Participatory Design Approach to Internet of Things: Co-designing a Smart Shower for and with People with Disabilities

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Abstract. Smart home products are becoming widespread aiming to increase people's independence, especially for the elderly and people with disabilities. In order to design them suitably for this community, their involvement in the requirement gathering and design process is particularly important. In this paper, we report a study we conducted with six people having various disabilities. The aim was to identify the type of smart product that mostly increases their independence at home. We used three requirement gathering methods in a participatory fashion, namely, cartographic mapping, future workshop, and cultural probe. The outcome of the study revealed that participants mostly needed a product for a bathroom, specifically a smart shower. The initial prototype design of the product was developed together with participants. Researchers further investigated the prototype design using littleBits electronic modules. The smart shower is anticipated to have the most effect in increasing not only user independence, but also privacy.

Keywords: Cartographic mapping · Future workshop · Cultural probe Prototyping · Participatory design · LittleBits · Smart home · Internet of Things Disability · Elderly

1 Introduction and Background

The quality of life is steadily improving leading to an increase in life expectancy, which will result in the number of the elderly rising in the coming years. Demographers predict that the number of the elderly will increase to 30% by 2060, compared to 17% in 2009 [1]. Surveys show that 80% of the current elderly people suffer from at least one chronic disease [2]. In addition, the World Health Organization reports that 15% of world's population lives with some sort of disability [3], 3.8% of whom are people over 15 years old with considerable physical movement challenges. This trend shows that it will be difficult for this community to independently live alone.

The technology has the potential to help such community to increase or maintain their independence [4]. By using mobile technology and wireless integration, the cost of care for the elderly and people with disabilities can be reduced [5, 6]. Examples of such developments are many. For instance, there are systems developed that enable

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users to urgently communicate with their healthcare provider using pre-recorded audio messages that can be easily activated using a mobile device interface [7]. Since the elderly typically suffer from health issues due to their age, health care providers monitor their real-time condition using wearable technologies [8, 9].

According to Pew Research, 83% of experts claim that by 2025, Internet of Things (IoT) will be ubiquitous and positively affect people's everyday life [10]. The advantage of using IoT is their ability to communicate with one another to orchestrate and address user needs in a smooth manner, contributing to enhancing productivity and ease of life [11]. The proliferation of IoT devices has potential to help the elderly and people with disabilities to continue living independently in their preferred environment, such as, their home. Moreover, research shows that the transition from home to the health care facilities may cause increase in anxiety for the elderly and people with disabilities [12].

Examples of using IoT to help the everyday lives of the elderly and people with disabilities include medication reminder devices that help patients keep track of their pill taking routines [13]. In scenarios with blind people, an IoT-based indoor navigation is helping such users to easily find their way throughout large building facilities, which is the case with healthcare centers and hospitals [14].

IoT have also been proposed as a requirement gathering methodology to complement traditional methods when access to participants is difficult, such as people with disabilities [15]. Several other studies report a type of participatory design where participant requirements are collected by using sensors that passively collect data from an elderly person [16, 17]. Gkouskos and Burgos [18] have observed a difference between how participatory approaches differ depending on the field. The design fields have long tradition of participatory approaches and hence involve people through traditional methods, such as workshops, testing probes, and prototyping. On the other hand, health and engineering fields typically rely on technology-based user participation for data gathering, which has gained more importance with the introduction of IoT. In any case, extensive research shows that user participation helps build better usable systems [19]. Because of that, there are studies within the field of Ambient Assisted Living (AAL) that use participatory development approach for their solutions [19, 20]. Many other studies report the use of participatory approaches by involving primary users, caregivers [21], psychiatric patients [22], and the use of an interactive dollhouse for residential monitoring [23].

To make use of IoT and understand how those can benefit the elderly and people with disabilities, in this paper we report a study that we conducted following a participatory design approach. Our aim was to understand the everyday tasks and experiences at home of the elderly and people with disabilities in order to understand their needs. Especially, we wanted to explore how IoT devices could make people's lives easier, comfortable and more independent.

In order to identify common needs of our potential users, the requirements gathering was done by using various participatory design methods, such as, cartographic mapping, cultural probes, future workshop and prototyping. Participants' highest needs were linked to bathroom and kitchen activities. We focused on the bathroom scenario considering the importance of privacy related to activities typically conducted in such setting. This, likely also has a greater impact in user's independence.

