Older People Inventing their Personal Internet of Things with the IoT Un-Kit Experience

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ABSTRACT

We introduce the IoT Un-Kit Experience, a co-design approach that engages people in exploring, designing and generating personally meaningful IoT applications and that also serves as a means to explore IoT kit design through in-home workshops. Un-Kit represents a seemingly uncompleted set of sensors, actuators and media elements that have a decontextualized appearance - *un*finished state, *un*defined purpose and *un*boxed form. The approach emphasises users contemplating and experiencing the IoT elements in their familiar space through detailed and layered conversation with researchers; rather than focusing on connecting up the kit itself, thus their ideas are not constrained by the kit or their competence with it. We illustrate the approach through in-home workshops with older adults, envisioned users of IoT who have had limited voice in its conception. The Un-kit approach supported participants to lead the process and to imagine new artfully integrated designs, with personally legible interactions and aesthetic qualities that fit their desire. We offer insights for a more situated and responsive approach to design of the IoT and its constituent kits.

CCS CONCEPTS

• **Human-centered computing** → **Field Studies;** *Design Method; Co-Design.*

KEYWORDS

Internet of Things; IoT; toolkit; co-design; situated; older adults.

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1 INTRODUCTION

We present the Internet of Things (IoT) Un-Kit Experience, a co-design approach that actively engages people in exploring, designing and generating personally meaningful IoT applications in their own space through the use of different IoT elements. Un-Kit signifies the approach's utilisation of a seemingly *un*completed or *un*finished set of IoT components of sensors (e.g. pressure or temperature), actuators (e.g. light or motor) and media elements (e.g. speaker or display) without established connections; that have *un*defined purpose as the lack of connectors leaves open to interpretation what the combination of elements could be; and that are intentionally offered in a raw and *un*boxed form with a simple fabric cover that more or less adopts the shape of the electronic component, while making it easy and non-confronting to handle (Fig. 1).

Figure 1: (L) The Un-Kit IoT elements and (R) the in-home co-design using the IoT Un-Kit Experience.

To describe the IoT elements and possible connection between them, cards were used to represent people (neighbours, relatives, friends) and senses (sight, touch, hearing). The approach involves using the Un-Kit IoT elements and cards in in-situ workshops in people's homes in a collaborative and dynamic engagement between researchers and participants. The research team uses the IoT elements to materialise the participant's idea

in a rapid prototyping process, with the participant guiding the design, personally interpreting and contextualizing the IoT design in their own intimate space, generating situated and specific design ideas in situ. The IoT Un-Kit elements' open-ended purpose and malleable form support this process. Our aim is to understand the forms and kinds of interactions people imagine for a personal IoT through exploration of ideas for sensing and actuation in the context of relationships, embodied experience and place.

Most making with toolkits focuses users on what is possible with the kit [14,30,35], with users typically taking some time and energy to first get familiar with the kit, which then limits what is possible for a novice user to accomplish in a given timeframe. More importantly, the generative process often assumes that a 'problematisation' has already been done, typically by the researcher, who, like the toolkit, may have been predisposed to address a predefined problem for which the participant is assumed to be motivated to use the kit to create their design solution [58]. This has particular resonance in technology design for older people, whose needs are often oversimplified and typically already framed as overcoming decline of health, cognition and social relations [20,39,56]. We conducted IoT Un-Kit Experience workshops with four younger participants and two older adults in their individual homes. These workshops were part of a larger study on the Social Internet of Things with a broader aim to create technologies that foster social engagement that blends into and enriches peoples' routines with objects that they habitually use [9,13,61]. We illustrate the approach by describing the experiences of the two older participants in response to Roger et al's questions about toolkits for use by older people, "What would it take to create equivalent [stimulating] forms of new output (physical or digital) that could enable people to be even more creative and fire up their imagination? What qualities of new kits might support greater invention?" [56,p.3921]. We argue that the open-ended characteristics of the approach and uncompleted feel of the IoT elements unlocked new avenues in understanding the design and role of personal IoT by focusing on (1) situated passions, (2) relationships, (3) object and environment specificities and (4) orchestration of the approach. We expand upon approaches to design of the IoT and constituent kits by contributing making processes and outcomes that people, particularly older people, desire and personally value. The IoT Un-Kit Experience is a responsive approach to the user's context and experiences, and fosters a focus on understanding the design opportunities and goals themselves through a collaborative in-home exploration and in situ facilitated design, rather than an end-user hurriedly completing an undeveloped idea with a kit themselves.

2 BACKGROUND

In this section we present the use of toolkits in design and the different approaches and methods that engage older adults in the discussion of future technologies. We then identify the need for toolkits that support a more personalised and contextual approach to design.

2.1 Kits to Explore, Imagine and Experience Future Technologies and the Internet of Things

Toolkits are sets of various components built for non-designers in order for them to participate in the making of design artefacts [59]. Fischer [23] envisaged that kits could allow us to replace human - computer communication with human-problem-domain communication, allowing kit users to work within a kit environment to solve the problems of a domain, without worrying about using a computer. However most kits have struggled to meet Fischer's aspirations to address real-world complexity and tend to address problem domains of smaller scope.

Kits are popular because they can engage people in hands-on technology creation without necessarily having to understand all of its underlying details. The hope is that people can invent new forms of technology such as an IoT that suits their various desires and needs. With this in mind researchers have developed a variety of toolkits and incorporated them into co-design workshops or home trials. Toolkits are often used in the generative phase of design to collaboratively build prototype artefacts [58], however, guided strongly by the tangibility and material affordances of kit parts, users often turn their focus toward what is possible with the kit [14,30,35] rather than thinking about what they really want to design.

