like the e-mail address of the primary contact person, who receives messages from the need help app (S7).

The script displayed below was taken from the configurator app. By editing lines of script/code on the main module (using a text editor app), the user can program specific system behaviour. In the below example, the first button of the input bar (M3) is programmed to open the Google search engine in the browser app. At the touch of this button, the small LCD (M6) will be first cleared and then a prompt is printed in order to assist the user in operating the computer. The second line of script sets the second button of the bar to open the e-mail app (S4). The third line of script causes the ambient light module (M7) to blink, whenever the photo app (S3) receives a new image. At the same time, notification sound "tamtam.mp3" is played.

```
BUTTON:pressed1|URL:www.google.com|LCD:
clear|LCD:Please enter query|LIGHTS:off|
```

```
BUTTON:pressed2|APP:email|LCD:clear|LCD:T
his is your email account|LIGHTS:off|
```

```
EVENT:newphoto|LCD:clear|LCD:You have
received a new photo!| LIGHTS:blink|
SOUND:tamtam.mp3|
```

Besides the components described above, the Infobricks Starter Kit included an additional package with utensils to support the user in customizing their system (see Figure 4). This extra package was also provided to P7, who we invited to make use of Infobricks in her home, as described in the next section.

4.3 Results III "Lived Scenario" Featuring P7/P8

As a final step of our investigations, we wanted to take a look at how Infobricks would be employed to assemble a customized and accessible computer in a natural setting. Thus, the following section may be read as a "lived scenario" which illustrates the kit in use. To come to the point first, Infobricks was used to create a DIY-computer shaped like P8's favourite pet, a dog.

While we expected P7, perhaps, to paint Infobricks and the keyboard in different colours in order to facilitate usage, or make some modifications to the casings even, we were surprised by the extent to which P7 made adaptations to the form factor of the system.

Being a big-time dog lover (both P7 and P8), P7 reworked Infobricks into the sculpture of a dog resting on his legs (see Figure 5). In line with this design concept, the keyboard was 'placed on a meadow' (made of cardboard) together with 'feeding bowls' functioning as pencil holders (see Figure 6).

We go on to report the user experience from P7's as well as P8's perspective.

Feedback from P7 about Infobricks

P7 appreciated the concept of Infobricks:

"I love the idea. A kit like this empowers me to help my mother ... Actually, I was never a big help with technology. All I could do so far was assisting her in buying a good remote control for the TV."

Moreover, as a tinkerer, she enjoyed the process of building the device (captured in Figure 6), and P7 repeatedly stated that she was highly motivated by "the neat toolkit" to build the system for her mother.

She decided to keep the system relatively simple and selected the main module, a key bar, a speaker, the keyboard, and the small LCD display to be incorporated into her computer. P7 also integrated the RFID reader module into her concept, as this allowed her (if needed) to extend the system by a (theoretically unlimited) number of RFID tags representing URLs to be opened or other actions to be triggered on the computer.



Figure 4: Left: The Infobricks Starter Kit also included one package with utensils (U) in addition to the box with the computer modules (M) as previously introduced in Figure 3. These utensils enable the user to further customize their Infobricks Kit. They entail a hot clue gun (H), air-drying modelling compound, different colours and brushes (C), and blank wooden labels (L). Right: Wooden keyboard as included in the Starter Kit painted with different colours to support the user while typing.

After a discussion with her mother P8, she assigned the following functions and apps to the hardware keys of the bar: *go to home screen, go back, shut down, weather forecast* for the hometown of P8 and other locations where her family lives, *search engine, e-mail, photo app, phone book/contacts*.

Regarding the user experience of assembling Infobricks, P7 stated that she could handle the software configuration, but she preferred more comfortable configuration tools such as a “setup-wizard”, since P7 was “not a computer person” (P7). In addition, she was encouraging us to build smaller modules for the next iteration of Infobricks to be able to design “refined sculptures”.

Feedback from P8 about Infobricks

While a detailed evaluation of the ‘dog-computer’ is out of scope of this article and P8 has only used the system for two weeks to date, we still want to conclude this findings section with feedback by P8.

P8 was very pleased by her ‘dog-computer’. This was due to her appreciation of the effort that P7 invested into its design, but she also enjoyed the way it looked and integrated into her home office. Not less importantly, she was very satisfied with the usability of the device:

“This computer makes using a range of useful programs very easy ... I feel confident using the device.” (P8)

Over the course of the first two weeks, P7 and P8 informally evaluated the ‘dog-computer’, similar to a professional HCI researcher who conducts an assessment of a system. Based on this evaluation, in the near future, they plan to readjust the programming of the keyboard bar, as some keys are currently rarely used, and other apps/shortcuts are needed more urgently:

“The good thing is, that I can react immediately if my mother is not happy with the functions. I

simply reconfigure the buttons or make a new [RFID] tag. ... With conventional devices this always led to frustration, because we couldn’t solve the problem on our own. We had to find a really skilled person or buy a new device. ... With this computer, on the other hand, we can fix it, make it even better, and enjoy this activity at the same time.” (P7)

5. DISCUSSION

In this paper, we have introduced Infobricks, a new type of accessible computer, which is characterized by its high degree of customizability. It can be seen as an ‘unfinished’ set of building bricks that have to be assembled in a meaningful order by the maker or user. Hence, it contributes to the literature about computers for older users, but also to the research about how the constructive energy of makers can be drawn on to accomplish exciting things.