2 Participatory Design

The application domain of IoT is evolving, but it is still dominated by a technical focus. Koreshoff et al. [24:365] discuss how HCI can be more deeply engaged in IoT "to ensure that people, their particular needs, contexts, situatedness and interests" are included in IoT. To bridge the gap between a technical orientation and human-oriented approaches, they argue that Participatory Design (PD) as a design approach can include human-centred concerns to IoT [24]. Following this suggestion, we included PD to give space to persons with impairments and to their wishes and demands to facilitate their everyday lives using digital services (IoT applications). Hence, the project revolved around PD values such as co-design, participation, cooperation and situatedness [25]. Therefore, we used three different participative methods to involve participants in co-design sessions: cartographic mappings, future workshop, and cultural probe. In total, six participants were involved in several of the methods, but not in all. Table 1 gives an overview of the methods in which each participant took part, along with other details, such as, age, gender and the type of disability.

Table 1. List of participants

Participant	Age	Gender	Type of disability	Participation session
A	30	Male	Paraplegic	Cartography, probes, future workshop, prototyping (paper, GUI)
B	40	Male	Paraplegic	Cartography, probes, future workshop, prototyping (paper, GUI)
C	20	Female	Paraplegic	Probes
D	87	Female	Arthritis, paralyzed	Cartography
E	33	Female	Cognitive, paraplegic	Future workshop, prototyping (paper, GUI)
F	28	Male	Blind, paraplegic	Probes, future workshop

2.1 Cartographic Mappings

Cartographic mapping is a participative method to visualize people's activities and doings in their everyday lives. The method is simple and does not demand any preparations in advance. By using only materials familiar to all, such as images, paper, post-it notes, and pencils, participants are encouraged to start telling their stories and to visualize their experiences and wishes [26, 27]. Two sessions, involving three persons with physical impairment (refer to Table 1), were conducted in two different ways; one participant via skype and two other participants in a face-to-face group meeting.