A number of kits have been developed to help people think about designing an Internet of Things. Fischer et al [24], using an IoT kit with a screen-based interface for households to gather environment data, found that users undertook situated sensemaking, understanding sensing device readings in relation to the goings-on in the home and the device placement. Cho and Saakes' DIY Toolkit enabled participants to personalise the mapping of sensed environmental data onto moving tangible table-top displays [14]. Physikit, a kit of cube shaped interconnecting devices for interrogating home environmental data [30], was appropriated by users in

their homes, although it was not used in ways far beyond its intended environmental data mapping purpose. The Loaded Dice toolkit, took a similar form, with wirelessly connected cubes embedded with various sensors and actuators designed to explore how visually impaired people could use to IoT devices to explore and solve daily problems [35]. The Dice were useful but gave pause for thought about how the physicality and functionality of kits might both afford and at the same time constrain creativity when one group steered away from the Dice to instead discussing their own bodily and sensory awareness (e.g. knowing it had rained overnight due to feet feeling the wetness of the pavement, a certain scent in the air or hearing melancholic birdsongs). These studies reveal how the qualities and purposes of the toolkit (form, shape, functionalities, modalities, etc.) influence the degree of appropriation that is possible.

Current IoT devices typically utilize small screens and voice input [25], lacking contextual mappings and more tactile, emergent, rich and collaborative qualities of interaction. Use of the cube shape is prevalent in IoT device research because cubes have the affordances of being easily aligned, stacked and produced. This cubic trend suggests opportunities to venture to other shapes to cater to needs that may be missed by cubes [34].

Towards a more personal and accessible approach than the construction of technology from a kit [10,52], Perner-Wilson and Buechley proposed the kit-of-no-parts approach to building electronics from a diverse palette of craft materials and skills [52], such as sewing, knitting and crocheting. They assert that this approach is more personal, understandable and accessible than the construction of technology from a kit of predetermined components, and allows people to exercise their creativity [10,52] by leveraging existing skills. Mellis et al also proposed to break the mould of toolkits by eliminating the need for custom modules, with their Untoolkit approach. Untoolkit utilises conductive ink to draw circuits on paper with electronic components simply stuck onto paper and libraries supporting easy ways to program simple microcontrollers. The approach enmeshes use of electronics and software into strong crafting traditions [43]. Reflecting upon [43,52] and the wide array of toolkits presented in research, Meissner and colleagues [42] argued that these approaches "still frame learning in the traditions of engineering" and that even though they seek to break away from pre-determined components, they are still somewhat limited by "material constraints and a specific modality of guidance". Meissner et al propose Schnittmuster, a meta-toolkit approach motivated by facilitating learning about electronic concepts, material freedom and flexibility. They illustrated the approach in the design of a capacitive touch sensor and then implemented the concept in a variety of different materials and contexts, (including knitting, quilting and glass crafts), illustrating the potential for crafting one's own components to suit the context, while learning about electronic concepts. The approaches in [42,43,52] are very inspiring in the way that they leverage and encourage making skills and conceptual learning through more open-ended conceptualization of kits. Our work draws upon this more open-ended conceptualization of kit components and also shifts the focus towards understanding as inspiration the everyday practices in which IoT elements are envisioned to be embedded. In this regard, kits with predefined forms, functions and connectivity have difficulty in capturing in situ, in-the-moment design ideas of specific situations within the context of the participant's life. Participants in turn struggle to translate the value of the envisioned ideas to a particular context of interfacing them in their own world. Creativity with kits is both enabled and limited by the functionality of components, the confines of form, flexibility in connection, pre-imagined purposes, the skill of the maker and the facilitation of the design process. We seek to navigate these aspects in creating the IoT Unkit Experience.

2.2 Engaging Older People in Design

Generally, older people are expected to benefit from the development of IoT but products and services are typically framed on the 'need' to overcome decline of physiological health, cognition and social relations [3,15,18,21,53] through tracking and monitoring. Very often, older adults are relegated to a role of passive recipients of these technologies, and are not actively involved in their conceptualization and development. In addition, older adults with accumulated life experiences grow more diverse in lifestyle [20,39,56] such that oversimplification of technology design to only addressing decline [68] will fail to capture opportunities [49] that may best enhance older people's lives. With society's negative perception of ageing [11,48,60], there is a common assumption that older people cannot master technology [20], in spite of the fact that they use and master all sorts of technologies every day.

Although there is reluctance by some older people to participate in technology design processes [20,56,71], HCI research has endeavoured to elicit the voice of older

poeple [36] by using co-design methods [45] and by continually involving older people in projects to design new technologies [5,50,56,62] in hands-on ways. Methods have involved experiencing new technology within morning teas [9], using objects as probes [41] such as an interactive dollhouse with home sensors [33], and exploring personal items brought to workshops [36]. While these methods are effective in engaging older adults, researchers have expressed challenges in eliciting design ideas [70]. Co-designing with older people is with the hope of promoting positive ageing [20,39,47,70]. However, as much as positive models of ageing have their advantages in design, they have also been found to amplify negative perceptions and feelings about old age [11] that may also reflect in the design of smart homes, mobile and wearables and other technologies envisioned for older people [66].