The concept for and specification of Infobricks has been carefully established with the help of six makers. Rather than stopping at this point and summarizing the ‘implications for design’, the paper further presented a fully implemented prototype for Infobricks as an embodiment or additional representation of the gained design insights.

In the “lived scenario”, we have seen how Infobricks could successfully be employed to empower both P7 and P8 with technology. While P7 enjoyed the process and having access to higher-level technological tools (the Infobricks system), P8 felt empowered, because she now had access to an easy to use Internet computer. Hence, we can reconfirm the observation by Hurst and Tobias (2011) that DIY-assistive technology can be a useful means to empower novices and non-engineers. This close relationship between *making* and *empowerment* was reported in the literature before (Grimme, Bardzell, & Bardzell 2014).

In the case of Infobricks and the ‘dog-computer’ as created by P7 and P8, accessibility was facilitated by allowing the participants to choose between different hardware and software components as they thought they were appropriate. With regard to hardware elements, they could even modify these components to a larger extent, for example, by painting the buttons or incorporating everyday objects using RFID tokens and stickers. The software elements could not be customized to the same extent, however, P7 and P8 could choose between built-in Android applications and simplified software functions provided by Infobricks such as a the search app (S6) or need help app (S7).

As outlined by Hurst and Tobias (2011), control over design elements and passion are seen as important facilitators in the design of successful DIY-devices. This we also found in the interviews of part A. Our interview participants stressed on

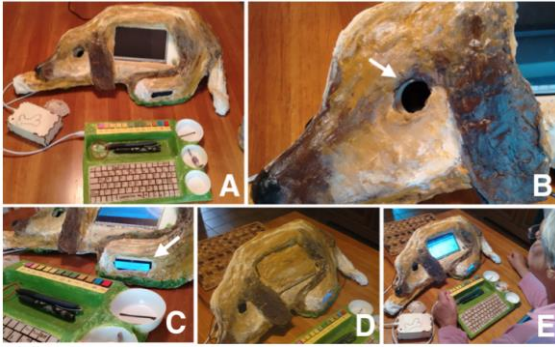


Figure 5: Finished DIY-computer as designed by P7 and co-designed by P8, and assembled by P7. The concept of this computer was to embed Infobricks in a dog's sculpture since both P8 and P7 were huge dog lovers. Image (A) shows the setup comprised of main computer (dog), keyboard, and optional RFID reader. As displayed in image (B), P7 used the speaker module to create the dog's eye (marked with an arrow). This design feature also led to a satisfying audio experience. Image (C) marks a small LCD feedback display with an arrow, which is embedded in the dog's leg. As visible in image (D), P7 created an optional cover for the screen when the computer is not in use. (E) shows P8 using her new and accessible DIY-computer in the shape of a dog.

multiple instances that being able to customize and modify the components was very important for them. We even observed passion, during the field deployment, when P7 created her own 'dog-computer'.

Phillips and Zhao (1993) identified reasons for the abandonment of conventional assistive technologies (cf. related work section). Crucial factors were the lack of user involvement in device selection and the ease in obtaining appropriate devices. We argue that, in the case of Infobricks, these factors are less likely to become relevant. In fact, user involvement (P7 created the system for and with P8) is one of Infobricks' strengths, which guaranteed that P8 received the device she wanted. In addition to a lack of involvement, a change in abilities and preferences can lead to



Figure 6: Keyboard with quick access buttons as assembled and photo-documented by P7. (A) Keyboard from Infobricks and three old Tupperware bowls arranged using cardboard and glue. (B) Assigning functions to the quick access buttons and deciding the colouring. (C and D) Finished keyboard with storage area for pens and paper clips etc.

dissatisfaction (Phillips & Zhao 1993). As stated by P2, a system like Infobricks can dynamically take these issues into account by its "plasticity". Other important reported factors such as the aesthetics (Hook et al. 2014) were also in direct control of the users or makers of Infobricks. Interestingly, in the study on hand, none of the participants commented on the time that customizing an accessible computer would demand. Perhaps, time is not a very relevant factor to a community of 'enthusiasts' (Dougherty 2012).

6. CONCLUSION AND FUTURE WORK

In this article, we presented the design process of Infobricks, beginning with requirements gathering, showcasing the finished prototype, and illustrating its use within a field deployment ("lived scenario").

The motivation of Infobricks was to provide makers and interested tinkerers with a toolkit that empowers them to create their own DIY-computers. In particular, Infobricks was conceived as a tool for building accessible computers to support users with special needs in accessing services such as Internet computing. To date, to the best of our knowledge, no such highly modular and customizable device has been investigated in the context of *making* computers for older users.

The input that we obtained from the makers to inform the design of Infobricks proved valuable, as it both revealed interesting insights regarding such maker systems/tools and because Infobricks was well received in the "lived scenario" we presented.

In summary, drawing on the power of maker-enthusiasm, Infobricks demonstrated a lot of potential, and there seems to be plenty of angles to this concept that deserve further explorations.

As next steps, we want to study over an appropriate duration of time and with multiple participants, to what extent users with special requirements or needs, e.g., an older user like P8, can benefit from the assembled computer. That is, we want to evaluate accessibility *per se* and thoroughly (out of scope for this paper). Finally, as the participants in this study have suggested, it might be interesting to look into other domains besides *maker-made* accessible computers, e.g., introducing Infobricks as an educational tool (P2) or letting older users create their own computers (P3), instead of delegating this task to younger makers.

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