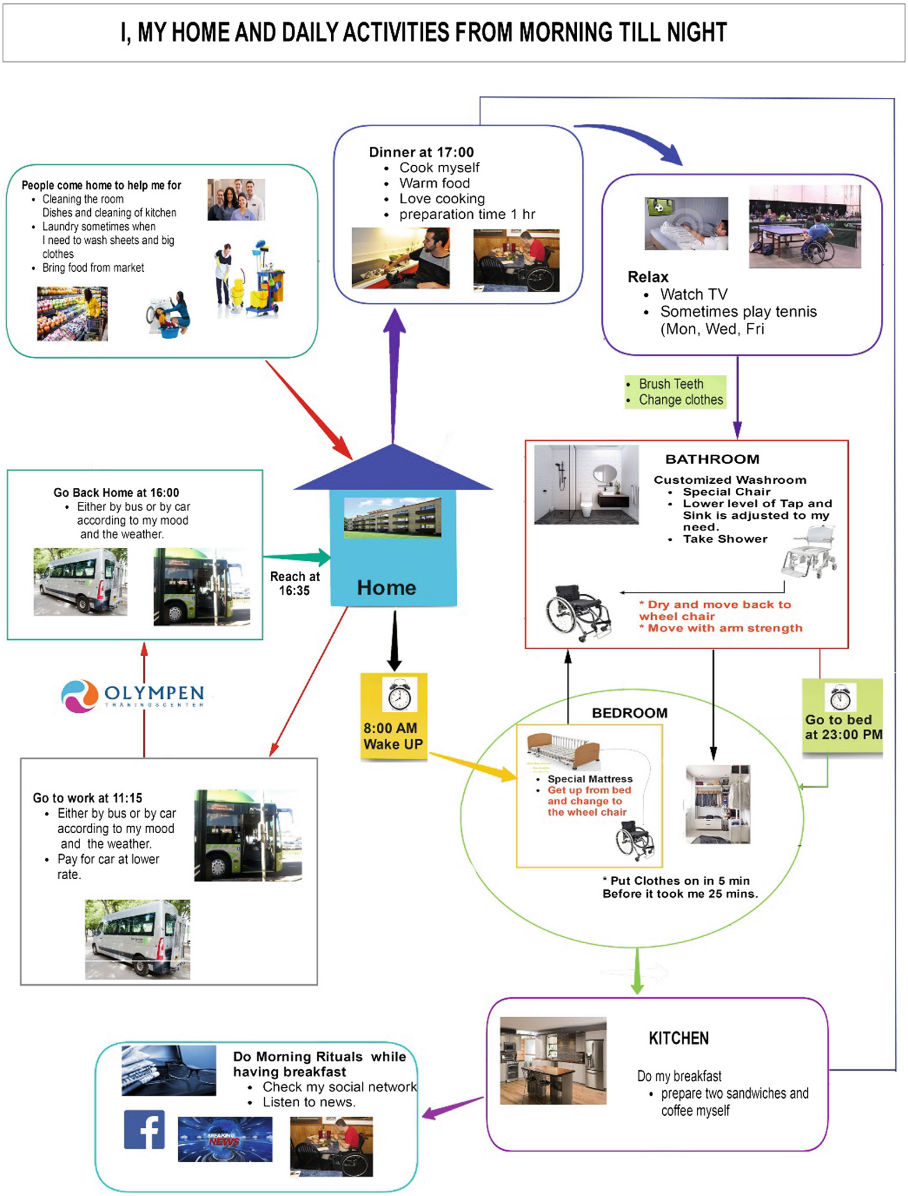

Fig. 1. Whiteboard activities with one participant.

The activities were titled "I, my home and daily activities from morning till night". Sessions started with a welcome note and introduction of the researchers. Participants were briefed about the method, its title, the aim, the procedure, and its limitations. Considering the physical state of the participants, as two of them were on a wheelchair, we used the RealtimeBoard [28] application instead of tangible cards. This helped minimise participants' physical moves, save time, and prevent them from getting tired. RealtimeBoard is a simple and graphical way to organize cartographic mappings from investigation and brainstorming to visualization and examination.

During the sessions, participants were encouraged to elaborate on and visualize their daily home activities from the time they wake up until they go to sleep. While participants told their experiences, the researchers noted those activities using a whiteboard (within the RealBoard application). This whiteboard was then used by participants to enrich the identified activities using images and shapes. In cases when it was not easy or quick to find an image, researchers assisted the participants. Each session lasted approximately 1 h and 30 min. Figure 1 depicts the whiteboard generated with one participant.

2.2 Future Workshop

The future workshop represents a multiple phase method, which involves participants to develop plans for a possible future [29]. The development of ideas goes through four phases: preparation, critique, fantasy, and realization. According to Bødker et al. [30], by involving and engaging the participants in these phases, multiple ideas and different suggestions quickly emerge, which are then considered by researchers and participants.

Four participants took part in this method, three were paraplegic, one was also blind who performed the workshop with the help of a care assistant. As part of the preparation phase, the theme and method were presented to participants in a welcome atmosphere in order to conduct collaborative approach with adequate transparency to explore participants thoughts. Then, the board was separated in 3 columns corresponding to the next three phases.

Within the critique phase, the discussions led towards the investigation of problems related to current situation of participants. Keywords of issues identified were written and pasted on post-it sticky notes on the appropriate column to be visible for all participants (see Fig. 2).

Based on priorities stated by the participants, the post-it notes were grouped in order to develop possible suggestions. These suggestions were then written down and prioritized based on the participants' wishes. In the fantasy phase, these suggestions were reviewed and discussed, while in the realization phase those were discussed for possible implementation. The workshop completed in approximately 2 h (30 min for each phase) and finalized with 15 min concluding discussion.

Fig. 2. Future workshop post-it sticky notes.

2.3 Cultural Probes

Cultural Probes can be defined as ‘*collections of evocative tasks meant to elicit inspirational responses from people*’ [31:53, [32]. This method helps in understanding and gathering rich information about a setting or situation by user participation [33]. It was also chosen because access to homes of participants with disabilities was not possible.

For this method, four participants (refer to Table 1) were involved. In a period of two weeks the probes method was completed including delivering and collection of packages. The probe package contained task cards and few reminiscent images about daily activities at home. The packages were personally delivered to and collected from three participants, and emailed to the fourth person. Also, a short introduction stating ‘this kit is a way to get to know your needs better’ was given before handing over the probe kit.

The probe package was designed keeping in mind the common interests and constraints to support various needs of participants with disabilities so that they could give inspirational suggestions within the comfort of their homes. Simple instructive words were used on the task cards to enable participants understand and complete the tasks without researcher’s guidance. Task cards also included images to allow participants enough space and possibilities when providing suggestions. The materials were in English based on the preference stated by participants when consent was received.