IoT technologies have potential to fit into older people's everyday lives by enhancing objects that they use habitually [7], but very often technologies targeted at older people are conceived and marketed with more attention to the peace of mind (or lack thereof) of their adult children [1,46,57]. It important to create technology that is first and foremost personalised, meaningful and gives agency to its primary users [2,28,36,60,63], while acknowledging the needs of other users. The IoT operates within a social and relational context and thus needs to be conceived of as a Social IoT [64]. A user study of older people using the output of InfoBricks, a prototyping kit that allows creation of imagined technology [28] showed a need for tools to support participants and designers to imaginatively concretise abstract concepts that match the user's context. In using the Makey Makey with older adults, Rogers et al noted that although their participants found the activity of making with the kit enjoyable, they felt that they tended to "accept" technology rather than be the ones creating new technology [56]. They suggested that kits should support everyday needs, practices, routines and work with the objects of daily living. However translating older adults' needs into meaningful and relatable designs remains challenging as personalisation and appropriation of technology happens over time [2,12,17,63]. Lim et al's (2013) 'Discovery-Driven Prototyping', inspired by Gaver et al's cultural probes [26] and Hutchinson et al's technology probes [31], involved home trials of a set of semi-finished prototypes as discovery tools that resulted in users appropriating the usage of the prototypes over weeks of use [40]. The IoT Un-Kit Experience approach instead is exploratory in a home-based workshop setting and heavily relies on the researchers' participation [37,58]. It draws from a tradition of dialogical methods, such as 'Dialogical Probes' [65] that emphasize the engagement of the researchers with the participants, somewhat relegating the Un-Kit IoT elements to the peripheral role of enabler, a demonstrator of ideas, and a reason to be there and engage in a particular conversation.

Assumptions about the 'needs' of older people and the challenges in engaging them in the discourse on and design of new technologies stem not only from prejudices about old age, but also from limitations of existing co-design approaches, tools and materials [58,59]. We therefore aim with the IoT Unkit Experience to contribute a method that respects older person's abilities and needs, inspired by [7,20,22,39,56], and that scaffolds these in such a way that the older person can ably participate in and preferably lead the process.

3 APPROACH: THE IOT UN-KIT EXPERIENCE

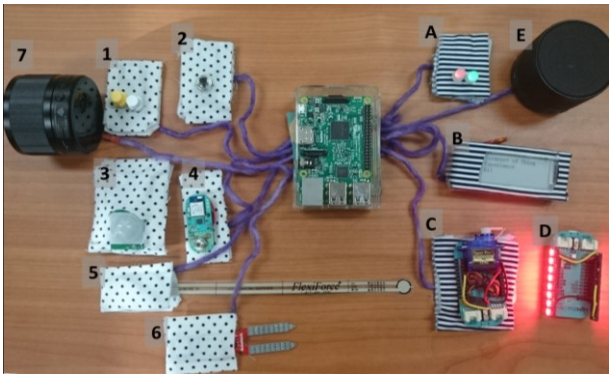
We conceived the Internet of Things Un-Kit Experience as a co-design approach conducted in the early phases of design, which comprises the IoT Unkit elements and the workshop approach presented in sections 3.1 and 3.2 respectively.

3.1 The IoT Elements Set

The Un-Kit includes a set of reusable sensors, actuators, and media elements that can easily be combined and interconnected by the research team, supporting users to prototype scenarios in situ. The Unkit supports people to imagine new forms of technology in the home or ways to connect with others through augmenting things that they use in their domestic routines and hobbies. In particular, the media elements were implemented to enable audio recording and playback which many other kits (focusing often on environmental sensing) did not support. Unlike existing kits that are aimed at learning about the electronics, the specifics of the interaction, or to make sense of data we focus on the experiential aspects and co-creation of a personal IoT. We have implemented a total of six types of sensors, four types of actuator and two media elements that connect to a central gateway wirelessly as shown in Figure 2.

Sensors/Actuators. The Un-Kit offers six types of sensors: buttons, rotatable knobs, motion detectors, temperature sensors, force sensors and moisture sensors; and four types of actuators: audio, motor, light, and text displays. Sensors and actuators are shown in Figure 2 and summarised in the figure caption. A Light Blue Bean

micro-controller with CC254x Bluetooth SoC, powered through a coin cell battery, acts as an interface with lower power sensors and actuators. The Bean+ which has a larger LiPo battery interfaces with more power hungry sensors and actuators such as the motion sensors, step motors and LED arrays.



	Sensor / Input	Actuator/Output
Media Bits	Microphone (7)	Speaker (E)
Motion	Motion detector (3) Force detector (5)	Motor (C)
Visual	--	Light (A and D)
Text	--	E-ink Display (B)
Environment	Moisture detector (6) Temperature detector (4)	--
Tactile Input	Buttons(1), Knob (2)	--

Figure 2: IoT Un-Kit components of sensors and actuators with Raspberry Pi in the middle. The purple yarn was used to explain connection possibilities to our users.

Media Elements. The media elements in the Experience Un-Kit are Bluetooth devices that contain both a speaker and microphone. We implemented our media devices such that participants could easily experience connecting around routines, objects and social relations using sounds, i.e. record and playback of voices from family, the sounds of cooking and specific bird sounds.

Central Unit. To simplify the deployment a central unit running on a Raspberry Pi micro-computer board works as a Bluetooth gateway and hosts a visual programming interface. NodeRed (see Fig. 2), an open source flow based programming environment developed by IBM is used by the research team to easily connect components into meaningful applications during the workshops. The central unit also runs a local MQTT stack that provides the necessary messaging between components independent of Internet connectivity.

Programming Interface. NodeRed, a visual browser-based programming interface was used to provide a means of wiring up different wireless devices. As programming the graphical blocks requires knowledge of Javascript programming language and understanding of wireless connection between devices, the technical implementation was facilitated by the research team and was not a concern nor was done by the participants, who were free to focus on the interactional details and reflection.

3.2 The Co-Design Workshops

The co-design workshops were conducted for at least three hours in the homes of our participants making the process individualised and personal as the participant explained their daily routines, favourite spaces in the house, and their hobbies and relationships.

3.2.1 The Participants. Through a community group we disseminated a call for participation for the workshop and two older women volunteered to participate – Ann and Val (pseudonyms). Both are independent and capable women who each support an adult child that still wishes to live at home with them. Both are first time research participants who regularly volunteer in their community. They have very distinct characteristics, one being a technology enthusiast, the other a sceptic, one having a fractured relationship with daughters, the other having a loving relation with an only child, one a bird lover, the other annoyed by plant-preying upon birds. We describe Ann and Val's cases in detail to emphasise quality over quantity of insights [69] and in order for us to contextualise in detail their experiences -- the kinds the approach hopes to capture. The contrast in the cases shows the capability of the approach to engage different people.

Ann. Ann is in her 80s and lives with her son. She is originally from England but has lived in Australia most of her adult life. She's glad her son decided to move back home as he is handy with repairs and heavy labour tasks in the house. Ann has a fractured relationship with her daughters. She lost contact with her daughter in the United Kingdom. As for her other daughter in Australia, Ann said she is very busy and she doesn't want to impose on her for visits or constant communication. Rarely, they drop messages in FB Messenger such as picture of birds on her daughter's land. Ann's week is jam-packed with her volunteer work – court support (crowd management, interpreting, etc), church choir, pastoral care (age care, coordinator/assistant in a parish) to name a few. Because of this she is constantly on her computer too – email, Facebook, LinkedIn, tracking orders. When she is not volunteering, Ann loves to explore the city through its public transport. She does not drive because of her visual

impairment. Ann is an enthusiast when it comes to technology; an open and eager recipient.

Val. Val is in her 70s and is a former school teacher and a retired government employee from the Philippines. She was a processing officer in the internal revenue office, which allowed her to interact with people on a daily basis. When she retired, her only daughter requested that she lives with her, her son-in-law and three grandchildren for six months each year in Australia. When in the Philippines Val lives in their family home independently. This living setup enticed Val to social media and messaging applications like Facebook, FB Messenger and Skype to stay connected to important people in her life. The same mediums of communication are used to fulfil her roles as head volunteer in her parish church. When Val is home (Australia), she loves to cook for her family, read books, watch soap operas and tend her garden. She does a regular morning walk, goes out with friends and attends to her volunteering duties. In terms of exploring new technologies, Val is very conservative, reluctant and is basically a sceptic.

3.2.2 The Workshop Flow. Two and then three researchers conducted the in-home co-design workshop at Val's and Ann's home, respectively. The workshops were facilitated in such a way that all the technical components and configurations/reconfigurations are handled by a member of the research team, whereas the participants lead the walkthrough in the home.

Setup. Beginning the workshop, one of the researchers sets up the IoT Un-Kit on a table while the rest of the team talks with the participants; the setup of the Un-Kit can take several minutes, because all the modules need to connect wirelessly to the central unit before the work can start. Engaging with the participant, one researcher introduces the study, project goals and research ethical clearance. We then begin with asking the participant to share a little about herself, her hobbies and interests and her family. We in turn share details of ourselves to establish a conversation, rather than an interview.

Laying down the cards. We show the IoT elements and use cards (Fig. 3) to explain the different components. We represent sensors with cards of the human senses – sight, touch, taste, smell and hearing; and actuators with various representations such as a singing bird or trumpet (sound), dancing lady (movement) or light bulb (visual light). We introduced one device at a time, placing them on their respective cards. The Raspberry Pi computer in the middle is represented by a box with yarn coming out from both sides showing the connection possibilities between sensors and actuators. The cards showing silhouettes of people get the participant to think about social relations -- who they want to connect with and in what way.

Figure 3: Cards used to simplify the concept of sensing.

The Walkthrough/Passing the Baton. We continue to explore the participants' favourite (or least favourite) objects in the home and their everyday routines and practices. Upon reaching this point, our participant takes us on a tour, and basically takes control, showing where these objects are, what activities are associated with them, and the people they remember based on the objects. The walkthrough opens up ideas and opportunities on how technology may enhance or augment everyday life, elicited by the objects, practices and events the participants decide to share. In this walkthrough, the participant proudly shared their interests, their strengths and their passions. Depending upon the activity or routine that the participant is showing us, we hand them different sensors and actuators that they may try to place around objects that they think they might want to augment and then we further discuss ideas with them. They then decide which one they would like the team to prototype.

Dynamic co-creation. Based on the ideas generated we then assemble a low-fidelity prototype using elements from the Un-Kit. For example if the participant was invested in her garden and preferred to create a design around the routine of gardening we may suggest specific sensors such as a moisture detector for the plants, a motion sensor for detecting the presence of birds, and, depending on the scenario, appropriate actuators and media elements. As the prototype is being created by a research team member, discussions of different possibilities are being considered by the participants. They would comment and make suggestions on the interaction design until they deem the prototype satisfactory to them. Suggestions or concerns are being taken into account immediately during the prototyping process and are catered for by changing elements to meet their

preferences. The user's idea transforms into a prototype built almost instantaneously for the participant to experience. We then move to the actual space where the technology is intended to be used, inviting the participant to reflect on the experience of the design in place. We conclude by debriefing and reflecting on the design and process during a round-table type discussion with the participants.

3.3 Analysis of the Creative Process and Outcomes

Audio recordings of the conversation were professionally transcribed and later annotated by the research team. Reflection on each workshop started immediately after each session, as the team was returning to our offices from the participants homes. We discussed elements of relevance, interesting events, things or objects we observed in the homes that captured our attention, as well as our take on the input we had received, including aspects that may escape the recordings, such as our own feelings and impressions. Given the overall topic of our research of understanding people's hopes and desires for the forms and kinds of interactions for personal IoT, we were particularly alert to themes of agency, empowerment, engagement, and reciprocity [8]. Later, working on the transcripts, we conducted a more formal analysis using a mixed top down (driven by aforementioned themes of theory and concepts) and bottom up (data driven) approach. Other key themes emerging from the analysis were the situatedness of interests and passions, each having special places in the house; the importance of relationships and how objects reveal bonds to people and memories that can be enhanced with design; the way places and relationships are linked and interdependent; and how the Un-Kit itself can help to explore these elements, but also comes with costs and limitations. We use this as a structure to present our findings in the next section.