In total, there were seven inspirational task cards along with seven images portraying all rooms that a typical apartment has. The tasks contained daily activities that are typical for a home setting. Participants were supposed to look at each image and write answers at the back of the card (Fig. 3).

Fig. 3. Cultural probe inspirational cards.

3 Lessons Learned

The outcome from the three participatory design sessions revealed that participants priorities and needs were related to bathroom and kitchen. Initially, the use of cartographic mappings enabled us in a co-design fashion together with participants to restructure the study and learn how to systematically map and understand participant's activities. The analysis of the activities revealed that despite all participants being on a wheelchair and having the same daily routine, they handled them in different ways. For instance, one participant takes off his shoes and socks himself while the other one needs help.

The future workshop revealed and demonstrated many issues participants had related to physical activities, such as, opening and closing a door, clipping the nails, brushing teeth, and putting shoes on and off. In the kitchen, the position and location of different equipment and objects presented a problem. For instance, the height of cupboards and fridge shelves were not suitable for participants that use a wheelchair. Activities related to cooking were also found difficult for participants, such as, stoves and other food preparation devices. In the bathroom, participants noted that showering demanded immense effort. Particularly, issues were related to shower seat, shower jet adjustment, control of temperature and water pressure, and moving from the wheelchair to the shower seat. When participants took a shower alone, often they felt the need to contact an assistant to help them with reaching the shower head or the soap. Since typically they did not bring their phone in the shower cabin or simply forgot to do so, often they were forced to move out of the shower, to put clothes on, and use the wheelchair to reach for the phone. All these issues made participants tired when taking a shower.

The probe method revealed the difficulties participants faced during their everyday chores at home. It provided rich data, which helped us understand how participants moved around the house, and what were the key areas that they needed most assistance. Several different ideas and opinions emerged after the analysis of responses on the images. For instance, one participant stated that he felt most comfortable in his bedroom, however he was not happy with his wardrobe as he faced problems when reaching the clothes because the closet was not customized or adjusted to his height.

This method formed a basis and helped researchers to narrow the collection of ideas received from analysis of all methods leading towards creating a smart device for the people with disabilities. It also aided the researchers to get acquainted with the homes of participants and provide a rich picture to inspire the design of a device.

Ultimately, a smart shower, smart refrigerator, and a smart oven were three proposed devices after conducting the participatory methods. Based on various aspects, such as feasibility of the production, processes and the cost of the device, the smart shower device was mutually chosen by researchers and participants. Considering the cost aspect for instance, the device is likely to have an overall lower cost compared to other proposed devices, due to their complexity features.

4 Prototype Development

Following the requirements gathering phase using three participatory design methods, we were ready to explore and design the product that our participants mostly preferred. We continued to involve participants in the design of initial prototypes; we used three participants that also participated in requirements gathering methods [33] (refer to Table 1). The prototype design went through three phases; (1) paper prototype using sketching, (2) digital prototype using Photoshop PS6, and (3) an advanced prototype using littleBits [35]. Participants were involved only in the first two phases.

4.1 Paper Prototype

Taking in consideration the participants' physical disabilities and special needs, we found that the use of paper prototyping should be an appropriate and easy way to make a prototype in a short time frame [34]. Additionally, Lowgreen and Stolterman [36] argue that using low tech prototypes helps to generate more comments and discussions, since participants get the impression that they can contribute easily to an early stage prototype rather than a refined version. The prototype was created using white papers, coloured pencils, markers, eraser, ruler, scissor and tape. With the paper prototype, participants were able to envision their original ideas about the design of the device and customize it according to their wishes and demands.

Initially, participants were informed about the overall purpose of this workshop and the goals to be met. In previous sessions, we had decided about designing a smart shower, while now we started by brainstorming of ideas on how to design the smart shower. Device options, such as, buttons, screen, mic, speaker, colours, were discussed. We then proceeded in discussing the physical aspects of the device including its size, shape, and placement of the device in a bathroom. Although participants had no sensory disability, such as, sight and hearing, they were reminded that the device should also be used by people with such disability.