4 FINDINGS

The in situ workshops were found to be effective, with participants naturally taking the lead and steering the conversation towards who they are, what they do, their activities, and the important people in their lives that they hope to connect with. The Un-Kit IoT elements were malleable to their preferences, a point of interest at times, and at other times very much peripheral. We found that more interesting and less prosaic design ideas arose when the conversations became detailed, delving into the specificities of relationships, passions and pre-occupations, prompted by the objects and places within the home. By introducing the *un*defined, *un*finished and *un*boxed kit elements into this detailed conversation, it became possible to envision IoT purposes, connectivity and aesthetics of interaction and also to understand what was unnecessary or might be jarring and annoying. These nuances and subtleties take shape more convincingly when discussed in the context of personal relationships and activities.

In summary, we found that quality design conversations emanate from being personal, situated and detailed and layering IoT design ideas into these contexts. We identified this in four ways: (1) Situated Passions: Co-designing in situ in an environment where the participants have a sense of command, ownership and detailed knowledge, where the IoT is envisioned to be used, leads to participants revealing their passions and preoccupations that help to uncover potential purposes for IoT designs. There are typically many references to these passions within these personal spaces.; (2) Relationships Revealed: Being within the home and having a cup of tea seems conducive to reflective conversation about people significant to the participant, including foibles, highs and lows, longings and regrets and opportunities for connection. Walking through the home the relationships unfolds in layers, with threads of stories about loved ones being picked up and elaborated as objects and places trigger memories and ideas. In the home, there are many reminders of memories and loved ones. This approach facilitates consideration of ways in which connections might be made by IoT designs within the intricacies of personal relationships and place; (3) Object and environment specificities: By focussing on objects within the place, one sees the detailed qualities of the objects, such as the damp environment in the back of a cupboard, the knitting partially finished in the basket. Playing with the IoT components in this context helps to reveal the situation for the component – the form that it needs to take to fit with the environment and the aesthetic qualities to create the right mood. By beginning with the bare IoT components we could begin to elaborate them and the experiential qualities that they needed to possess to fit the context; and (4) Orchestrated: Through iterative conversation and appropriation of home objects together with IoT kit parts we fashioned and completed an interactive prototype. One team member focussed on connecting the kit parts, orchestrating a design, in Wizard of Oz fashion, except that the prototype actually worked, and the wizard was very much visible. We refer to it as a Wizard of Is prototype, or more affectionately, a Wozard of Iz. Research team orchestration of the final prototype

relieved the participant from having to deal with the technology and allowed us to undertake more sophisticated tailoring than might be done with most kits. Creating a working prototype on the fly enabled us to get feedback, and was also intended as an act of reciprocity to show what an IoT design could do and look like. It also guided us to reflect in more detail on what a kit that didn't need a researcher to connect it might look like.

4.1 Situated Passions

During the walkthrough, participants led the way as they decided what they wanted to show us, their hobbies and interests, and the work they do in and outside the house.

Figure 4: Val in her garden and Ann with her fancy griller.

They became engrossed, enthusiastic and even passionate explaining to us why they love their favourite spot, what they enjoy doing and what keeps them preoccupied, Val's passion for cooking and gardening transcended in the way she took ownership of the workshop when she led us through her kitchen and garden (Fig. 4, left). Val could name all of the plants in her garden as well as the pests that prey on them and was keen to explore how technology could possibly protect her plants. She enjoys how her labour of love of her garden transforms into ingredients that she prepares for her family meals and values the way that her cooking brings the family together for mealtimes. The sense of pride in her garden, ingredients and cooking and how these passions work together to create her family mealtime atmosphere unfolded as she talked us through her favourite parts of her home and commented on potential IoT ideas. She declared that she wouldn't need anything to let her family know that dinner is ready, because the moment my granddaughter and grandson smells the food, *"'Ohhh... What's this smell? Oh!' They would demand, 'I would like to eat now!'"*.

Val's 'alert' plant rack idea came about on a walk through her garden, seeing her tomato plants. *"That one [pointing at one plant], I have a very big tomato, it was full of pecks of the birds."* Whenever she hears crows in her garden she runs down from her reading nook to the washing area, peeps through the window and throws a stone from a little pile, already prepared, to scare them. Val's design combined a motion sensor triggered motor and a speaker. We attached the motion sensor to the plant rack, with our team's technical wizard making the prototype scarecrow work, as Val mused *"Combination [of light and dark shades, on what colors the scarecrow should be]...That! Hmmm... (chuckles) Hat! Yes, they do wear a hat"*. Importantly, acknowledging her established habits and interests, Val didn't simply want the birds to fly away; she wanted an interesting looking motion activated scarecrow, and a speaker to know when the action was happening, so that she could peek through the window and watch the comedic and satisfying effect. And she could continue to throw stones too. She still wanted to retain some of the excitement and quirky arrangements that are weaved into the structure of her daily routines.

Ann's home walkthrough revealed her passion for gadgets and new technology – she had a number of unique and complex appliances including a complicated griller, food processor, multiple rice cookers, digital kettle etc. (Fig. 4, right). *"Theoretically, [puts jug] you hold this down and then dial that one and then just press that one and it heats it... if I want it coffee I do 90, if I want my infusion for my nose, or tea, I do 100, "*Ann said demonstrating how her kettle works. She loves different cleaning tools, considering some as her favourite items. She showed us her laptop explaining the many emails and tasks she does as part of her volunteer work. Upon seeing her knitting set, she relayed how she enjoys knitting. Although the IoT ideas developed with Ann were broad ranging, Ann's favourite idea related to a rather pragmatic aspect of her housekeeping, how the IoT could help her to know when moisture is building in her linen cabinet, so she could prevent damp and mold. In the walkthrough, we were curious guests as Ann and Val revealed their passions and identified purposes for the IoT.

4.2 Relationships Revealed

The Un-kit approach included cards with silhouettes of people, to serve as a reminder to ask participants about relationships and with whom they might want to share through a personal IoT design. At first participants described their family members in broad brush, but over time, as the conversations unfolded, we began to learn more about their relationships, with some intimate details revealed around particular relations that were very strong.

Ann's son lives with her, but she has little contact with her daughter who lives in Australia within 50km. Ann expressed a relationship so fractured that initially she was

sure that their lines of communication had closed off. Ann didn't volunteer further details about their relationship and preferred to move on to talking about her relations with the community. As a pastoral worker and part time legal worker, she is very active on visits within the community, arranging community events. She spoke enthusiastically about the vibrant and diverse cultural backgrounds of people in her neighbourhood, commenting that she didn't feel a need to travel to experience the world because she could meet people from anywhere within her community. *"One of my favourites … we organised just a little walk around the city... The Muslim men offered to carry our banner that said Believing Women for a Culture of Peace… We went to the synagogue, the Greek Orthodox Church. We went into the mosque and they fed us."*, Ann fondly recollected.

Figure 5: a. Ann's spot at her back porch, b. Ann's knitting setup inside her house, c. Val's cooking area

She talked a lot about their choir and the different songs within the community, which led to ideas about a quirky personal community radio to share when particular people in the community were singing songs or playing music from the about the house. Later, on the walkthrough by her back porch, explaining she has a lot of bird visitors there, Ann paused to reflect that both she and her daughter enjoy the variety of birds that fly in their backyard remembering the rare moments she sends her photos of birds. Although the conversation about her daughter seemed to have closed, in the moment of being on her porch (Fig. 5a), Ann saw an opportunity for them to connect by sharing sightings of birds, *"I have trees along the back there and I sit there and we've got new birds coming in… I could share it with my daughter."* Ann saw it as a gentler way to interact, sharing something beautiful in nature that was less likely to raise confrontation and could build rapport through a new and different medium of birdlife.

Val, lives with her only daughter, with whom she has a strong bond. She thinks that the communication technology they use suffices for them but she sometimes feels annoyed by her daughter's concern, such that she wondered whether a design could mitigate the situation of her daughter constantly texting and calling her. "*She stresses because I don't answer her calls. So sometimes, she calls my niece, 'Where is Mama?' 'Of course, out as always!' [laughs]"*, Val reminisces on her daughter's worry when she is back in the Philippines. Regarding gathering the family for meal times, Val felt that the aroma of her cooking was enough (Fig. 5c) for the family to huddle towards the table, with no IoT needed. However she pondered whether food aromas could be detected in order to connect with family from afar during the routines of mealtimes.

We found that empathetic and open conversations around the dining table and then moving through the home, gave a chance to ponder, revisit and reveal relationships over the course of the workshop, and to imagine how the IoT might support them in new ways.

4.3 Object and Environment Specificities

During the walkthrough our participants took cues and inspiration from objects and spaces around them. Discussing the Un-kit elements in these spaces helped to reveal detailed interactional considerations. It was being on her back porch that caused Ann to pause and contemplate her relationship with her daughter. This is a place where she enjoys quiet time, and reflects as she watches nature – the sunset, animals and especially birds that visit (Fig. 5a). It was at her favourite lounge chair (Fig. 5b) where she does her knitting, that Ann revealed her frustration when she runs out of yarn *"I'm knitting away and I'm not looking at the wool, then all of a sudden, the end of the wool is there and it's too short for me to do anything. I've got to undo it."*. She asked whether an IoT device might help avoid this. Ann showed us favourite cleaning tools and gadgets that she has grown love-hate relationships with such as her digital kettle *"The jug, yes, it's a pain, it's digital…"*. She has mastered them, but relegated some to the cupboard, as she doesn't find much need for them. However, it was when Ann came to her bedlinen cupboard (Fig. 6c) that she was most excited about an IoT device, inspired by the moisture sensor in the IoT Un-kit. Ann wanted to be alerted when her cabinet is accumulating too much moisture.

At Ann's request, we demonstrated a moisture sensor triggering a sound, by placing the sensor in damp tissue paper (Fig. 6b). As we worked through the idea with her, it became clear that the particular nature of the sound to alert her to moisture was important to her. At first she wanted a natural sound. We searched on a mobile phone

for media on the Internet and tried a bird sound, but then she thought she would only confuse it with the birds outside. When she suggested the sound of a river we found some river videos, but they were quite noisy and not as therapeutic and distinctive as we had all first imagined. Ann thought she would confuse the sound with her washer. We found a synthetic raindrop type sound that was quite calming and pleasantly conjured up the feeling of water dripping, and pitter-pattering. This was the sound that Ann liked, as it was playful, calm, pleasant and distinctive. She would be pleased to hear it as an alert if her cabinet was becoming moist.

Figure 6: a. Val's 'alert' plant rack idea, b. Ann experiencing the interaction of her idea and c. her linen cabinet.

Ann made it clear that she could open the door to keep it aired (Fig. 6c), but she just wanted to know when she needed to do so. She didn't want an automated drying solution, just an alert to the moisture building. The importance of the aesthetic qualities of the interactions became clear as our participants imagined their designs. From the look of a scarecrow (Fig. 6a), to the sound of dampness they wanted aesthetic qualities that evoked the kind of mood and emotion they wanted to create. As Val contemplated what sound would best scare off crows and at the same time prompt her of the situation, she decided against a bird sound, pondering, *"I think dog bark is okay... Yes dog is much better."* She wanted an effect to shock the crows but then realised, *"Maybe not… It will disturb the neighbours if it goes off every now and then."* A discussion then ensued about how intelligent crows are and that a randomise sound might be best. In the end, Val settled for a bird sound and imagined it be randomised. She was satisfied with the concept and how she designed the scarecrow prototype herself.