With the occasional help from researchers or facilitators, participants started to cut the white papers in different sizes that they imagined the device size. The participants were asked to think about the key features to be placed on the device. Various features were suggested and the most important ones were decided, which included the water temperature control, pressure control, and the assist alert button. One participant stated that "*the shape of the buttons for every function should be different to make it easier to find and work with*". Hence, the buttons were designed to have distinctive shape, colour, and dimension in order to be accessible and usable by people with visual impairment. Other features, such as, voice interaction and language options, were discussed to be important to be included into the design. The design process with participants took approximately one hour. In the days that followed, researchers refined the paper prototype and it finally looked as in Fig. 4.

Fig. 4. Final paper prototype.

4.2 Graphical User Interface Prototype

A week after the paper prototype session, the same participants were invited again to take part in designing a digital prototype. The session started by showing them the improved paper prototype, to confirm their vision. Participants continued to discuss and provide their suggestions, while two researchers implemented those on a computer using the Photoshop PS6 application. Besides providing enhancements regarding its look and feel, the digital prototype also was used to explore how the device would be used.

The device is envisioned to be operated using two interaction modes; by pressing the buttons or by voice commands. The device is turned on when the user sits on the washing chair, which activates the pressure sensor. A blue light then comes out from the device along with a greeting message. By pressing the Start Shower button, the water will start pouring and a voice feedback is heard stating “Shower is On”. The user then can adjust the water temperature and pressure either by pressing the appropriate buttons or using voice commands. The device is paired with care assistant’s mobile phone, which notifies her via a text message that the person is in the shower. This will keep the assistant aware in case the user needs any help. If such cases arise, the user presses the alert button, which sends a message to the care assistant stating “I need your help”. The response from the care assistant is displayed on the device screen along with a voice message coming out of the speaker. If the alert button is pressed once, a message is sent; if it is pressed twice, a call will be initiated to care assistant’s mobile phone (Fig. 5).

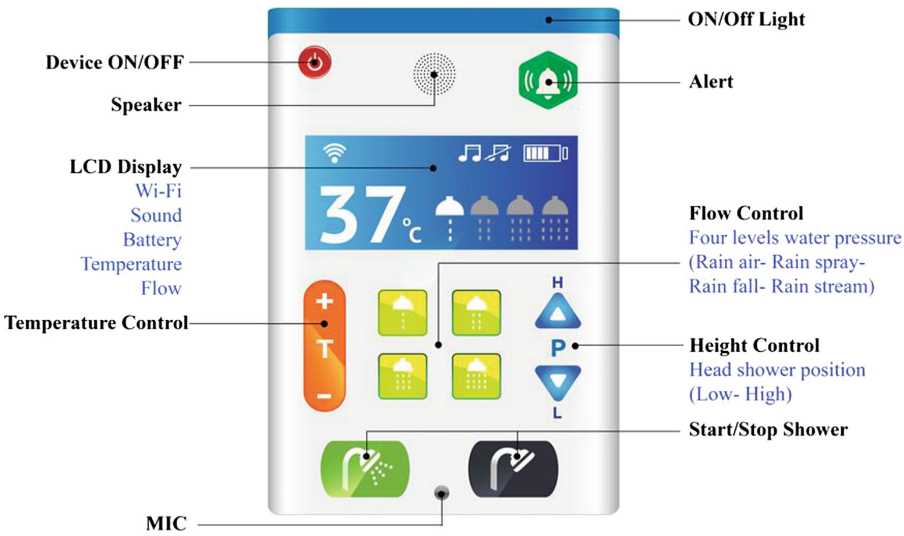

Fig. 5. Finalized digital prototype of device.

Other relevant buttons are also designed on the device that provide several functionalities. The position of the shower head can be adjusted using triangle shaped buttons labelled with letters “H” and “L” for high and low, respectively. The temperature control button is denoted by “T” and “+” and “−” can be used to increase or decrease the water temperature respectively. At the center of the device, four squared buttons are placed to regulate the typology of the water flow. Besides the speaker that provides auditory feedback, the device also has a display to show the temperature degrees, jet flow type, battery level, Wi-Fi connection, and music on/off.

Lastly, the shower can be turned off by pressing the dark grey button with head shower icon on the bottom. This will stop the water flow and an audio feedback is heard from the speaker stating ‘Shower is Off, Thank You!’. At the same time, the care assistant is notified via a text message.