4.4 Orchestration

The IoT Un-Kit Experience approach requires orchestration of several factors for successful co-design – the participant, the environment where the co-design took place, the malleable IoT elements, the cards and the research team themselves. The team's "Wizard of Is" configures the IoT elements to rapidly prototype the participant's design idea on-the-spot. That is, someone whom the participant can see and talk to makes the technology work for them, allowing the participant to reflect on and refine their design idea, while not being burdened to figure out the kit themselves. *"Okay, you guys keep talking. I just need a few minutes to get the stuff working."*, commented the 'wizard' as ideas from Ann and research team flowed about the interaction experience.

The Unkit Experiences allowed us to explore how the kit itself would need to be designed if it were to be used more independently. Incorporating sensors, actuators and media elements in such a way as to make them easy to put together but sufficiently open and powerful to express a variety of design ideas involves the inevitable trade off of what should be within the scope of a kit, and what should be left out, because kits, by their very nature, cannot do everything.

The use of cards with images of the IoT elements and the human senses proved to be helpful for explaining the IoT capabilities and making the IoT elements relatable. Using the cards the team was able to explain how some sensors match the body's senses, how actuators express light, sound or movement and how things might be connected, which our older participants appreciated. Heidt et al similarly used cards in project Miteinander to engage older people in design of intelligent things [29]. We found the cards demystified the complexity of the IoT by modelling the interaction and showing possibilities for how people and things could connect simply by laying out cards, sometimes with sensors and actuators, on the kitchen table. The cards and the technology elements supported each other, the cards supporting abstraction while the technology elements were graspable pieces of a future design that became familiar to the participants. *"At the start, I really was so confused. What are these little things … What is the effect of these tiny things to me? Later… I understood."*, Violy reflected on the process. We believe that components should only draw a focus to their details of operation, when these details inspire consideration of particular qualities of interaction, rather than in order to figure out technical details relating to their logics of connection. This and the dynamic engagement between participants and the research team shifts emphasis from the kit as a charismatic gadget to be connected, to firsthand experiences in the domestic context and the ways in which IoT elements might fit with opportunities and problems identified within the context.

5 DISCUSSION

Through our exploration of the IoT Un-Kit Experience with older people, we offer the following insights into the co-design process and the design of IoT kits.

5.1 Situating the Co-Design Process

Situating the co-design process in the home increases the agency of the participants. Although workshops are often held in public and community venues, possibly bringing personal objects from the home to spark ideas [36], we purposely conducted our workshops in the homes of older people where their identity and personality are strongly reflected in the objects within the home [7,67], the daily routines they practice [41,72], and the arrangements they maintain [27]. The IoT Un-Kit Experience was used by weaving it into a conversational exploration of the home where many ideas are triggered in situ by occasioning upon places, objects in their places, and objects in their relation to other objects. However we found the participant's interests and the organisation of their home to be the best guides to steering the design process, once the overall goals of the research and the IoT Un-Kit has been introduced. That said, the process does still require artful facilitation. As a researcher one has to be an empathetic conversationalist, listening attentively, taking an interest in the participant's life experiences, supporting them to elaborate in directions of potential interest and judging when to turn focus to the IoT elements and design ideas amidst the ethnographic activity. Similar facilitation was also emphasised by [42]. The proposed approach encourages 'embodied knowing' [37] and flexibility to dynamically respond to the situation at hand.

The researchers acknowledge that the home is an intimate space and not everyone would be comfortable holding the workshop in their private space. Extra effort may be needed in ethical clearance processes and relationship building in order for home visits to occur. Having paid attention to this, we found participants who trusted us, researchers who were not well known to them, to visit their homes. We valued the participants' welcome and candour about the spaces in their home, their personal stories and practices.

5.2 Against Automation, towards Artful Integration

It is important to note that our participants neither designed a device that would track their health, would monitor their movement or would automate tasks. Their design ideas were about connecting with people, hobbies, interests and concerns in artful ways that retained their own agency. Older people value the 'doing' [72] in their everyday, taking ownership of and pride in their to-do tasks and routines to be accomplished. They are theirs to perform [27,44,72] and automation is often not welcomed [38,39,55]; they personally cherish and practice their agency. Overall, the approach supported artful integration in design, rather than designs from nowhere [6,56] by considering and respecting what is already in-place be it practices, routines or arrangements in the homes of older people. We argue that in addition to openness in the kit elements themselves, as presented in the Un-Kit, it is important that activities with kits are situated in ways that support detailed conversational and spatial exploration of authentic settings such as the home. Design needs both the richness of ethnographic exploration and personal reflection as well as good kits for use in situ.

5.3 Qualities of Interaction

In designing IoT, there have been calls for more embodied and rich interfaces that do not centralize the interface in a tablet or screen [25], and that do not only employ cube shapes [34] or isolated activities [56]. Our IoT Unkit offered media elements as well as a variety of sensors and actuators to foster designs using multiple modalities allowing rich contextual mappings [25]. Participants developed detailed ideas about the interaction aesthetic that would realise their design vison. Combining the unpackaged form of the IoT elements with their own objects, fabrics and materials, participants could contextualise them to their liking, exploring aesthetics that fit with their design concept. This notion of a strong aesthetic is consistent with Hygge, a Danish concept that connotes the mood of cosiness, where the expectations of aesthetic qualities infuse expectations for interaction [32]. Moreover our participants would craft and discard aesthetic ideas until they got them right in a manner similar to paper crafting processes [43]. The orchestration of the different components of the IoT Un-Kit Experience led to design ideas and interaction styles generated, discussed and tweaked by users that were thus legible to them[52].