4.3 Prototype Using LittleBits

Considering the hardware aspects of the smart shower, such as pressure and temperature sensors, we explored the idea of enriching the prototype using electronic building blocks called littleBits [35]. These electronic components are attached together in order to perform a function. To illustrate it simply, for instance, a component with a button could be attached to another component with a light, and a simple function could be that the light will turn on, when the button is pressed.

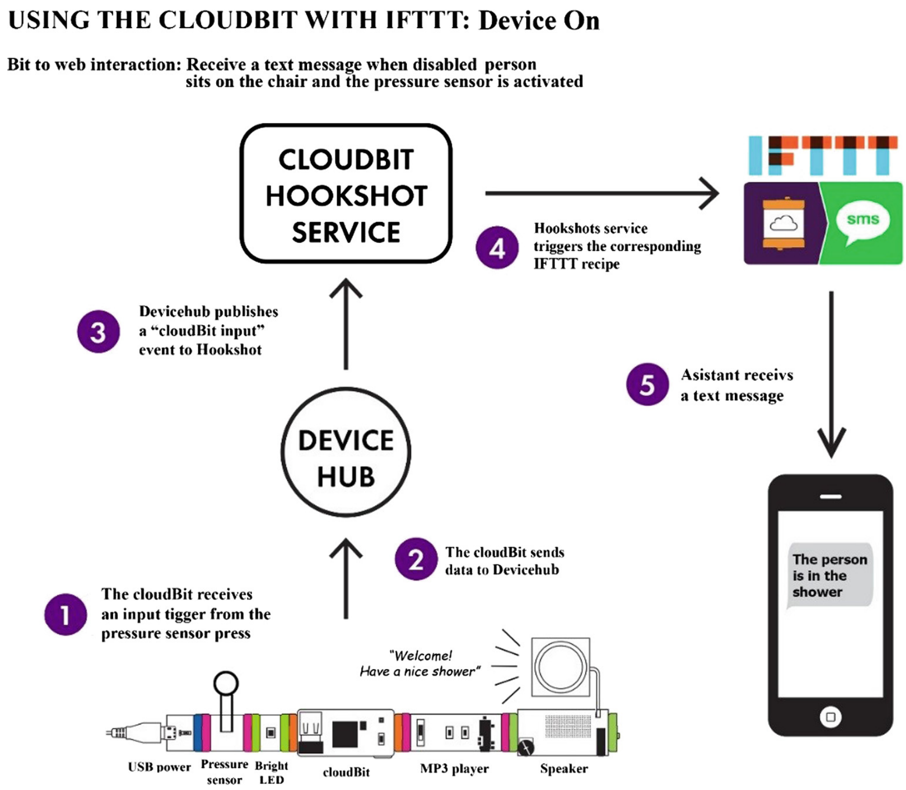

Fig. 6. IFTTT, sending message to a care assistant when the device turns on.

For the prototype, two services, Devicehub and Hookshot, are used to connect the cloudBit and register the webhooks. The different functions of the prototype are implemented using IFTTT [37] app recipes and the cloudBit. With the help of cloudBit, a wireless enabled module (component), enables the prototype to be connected to the internet to perform functions. Once the connection is established, simple "If This Then That" code recipes via the IFTTT app are used to trigger actions that perform various functions. Some of the features of the smart shower device that were developed using the littleBits kit are: turn the device on, simulation of shower on and off, temperature

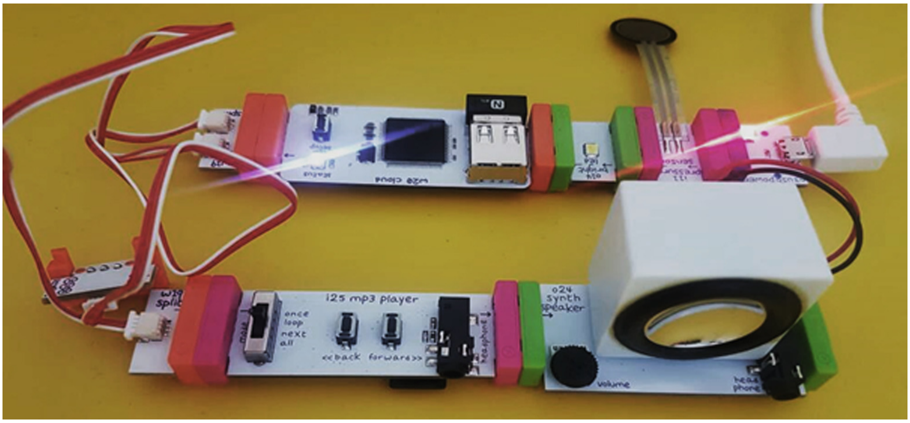

Fig. 7. Device On implementation using littleBits.

display, and alert notification. The IFTTT route of ‘device switched on’ function that sends an alert to a care assistant when a person is in the shower, is illustrated in Fig. 6 and its littleBits prototype is shown in Fig. 7.