5.4 Embodied, Personal and Creative Interaction.

The design ideas that emerged were consistent with other workshops exploring new forms of IoT technologies such as LoadedDice [35] and Frens et als' IoT Sandbox [25], however the designs of our participants were far more personal and situated, more likely to consider relationships, and less likely to focus on automation. Both studies [25,35] have called for more embodied and

personalized interaction, with Leong and Robertson [36] pointing out that design must cater for personal unique situations in order to better serve the needs of older people [36]. Other research has called for kits to better cater to people's creative and expressive abilities [42,43,52,73]. We feel that the situated exploration of the IoT Un-Kit Experience responded to this call, leading to a detailed, intimate and personal exploration of the IoT led largely by prospective users themselves.

To the question of what qualities of kits might support people to be more creative [56], better elicit ideas from people, specifically older people, and cater to more personalised, meaningful interaction [25,35,36]? Our study reveals that it is important that kit components be adaptive and appropriable to different environments (with connectivity details minimized), allowing the opportunity to explore aesthetics and to merge them with their own objects and materials. Moreover the facilitation [37] and orchestration of the co-design process should enable flexible, embodied and situated engagement of participants. We expound on this below.

5.5 Trade-offs in Kit Finish and Specificity

We see a variety of kits, basic kits, educational kits, but more recently a trend to kits of no parts, the untoolkit, the context sensitive toolkit and now, our IoT Un-Kit experience. Our Un-Kit is distinct in that it emphasises an ethnographic and contextual enquiry that does not focus on building, and it uses a Wizard to fashion a prototype that is more than a kit designed for a layperson might achieve because the "wizard" can also code and configure. From it we have learned how the Un-Kit approach can reveal passions, rather than assuming them, reveal relationships and draw in inspiration from other objects and spaces. We observe that this Un-kit is part of a distinct trend (untoolkit, kit-of-no-parts) recognising that kits serve users well when they support leveraging other skills, materials and experiences.

Interfacing kit components to the outside world can present challenges due to the limitations in the characteristics of components such as strength, connectivity, quality of interaction, and the degree of choice in components and their effects [14,34]. While the tangibility of components fosters prototyping, this very advantage also skews activities towards considering what the kit can do, becoming absorbed into the closed world of the kit, rather than exploring what interaction is desired: the ideas may be constricted by pre-existing shape and predefined purpose of the kit [30,34,35].

The IoT Un-Kit Experience on the other hand with its *un*completed quality – *un*finished state, *un*defined purpose and *un*boxed form, focussed on fostering conversation and ideas rather than on the participants completing a design. The intent was to understand research questions about the nature of an IoT that people want, and the kind of kit that might be useful, rather than to demonstrate a finished kit product for end users, e.g. [14] or as an added element for crafting of the maker community [42,43,52]. Although the power of making is seductive, as is the premise that everyone should be able to make everything for themselves with kits, making everything is not for everybody. In our case, when engineering the Un-Kit, we began with an initial vision of enabling any person to prototype their IoT scenarios, but as the Un-Kit design evolved we had to compromise between flexibility, security, and amount of functionality. We finally settled on a configuration that allowed rapid prototyping or many scenarios, offering a varied set of sensors and particularly of media elements, that are notably absent from many other kits. We also wanted to create a self-contained kit that could work independently of broadband Internet connectivity. The necessary trade-off is that the Un-Kit requires expert participation by one member of the research team to write the few lines of Javascript code, or fix the configuration of a Bluetooth beacon. While research exists to allow end users to program their own IoT applications [4,16,51], it is hard to see how these could empower users to describe non trivial functionalities other than in the procedural and algorithmic way that computer systems rely upon, and humans are so poor at. And the needs for security and privacy, that understandably score very high in most users' priority list are even more challenging to get right, to the point that several commercially available IoT product are proving extremely hackable [19,74]. On the other hand people, including older adults, are very good at imagining ways to adapt and appropriate elements of existing technology into their own everyday life [54,63], and at describing goals they may want to achieve and values they may want respected. We can then imagine kits such as the Un-Kit that consultant designers use to work out product ideas with people, with the products then being tailor made to a professional level of fit and finish for people. Or different kits might have different foci to address particular sets of opportunities in the home.

We argue that the value in the *un*boxed form is also the flexibility to capture ideas that are less influenced by predetermined visions. This also allows participants to change their minds about the nature of the interaction and

its form, and to use different fabrics, forms and sounds to achieve desired effects. The IoT Un-Kit Experience approach with its malleable components, relatable cards, dynamic in situ individualised workshop with wizard-facilitated making process, engaged older people as it offered them the power to define the design purpose, to explore IoT concepts within their home, to choose aesthetics and interaction qualities that suited their situations, and it freed them from the need to focus on connecting up the kit itself.

6 CONCLUSION

In this paper, we presented the IoT Un-Kit Experience, a new approach in the design of IoT and its constituent kits that makes the design process more situated and responsive to user's contexts and experiences. The approach comprises using the IoT Un-Kit elements (with *un*defined purpose, *un*finished state and *un*boxed form) and cards in in-home workshops. These workshops involve a conversational exploration with researchers, led by the participant, contemplating the IoT elements within the personal space of their home. This process unfolded the participant's (1) situated passions, (2) personal relationships and (3) everyday objects and environment specificities, slowly sparking ideas of possible purposes for their personal IoT, and also revealing (4) orchestration needs in order to materialise and refine a prototype. Situated conversations revealed that older people don't want automation but agency, and that kits need to support more personal and creative interactions and aesthetics. While most kits focus their users on what is possible with the kit and connecting up a design, the Un-Kit approach instead emphasises the experience of people using the IoT elements in context, imagining personal IoT design possibilities that are meaningful to them.

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