During this study, due to limitations and some restrictions of using littleBits, several functions were not implementable like two-way communication using mic, height adjustment, pressure buttons, temperature increase and decreases as well as voice recognition functions.

5 Discussion

The contribution of this study lies in bringing the human-centred design approach to Internet of Things. Involving participants in the requirements gathering methods helped us understand their ways of doing things in their homes. Each requirement gathering method inadvertently served a different role. The cartographic mapping was useful to understand the differences among our participants, even those with the same disability. This indicates that people of similar disabilities should not be treated homogeneously as their wishes and issues might differ. The future workshop provided a full cycle of the design process, from identifying details about the issues, prioritizing among those presented, and all the way to giving suggestions about their implementation. Moreover, using this method, we were able to more accurately pinpoint what activities and in which settings provided most challenge for participants; which was the kitchen and bathroom. Finally, the cultural probes offered a richer context of the issues people faced, perhaps because they had more time to complete it (two weeks) and by asking their comments on the type of activities people conducted in each room of their homes.

Another important aspect that played crucial role when deciding to design a smart shower was the intimate considerations typically related to activities in a bathroom. According to Finken and Mörtberg [38:315], Beathe, a study participant, says: *“...do I manage to go to the bathroom, and take a shower, do we have toilets that work so*

I can ... the most embarrassing, I think, is being dependent on someone else to help me in the bathroom. It is absolutely the worst thing I know or are you forced to use diapers depending on that care workers cannot help you frequently enough – the most basic need. I think this is really important, one should start here [on basic needs] – other issues will also appear. Certainly, one can focus on other issues but just to start, what do you need, you need food for the day and you need to go to the bathroom and you need ... here I think it is the absolute first and most important [demands], because many [services/technologies] do not exist and the [designers] don't care enough". Thus, designing technological smart devices used in a bathroom to assist people with disability were deemed very important and significant.

An interesting finding from participants' discussions was their contradicting views about technology, some were interested in using smart devices and some were reluctant. The image of a smart house presented to participants during the probes method, raised many ideas and concerns about the usage of smart devices, which inspired them to brainstorm on how different technologies can assist in their daily life. However, one person expressed concerns that the usage of technology will make them lazy and the body inactivity will lead to serious health problems.

5.1 Ethical Considerations

This study required direct contact with participants for most of its activities. To respect participants privacy and inform them of the purpose of the study and their activities before they could participate, they were asked for a consent. Indeed, the consent was twice obtained from participants; first for agreeing to participate in the requirement gathering and prototyping sessions, and second for agreeing to write and publish this paper, albeit using only anonymised data.

The other privacy concern related to the smart shower device is its transmission of data. Although the device is only envisioned to communicate with a care assistant or a family member, its ability to connect to the Internet, makes it prone to attacks and revelation of sensitive data of the users involved. In general, the privacy and security issues related to Internet of Things are an important challenge nowadays and consequently a subject of intense research. With advances in the field, these concerns will be mitigated and the Internet of Things devices within the smart house eco-system will become more prevalent.

6 Conclusion

In this paper we report a study we conducted with six people with various disabilities in order to identify the type of smart product they judge most likely to increase their independence at home. Using three requirement gathering methods, cartographic mappings, future workshop, and cultural probe, we learned from our participants that a smart shower would be a product of their choice. This product will increase their independence, privacy, and it will be the most feasible for production.

Using two stages of prototyping, namely, paper prototyping and later graphical prototyping, participants together with researchers developed the features of the smart shower. The main features included, the ability to change the water temperature, water flow, shower head position, and an automatic alert delivered to a care assistant when the shower is in use. Finally, researchers have investigated the use of littleBits electronic modules to build a more advanced prototype. Due to the limitations of the littleBits, however, not all features were implemented.

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